Impact of 5G Industry Development on China's Electricity Demand During the 14th Five-Year Plan Period

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Abstract. Digital technology plays an important role in helping the global response to climate change, and emerging technologies represented by 5G are also an important guarantee for achieving the "carbon peaking and carbon neutrality" goals. As the focus of the "14th Five-Year Plan", the development of 5G and its industries has promoted rapid power consumption growth. However, it has also brought hidden dangers to the safe and stable operation of the power system. The 5G industry is divided into equipment production, base station operation, and technology application, and a forecast model for electricity demand in each link is proposed. The impact of 5G industry development on China's electricity demand during the "14th Five-Year Plan" period is quantitatively analyzed, which can provide a reference for the scientific development of energy and power "14th Five-Year Plan".

Keywords: 5G industry · equipment production · base station operation · technology application · electricity demand forecast

1 Introduction

China has put forward the climate goal of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060 at the 75th United Nations General Assembly. To implement the "dual carbon" goal, transforming and upgrading the energy internet are essential. Hence, it is urgent to provide strong support through the latest communication technologies to meet the growing communication needs. As a new generation of mobile communication technology aimed at the post-2020 era, the 5th generation mobile communication technology (5G) has the characteristics of high speed, low latency, and large connectivity, which can support on-demand customization and high dynamic expansion [1].

As a key construction goal of the 14th Five Year Plan, the rapid development of the 5G industry can not only accelerate the construction of digital China but also promote the rapid growth of electricity consumption. As a new driving force for China's future electricity demand growth, predicting the electricity demand of the 5G industry can help scientifically quantify the impact of the development of the 5G industry on China's

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electricity demand during the 14th Five Year Plan period, and thus formulate a scientific and reasonable electricity development plan.

The current long-term electricity demand forecast mainly targets a certain region [2] or the major industries [3], with less involvement in the digital industry. The research on 5G electricity demand mainly focuses on the electricity demand of 5G base stations [4] or the energy consumption of equipment inside the base stations [5], lacking research on the overall electricity demand of the 5G industry. Hence, this paper divides the 5G industry into 5G equipment production, 5G base station operation, and 5G technology application. Then, the electricity demand prediction model for each segment is constructed. Based on the current scale layout and future development trends, this study further assesses the overall electricity demand of China's 5G industry during the 14th Five Year Plan period and evaluates the impact of the development of the 5G industry on China's electricity demand.

2 Research Framework

The power demand of the 5G industry runs through all parts of the industrial chain. The traditional definition of the industrial chain focuses more on the hardware and the 5G-related equipment. These studies emphasized the analysis of the production process and technical standards of equipment but lacks in-depth research on the operation and application parts. Hence, a three-stage 5G electricity consumption prediction model is constructed, as shown in Fig. 1.

3 Analysis of Electricity Demand in the 5G Industry

3.1 Analysis of Electricity Demand in the Production Process of 5G Equipment

With the gradual promotion of commercial use, the production of 5G-related equipment is carried out synchronously. Therefore, measuring the electricity demand in the production of 5G equipment is more practical. Due to the complexity of the 5G equipment production industry chain, it is not feasible to calculate the electricity demand of each 5G equipment manufacturer. Hence, this paper approximates the electricity consumption of the computer, communication, and other electronic equipment manufacturing industry (CCEMI) as the main electricity demand for electronic equipment production, and replaces the annual electricity demand for 5G equipment production with incremental data. Figure 2 shows the electricity consumption of China's CCEMI from 2001 to 2020.

As shown in Fig. 2, the electricity demand for China's CCEMI steadily increased from 2001 to 2020. Prior to 2018, the growth rate of electricity consumption in this industry remained around 14.02% and showed a clear linear growth trend. With the freezing of the world's first 5G commercial standard in 2018, the new era of 5G commercial has officially begun, and the production of 5G-related equipment is also in full swing, driving the rapid growth of electricity demand in related industries. Compared to 2017, the electricity demand growth rate in China's CCEMI in 2018 was approximately 25.7%. The electricity demand of China's CCEMI from 2001 to 2017 can be expressed as follows:

$$E_c = 60.36t - 120667 \tag{1}$$

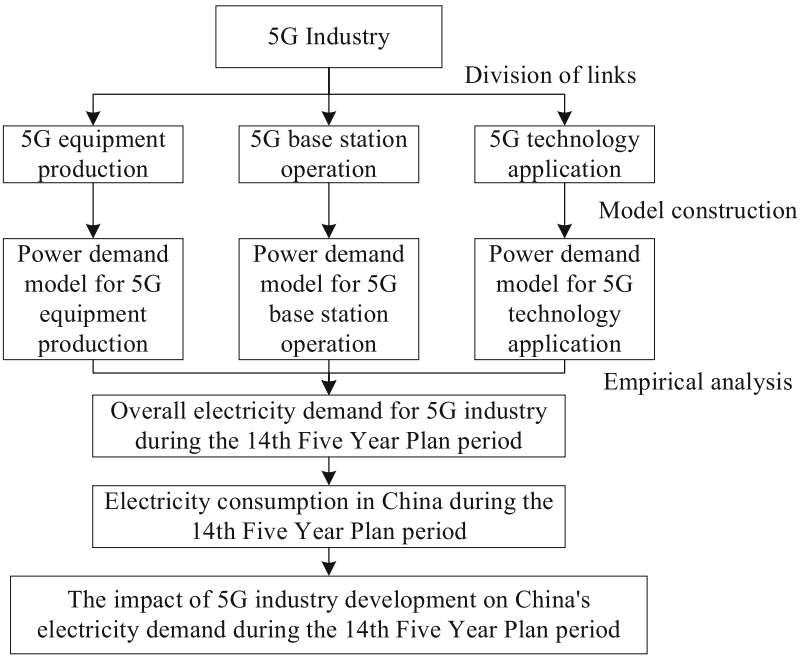

Fig. 1. The framework of the three-stage 5G electricity consumption prediction model in this paper.

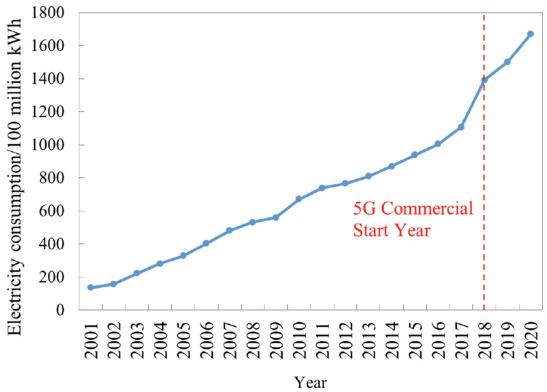

Fig. 2. Electricity consumption of China's computer, communication, and other electronic equipment manufacturing industry from 2001 to 2020.

where E_c represents annual electricity demand of CCEMI from 2001 to 2017, and t represents year.

The R^2 of the fitting result is 0.9980, and both the first-order coefficient and constant term pass t-test, which is significant at the 1% level. Hence, this function can approximately represent the electricity demand of CCEMI except for 5G equipment production.

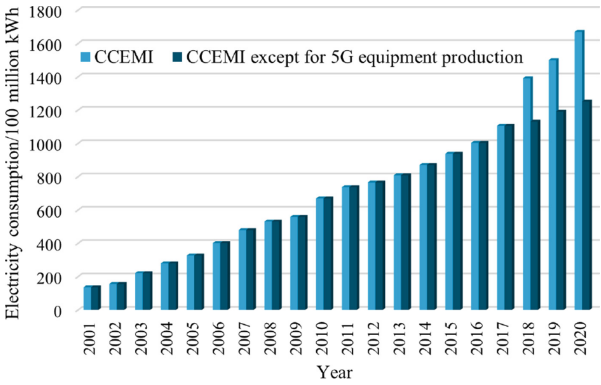

Fig. 3. Electricity consumption of China's computer, communication, and other electronic equipment manufacturing industry from 2001 to 2020 (excluding 5G equipment production).

Table 1. Electricity demand for China's 5G equipment production during 14th Five-Year Plan period.

	2021	2022	2023	2024	2025
Electricity consumption/100 million kWh	398.48	447.36	496.24	545.12	594

Based on Eq. (1), the electricity demand for CCEMI excluding 5G equipment production from 2018 to 2020 is derived, as shown in Fig. 3.

Figure 3 shows the electricity demand of the CCEMI without 5G equipment production, and the difference can be approximated as the electricity demand of the 5G equipment production process. The electricity demand for the production of 5G equipment in China can be expressed as follows:

$$E_p = 48.88t - 98388 \tag{2}$$

where E_p represents the annual electricity demand for the production of 5G equipment.

The electricity demand for China's 5G equipment production during the 14th Five-Year Plan period can be calculated, as shown in Table 1.

3.2 Analysis of Electricity Demand in the Operation Process of 5G Base Station

The electricity demand for the operation of 5G base stations mainly depends on the constructed number of 5G base stations and the electricity demand of a single 5G base station. Therefore, the electricity demand for the operation of 5G base stations can be represented by Eq. (3):

$$E_o = \sum_{i=1}^{N} e_{o,i} \tag{3}$$

where E_o represents the overall electricity demand for the operation of 5G base stations in China, $e_{o,i}$ represents the annual electricity demand of the i-th base station, and N represents the number of 5G base station construction in China.

Equation (3) summarizes the annual electricity demand of each base station through a bottom-up method and then calculates the overall annual electricity demand of China's 5G base stations. Although the bottom-up method can be more comprehensive and accurate, and the obtained electricity demand data is more authentic and reliable, it needs higher data requirements. According to statistics from the Ministry of Industry and Information Technology, China has built over 1.425 million 5G base stations as of the end of 2021. It is obvious that the bottom-up electricity demand estimation method is not feasible, so it is necessary to improve Eq. (3). Due to the integrated management of equipment implemented by 5G base stations, the composition and energy consumption of base station equipment under the same operator are basically the same. Therefore, the future electricity demand of 5G base stations can be represented by Eq. (4):

$$E_o = N \times \overline{e_o} = N \times \sum_{j=1}^{n} e_o^j \tag{4}$$

where $\overline{e_o}$ represents the typical power consumption of a single base station, which can be represented as the sum of the typical power consumption of various devices within the base station.

Taking a macro site as an example, a single 5G macro base station is mainly composed of one BBU and three AAU. Its electricity demand includes main equipment (BBU and AAU), air conditioning, and some other equipment, about 6711W in all. According to "China 5G and Data Center Carbon Emissions Outlook 2035", the number of base station construction in China during the 14th Five Year Plan period can be calculated using Eq. (5):

$$N = 68 \times 1.636^{t-2020} \tag{5}$$

Therefore, the electricity demand for China's 5G base station operation during the 14th Five-Year Plan period is shown in Table 2.

However, the high-power consumption in 5G base stations is becoming increasingly prominent, and it is crucial for operators to reduce the power consumption of base stations. Currently, energy-saving solutions for 5G base stations mainly include symbol shutdown, channel shutdown, carrier shutdown, and deep sleep. The consumption reduction effects of various solutions are shown in Fig. 4.

As shown in Fig. 4, the power consumption reduction of a single 5G base station under different schemes is about 10%–29%. Therefore, considering the energy-saving

Table 2. Electricity demand for China's 5G base station operation during 14th Five-Year Plan period.

	2021	2022	2023	2024	2025
Electricity consumption/100 million kWh	654.01	1069.96	1750.45	2863.74	4685.08

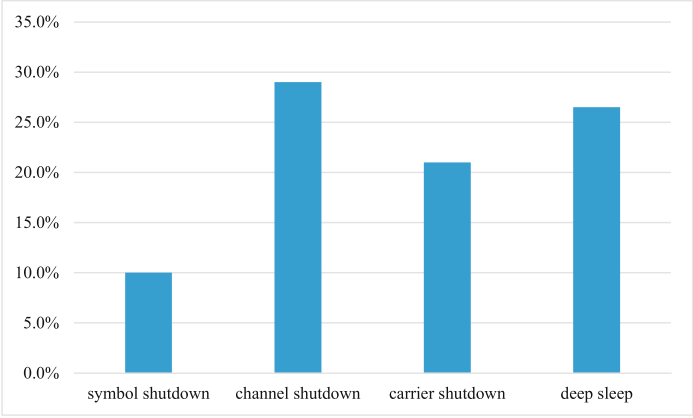

Fig. 4. 5G base station energy saving and consumption reduction scheme effect.

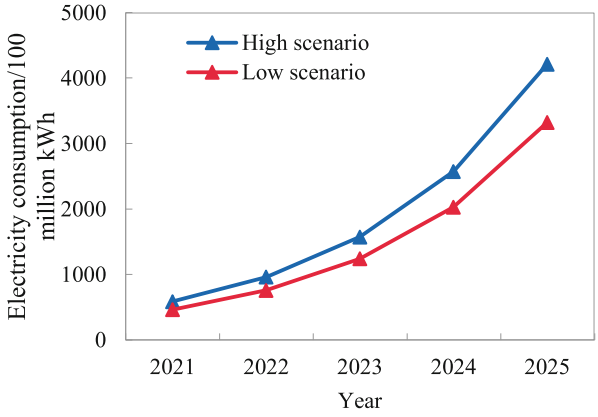

Fig. 5. Electricity demand for China's 5G base station operation during 14th Five-Year Plan period (considering energy saving and consumption reduction of base station).

and consumption reduction plan for base stations, the electricity demand for China's 5G base station operation during the 14th Five-Year Plan period is shown in Fig. 5:

3.3 Analysis of Electricity Demand in the Application Process of 5G Technology

Due to the short development time of 5G technology, there were relatively few access users and application scenarios in the early stages of the 5G technology application. Hence, there was relatively little electricity demand data for existing 5G technology applications, which also brought difficulties to the analysis of future electricity demand trends for 5G technology applications.

The Bass diffusion model and its extended theory proposed by Bass are often used as market analysis tools to predict the demand for new products and technologies for the adoption and diffusion of innovative products and technologies. The basic form of

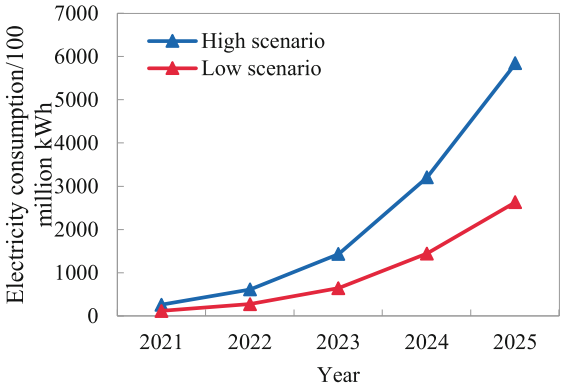

Fig. 6. Electricity demand for China's 5G technology application during the 14th Five-Year Plan period.

the Bass model is shown in Eq. (6):

$$\frac{dU(t)}{dt} = p[m - U(t)] + q\frac{U(t)}{m}[m - U(t)] \tag{6}$$

where $U(t)$ represents the cumulative adopters in the year t, p represents the external influence coefficient, q represents the internal influence coefficient, and m represents all the adopters.

Equation (6) can be transformed into the following equation:

$$U(t) = m\frac{1 - e^{-(p+q)t}}{1 + (\frac{q}{p})e^{-(p+q)t}} \tag{7}$$

$$u(t) = m\frac{p(p+q)^2 e^{-(p+q)t}}{[p + qe^{-(p+q)t}]^2} \tag{8}$$

where $u(t)$ represents the adopter in the year t. As an emerging communication technology, 5G meets the conditions of Bass model. Therefore, the Bass model can be used to predict the electricity demand of China's 5G technology application during the 14th Five Year Plan period, as shown in Fig. 6.

4 Analysis of the Impact of 5G Industry Development on China's Electricity Demand

Taking into account the energy conservation and consumption reduction of base stations, the electricity demand of China's 5G industry under different scenarios is shown in Table 3.

As shown in Table 3, the average annual growth rate of electricity demand in China's 5G industry is 46.23% to 53.56% during the 14th Five-Year Plan period. Of which, the average annual growth rate of electricity demand in the production process of 5G

Table 3. Electricity demand for China's 5G industry during 14th Five-Year Plan period.

	2021	2022	2023	2024	2025
High scenario	1248.01	2024.79	3506.84	6329.62	10657.56
Low scenario	980.46	1484.05	2386.08	4024.23	6556.37

equipment is about 8.31%. The average annual growth rate of electricity demand during the operation of 5G base stations is about 48.26%. The average annual growth rate of electricity demand in the application of 5G technology is about 86.25%.

As of 2025, the overall electricity demand of China's 5G industry is 0.66–1.07 trillion kWh. During the 14th Five-Year Plan period, the average annual growth rate of China's total social electricity consumption was 4.7%–5.6%. By 2025, China's total social electricity consumption is expected to reach 9.4–9.8 trillion kWh. Hence, in the early stage of the 14th Five Year Plan, the electricity demand of the 5G industry accounted for 1.18%–1.50% of the total electricity consumption in China. With the rapid development of the 5G industry, by the end of the 14th Five Year Plan, the electricity demand of the 5G industry could reach 6.69%–11.34% of the total electricity consumption in China.

5 Conclusion

The emerging digital technology represented by 5G is an important guarantee for promoting China's digital process and achieving the "dual carbon" goal. With the explosive growth of communication demand in the energy and power industries, the development of 5G and its related industries has gradually grown into a new driving force for the future growth of China's electricity demand. By the end of the 14th Five-Year Plan, the electricity demand of China's 5G industry accounted for approximately 6.69%–11.34% of the total electricity consumption. Of which, the electricity demand for 5G equipment production accounted for approximately 0.61%–0.63%; The electricity demand in the application of 5G technology accounts for approximately 3.39%–4.49%; The electricity demand for the operation of 5G base stations accounts for approximately 2.69%–6.22%.

Faced with the rapid development of the 5G industry during the 14th Five Year Plan period, the energy and power industry needs to accelerate the construction of 5G-related infrastructure, accelerate the deep integration of 5G communication technology with traditional energy and power industries, and explore new business models of "5G+electricity" and "5G+energy". At the same time, facing the explosive growth in electricity demand brought about by the rapid development of the 5G industry, the power sector needs to accelerate the implementation of the "14th Five Year Plan" for the power industry and improve the safety and stability of the power system operation.

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