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Can the Energy Internet Promote China's Energy System to Achieve Carbon Peaks in 2030?

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ABSTRACT

Energy Internet (EI), which deeply integrates digital and new energy technologies, is known to be an effective way to reform the energy system and lower carbon emissions. Current studies on the carbon emission reduction advantages of the Energy Internet mainly focus on the generation of renewable energy, rarely discussing the environmental effects of digital technology. This paper proposed a system dynamics model, which included a thorough evaluation index for EI's digitalization, to simulate the carbon emissions of China's energy system and forecast its peak time. The simulation results demonstrate that the construction of the EI could enable China's energy system to meet the carbon reduction commitment in 2028, with a peak of 11,633 million tons of carbon emissions. These findings might provide a new perspective for quantitative research on the environmental outcomes of the EI and the relationship between environmental improvement and economic growth.

Keywords: Energy Internet, digitalization, clean energy, carbon emissions, carbon emission peak, system dynamics

NONMENCLATURE

Abbreviations	
EI	Energy Internet
ICT	Information and communication technology
SD	System dynamics

1. INTRODUCTION

It is well noted that the traditional energy system dominated by fossil energy has resulted in challenges like energy crisis and environmental pollution [1]. Energy Internet (EI), proposed by American economist Rifkin Jeremy in 2011, is becoming the most practical solution to those issues, which is to build a new energy system that focuses on developing renewable energy sources (e.g., solar, wind, and biological energy) and aims to improve the energy efficiency with digital technology [2].

However, the environmental effects of the EI on the energy system are still uncertain as the digital products, services, and relative infrastructure are further expanded [3]. While "smarter" systems could reduce their carbon emissions by a factor of 10 by 2030 [4], energy-intensive digital technologies represented by ICT and the Internet may crowd out a certain amount of energy consumption space and generate additional carbon footprint, which is not conducive to green and sustainable energy development [4-5].

There is a hot debate over how digitalization will affect energy consumption and carbon emissions. Previous research mainly started from a micro perspective, investigating the impact of digitalization on some specific projects. Some scholars have testified that the energy use and carbon emissions of those projects can be reduced after the application of ICT [6-7]. However, some scholars have reached quite different conclusions, arguing that the relationship between ICT and its energy consumption may vary among regions [8], or the relationship is not significant [9] or ICT has a "U"-shaped impact on energy consumption [10].

It should be highlighted that those complicated factors mentioned above are not taken into account when evaluating the environmental effects of the Energy Internet. Most scholars tend to illustrate the environmental benefits of the EI from theoretical analysis and scenario studies [11-14]. For example, Zhao et al. (2018) set up a self-balancing scenario and an interconnection scenario for the global Energy Internet. They quantitatively assessed the environmental benefits of the growth and use of large renewable energy and the increasing proportion of non-fossil energy power generation [15]. However, the current research on the Energy Internet and its environmental effects is primarily centered on the viewpoint of energy transformation, paying little attention to the energy consumption of digital technology and infrastructure.

Mapping out the most appropriate pathway towards carbon peaking and neutrality is challenging for China. The energy industry is responsible for almost 90% of China's total carbon emissions [16]. In 2016, the central government started a plan of "Promoting the Development of 'Internet+' Smart Energy" and aimed to promote the energy industry upgrading by deploying EI [17]. Following that, investment in software and IT services has increased the most dramatically, indicating that digitalization has been regarded as the primary driver for the EI in recent years [18-19]. According to a report concerning China's digital infrastructure, as early as 2018, China's data centers consumed 160.8 billion kWh, surpassing that of Shanghai which has been one of the highest electricity consumption cities in China. Given the pressure to meet the carbon peak target in 2030 proposed by President Xi, it is worth investigating the environmental impacts of the EI and assessing its potential to assist China's energy sector in reaching carbon peaks on schedule.

In this paper, we propose a system dynamics model to identify the impact path of digitalization and clean energy construction on energy consumption structure, as well as to quantitatively evaluate the carbon emissions of China's energy system. The order of the remaining text is as follows. Section 2 of this paper presents the model-building process. Section 3 illustrates how data is collected and parameters are set. The results are shown in Section 4. The main findings of the study are summarized in Section 5.

2. METHODOLOGY

System dynamics (SD), which was first introduced by Lay Wright Forrester in the 1960s to address industrial problems, has proven to be a practical mathematical technique for dynamically dealing with linear and non-linear interactions in a complex system [20-21]. Therefore, this study uses the SD model to predict the commensurable changes in CO_2 emissions in China's energy system, with an emphasis on the influences of the EI's digitalization development and clean energy production on energy consumption in China.

The system boundary is determined to be the environmental impacts that the EI brings to China's energy system. To better understand how the EI affects the energy system, the digitalization subsystem is additionally introduced in this study. Therefore, the SD model is subdivided into four subsystems: the digitalization subsystem, energy production subsystem, energy consumption subsystem, and environment subsystem. The time frame is adequately extended to 2011-2035 to see if the EI can promote China's energy system to accomplish carbon peaking in 2030. The model test time boundary is 2011-2021, and the model forecast time boundary is 2022-2035.

The basic structure of the system dynamics model is given in Fig.1.

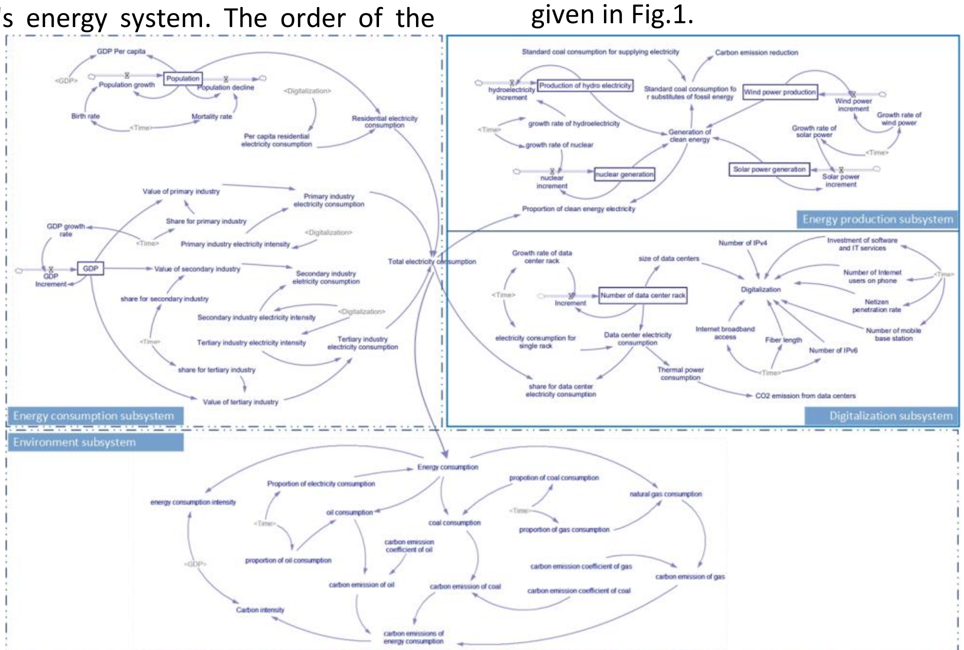

Fig.1 Dynamic modeling of China's energy system

3. DATA AND PARAMETER SETTING

Data from 2011 through 2021 is extracted from a variety of published sources. The data of the digitalization subsystem is obtained from <the China Science and Technology Statistical Yearbook>, <Statistical Report on the Development of the Internet in China>, and < Big Data Blue Book: China Big Data Development Report>. The data of other subsystems are derived from the < China Statistical Yearbook>, <China Energy Statistical Yearbook>, <China Electricity Yearbook>, <National electricity industry statistical snapshot list>, and <General Rules for Calculating Comprehensive Energy Consumption >.

Based on historical data, two methods of setting the main parameters are adopted in the paper. In the first place, the entropy method is applied to calculate the level of digitalization. Then, based on the ordinary least squares method, the relationships between digitization and the intensity of electricity consumption by industry and residents are clarified in this paper.

The data from 2022 to 2035 is a predicted value that is estimated in two ways. By reviewing the existing literature and the government's report, we obtain the values of the relevant parameters. For the predictive value of some data without available sources, we predict them based on the grey model.

4. RESULTS AND DISCUSSION

In this section, we will anticipate future carbon emission trends from the energy sector and evaluate China's ability to adhere to its carbon emission reduction pledges.

The forecasting CO_2 emissions of China's energy system, driven by the EI, are displayed in Fig.2. The most striking result is that the peak of CO_2 emissions from China's energy system, which is 11663 million tons, will happen in 2028. This demonstrates that China will successfully meet its commitment to reduce carbon emissions and reach its peak before 2030.

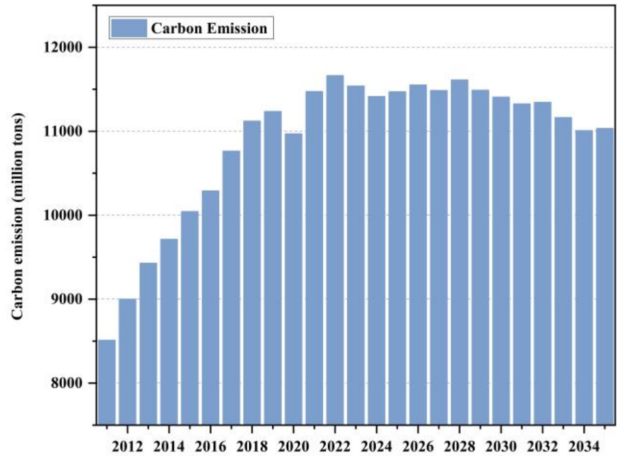

Fig.2 Forecasting results of China's carbon emission from 2011 to 2035

It is noteworthy that the development of the EI is a great guarantee for China to meet its carbon peak goal sooner than expected. For one thing, with the rapid development of digital technology, the way of energy consumption for companies and residents has changed. The consumption of electricity will increase from 284.82 million tce in 2022 to 3649.71 million tce in 2035, whereas the consumption of fossil fuels will decrease from 4147.05 million tce to 3768.52 million tce over the same period. For another, low-carbon electricity consumption will result from the development and use of clean energy, which provides a way to achieve green digitalization and makes the carbon emissions of digitalization no longer a problem. As we can see from Fig.3, as the EI becomes more digitalized, the electricity consumption of data centers will increase rapidly, while the carbon emissions of data centers will experience an inverted U shape and peak in 2028 as well.

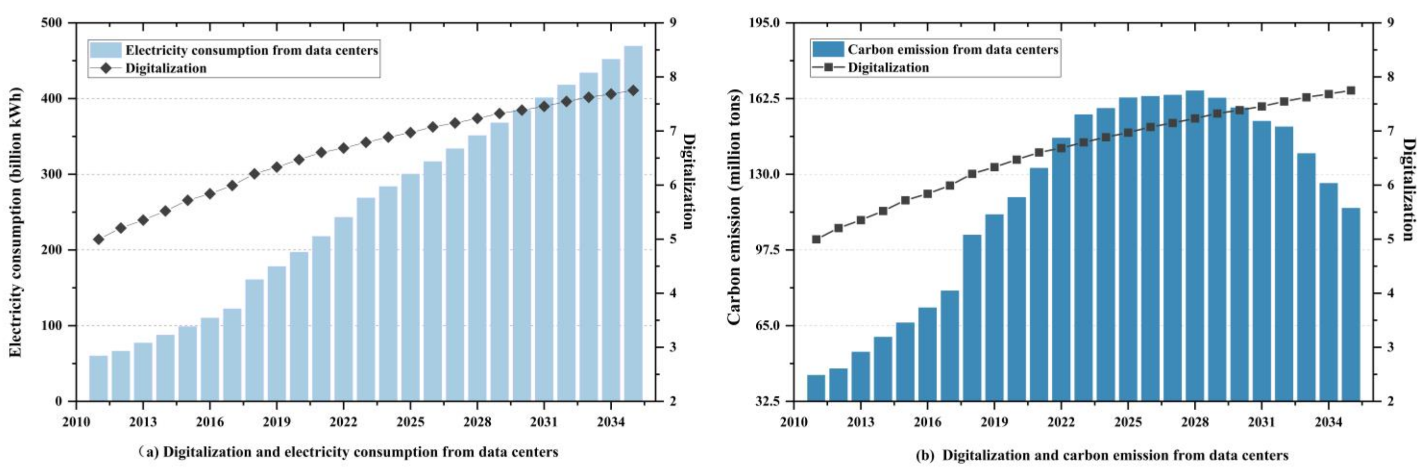

Fig.3 Digitalization and its energy consumption

5. CONCLUSION

While China is actively advancing the digitalization of the EI, attention has also turned to the issue that how much energy digital technology consumes. This paper establishes a comprehensive evaluation index of the digitalization of China's EI by the entropy method. Then, a system dynamics model containing the digitalization subsystem, energy production subsystem, energy consumption systems and environment subsystem is established to simulate the environmental benefits of China's Energy Internet for the energy system. The simulation results suggest that:

(1) The peak of CO_2 emissions from China's energy system is expected to be 11663 million tons and it will occur in 2028. China will undoubtedly adhere to its commitment to reduce carbon emissions and reach its peak before 2030.

(2) An effective assurance that China will achieve its carbon peak objective earlier than anticipated is the construction of the Energy Internet. Deepening digitization will decrease uncertainty in information flow and energy flow, revolutionize how people and industries use energy, and increase the share of electricity consumed by energy terminals. At the same time, thermal power generation will significantly decrease due to the rapid development of clean energy promoted by the Energy Internet, which will encourage power consumption and digitalization to be green and low-carbon.

In summary, the rapid construction of China's EI provides a guarantee for increasing China's economic growth and achieving carbon emission targets. The deep integration of digital technology and industry will promote the industry to carry out an all-around and fully connected upgrade and transformation, reduce fossil energy and resource consumption, and achieve double improvement of production efficiency and carbon efficiency. When digital technology and clean energy continue to penetrate and integrate, the Energy Internet may be one of the effective tools to promote the decoupling of economic growth and carbon emissions.

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