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ELECTRICITY FLOW OF PRESENT AND THE FUTURE IN CHINA: A PROVINCIAL PERSPECTIVE

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ABSTRACT

Considering the vital role of electricity in the energy consumption and electricity transportation being a bottleneck of high proportion renewable energy development in China, this paper assessed the current and future flow from a provincial perspective. According to the electricity flow in 2015, we found that most provinces mainly relied on local electricity power supply, while there was massive curtailment of the utilization of wind and solar power in some provinces due to the lack of electricity transportation capacity. From the perspective of provincial China-TIMES model in reference scenario, the southern and eastern provinces with large population or GDP will need to import electricity from northern and western provinces with high proportion integration of renewable energy. In the case study of Inner Mongolia and Henan in low carbon scenarios, the demand for electricity output capacity of Inner Mongolia is increasing and further optimization of the national electricity transportation capacity is needed as the increase in electricity flow.

Keywords: electricity flow; renewable energy; China; Provincial; China-TIMES

1. INTRODUCTION

Under China's Nationally Determined Contribution (NDC), the Chinese government proposed that the national carbon emissions peaks at 2030 or in advance meanwhile the renewable energy should account for more than 15% in primary energy in 2020 and more than 20% in 2030[1]. Because of the difference in economic development and energy reserves, each province should propose its own target of energy development under low carbon transition. There are huge differences in renewable energy reserves between provinces. For example, in Inner Mongolia, the proportion of national potential wind capacity on 70 meters is 56.9% and the proportion of national potential solar capacity is 34.1% with the population of 25.1 million in 2015. But for Henan, which owning a population of 94.8 million in 2015, the proportions are 0.152% and 0.288% respectively [2].

Fig. 1 shows the wind power, solar, and hydropower reserves, as well as population and GDP in 2015 for each province (Taiwan, Hongkong and Marco are not shown due to statistical issue).

Compared with Eastern and Southern China, western and northern China has considerably low energy consumption and high renewable energy reserves. It is worthwhile to analyze electricity transmission situation in China due to uneven renewable energy and electricity demand distribution. Zhang and Ma developed a multi-regional model to optimize the long-term electricity generation and transmission in China[3]. Taking regional resource endowments and air pollution control policies into consideration, the model minimizes the accumulative system cost. Zhang proposed an evolution framework of power system with high proportion of renewable energy[4]. Taking carbon emission reduction into account, Cheng and Xu presented a multi-period model and an optimization framework for China's power sector between 2010 and 2050. [5]. The studies above optimized multiregional electricity flow by considering the cost of power system, renewable energy integration or carbon emission. This study analyzes the current electricity flow between provinces in 2015. Besides, it applies a bottom-up energy system model to figure out the future electricity flow in the Reference scenario.

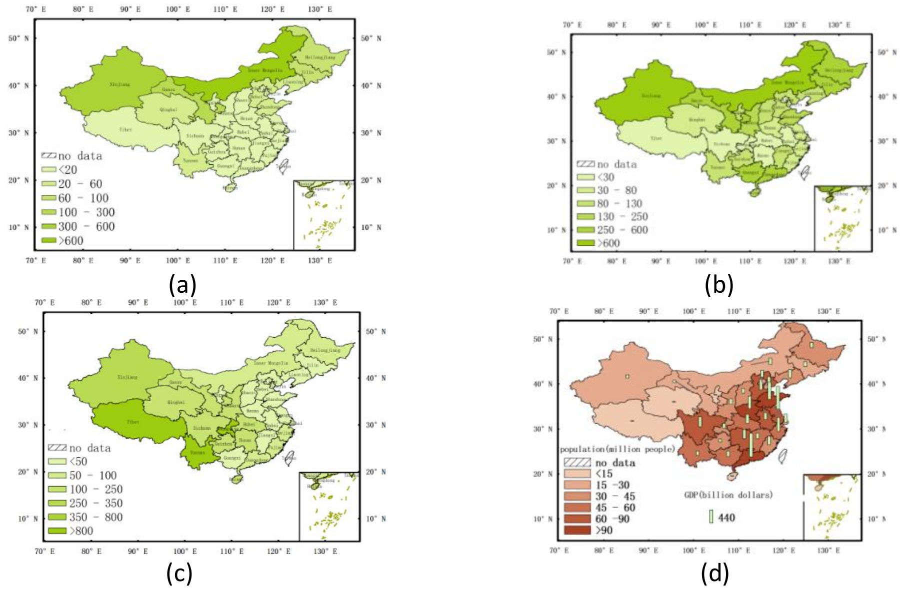

Fig 1. (a) potential wind capacity on 70 meters(GW) (b) potential solar capacity(GW)
(c) potential hydropower capacity(GW) (d)GDP and population in 2015

2. METHODOLOGY

This model is improved from China-TIMES model. China-TIMES model is an optimization model which figures out the lowest-cost combination of technologies and fuel mix over 2010-2050 to meet user specified energy service demand. Based on rich technology database and flexible application, the model can provide a detailed insight for the future development. The provincial model goes further to describe the provincial details that include energy extraction, convention and different end-use sectors. This model improves the methodology used in China-TIMES model to project the future energy service demand for the demand side[6-10]. Meanwhile the model adopts the original methodology and downscaling methodology together to get the future industrial energy service demand. The interactions between provinces are represented by the flow of electricity, coal, oil and gas.

3. SCENARIOS AND ASSUMPTIONS

In the reference scenario (REF), we take into consideration of the provincial targets of reduction of carbon intensity and coal consumption in the 13th Five Year Plan. And this study designs two low carbon scenarios CP30 and CPE with the constraint that the national accumulated carbon emission from 2010 to 2050 is respectively under 380Gt and 350Gt. In the scenarios, the national CO2 emissions can achieve the peak value in 2030 and in advance. In this study, the same electricity transportation capacity constraints are used in the reference scenario and low carbon emission scenarios.

4. RESULTS AND DISCUSSIONS

4.1 Current electricity flow in 2015

Figure 2 shows that Inner Mongolia, Jiangsu, and Sichuan account for 15.7%, 10.2%, and 7.8% respectively of inter-provincial electricity export nation-wide. Hunan, Jiangsu, and Shandong take up more than 8% of electricity import each.

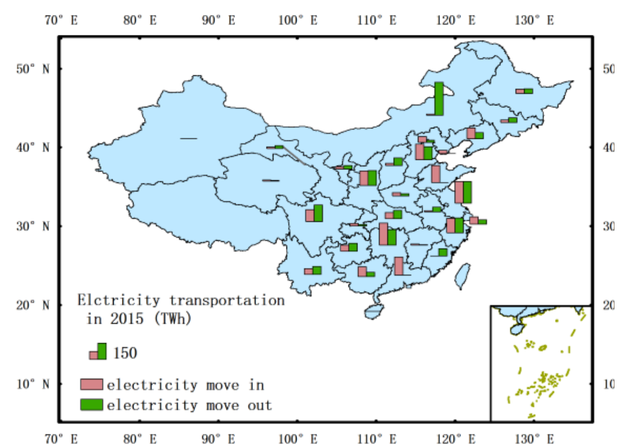

Fig 2 Inter provincial electricity transportation in 2015

The limited Electricity transmission capacity is one of the reasons for significant wind and solar energy curtailment in northern and western provinces. In 2015, the electricity export from Xinjiang was 0.21TWh. Meanwhile, the wind curtailment was 7.1TWh, which took up 32.5% of wind energy in that year.

To extend the transmission capacity of renewable energy, the government invested in building several high-capacity Ultra-High-Voltage(UHV) electricity transmission circuits. In 2016, 11 UHV circuits were put into operation. The transmission capacity of these circuits in total was 233.4TWh, of which 74% was for renewable energy transmission. In 2017, with a new UHV circuit put into operation, the transmission capacity of the 12 lines in total was 300.8TWh. in 2016, 7 UHV circuits were in construction, and 8 were planned to be constructed [3]. However, the utilization rate of some UHV lines are low. For example, the designed capacity of Zhe-Fu line is 6.8GW to 12.5GW. But in 2016, the actual transmission capacity of Zhe-Fu line only reached 1.71TWh. Therefore, the power grid has enough inter-provincial electricity transmission capacity and construction ability, and it is possible for china to access high proportion of renewable energy.

4.2 Electricity flow in the future

This study explores the future electricity flow in 2050 in REF. In this case, Inner Mongolia, Hubei, Xinjiang, and Sichuan account for 56.5%, 7.7%, 6.5% and 6.1% of total electricity export. Henan, Tianjin, and Guangdong account for 19.4%,9.6% and 9.0% of total electricity import.

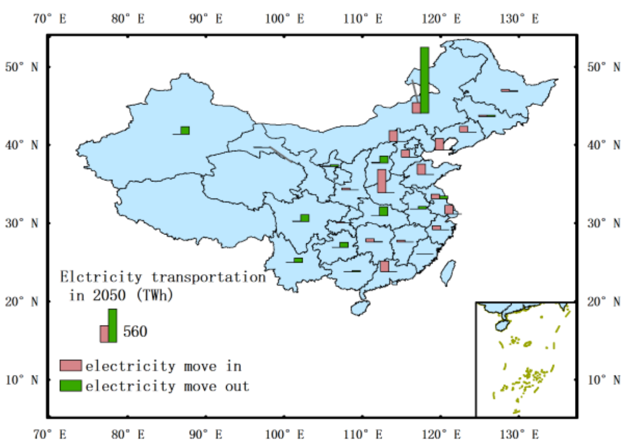

Fig 3 Inter provincial electricity transportation in 2050

Figure 3 shows that the major provinces where electricity moves out will be Inner Mongolia, Hubei, Sichuan, Xinjiang, Yunnan and Guizhou. Most of the provinces will have high proportion integration of renewable energy. For instance, renewable energy will take up 31.8%, 51.2% and 58.1% of the total electricity generation in Inner Mongolia, Hubei and Sichuan respectively. The northern and western provinces with great renewable energy reserves will become major provinces where electricity move out. The southern and eastern provinces with large population, higher GDP and higher electricity demand will become major provinces where electricity move in.

The 28 UHV lines cover the major provinces where electricity moves out and moves in. There will be 6 UHV lines starting in Inner Mongolia, 3 UHV lines starting in Sichuan, 3 UHV lines starting in Yunnan and 3 UHV lines starting in Xinjiang. In 2015, the UHV lines were planned to transport not only renewable energy but also for coal power. The provinces exporting coal power like Shanxi and Shaanxi will reduce the coal power by the targets of reduction of carbon intensity in the 13th Five Year Plan. There will be 4 UHV lines starting in Shaanxi and 2 UHV lines starting in Shanxi. However, Figure 3 shows that the coal based provinces cannot provide plenty of electricity as renewable energy based provinces like Inner Mongolia. Therefore, further optimization of the national electricity transportation capacity is needed.

4.3 Electricity flow in the low carbon scenarios

In REF, Inner Mongolia will have the largest output of electricity and Henan will have the largest input of electricity. This study chooses Inner Mongolia to analysis the electricity moving out and Henan to analysis the electricity moving in in the low carbon scenarios.

4.3.1 Inner Mongolia's electricity output

In 2015, the proportion of non-fossil energy electricity capacity accounted for 30.1%. In Inner Mongolia's 13th Five Year Plan, Inner Mongolia planned to be the energy output base and to increase the wind and solar power capacity to output electricity. Fig 4 shows the future electricity export industry in Inner Mongolia. In CP30's projection, Hebei, Hunan, and Shandong will become more active customers. Anhui and Shaanxi will become electricity importers in CPE's prediction.

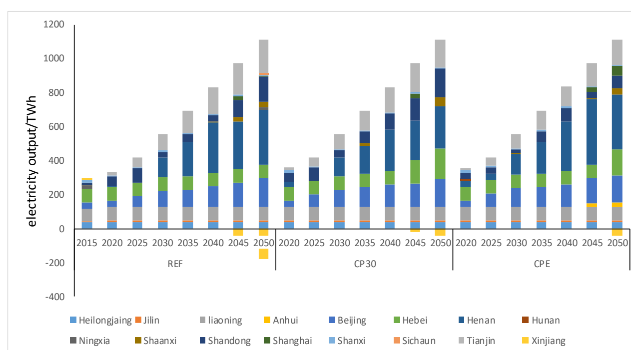

Fig 4 electricity moving out in Inner Mongolia

4.3.2 Henan's electricity input

In Henan's 13th Five Year Plan, it is mentioned that the adjustment of energy structure is a difficult task for

Henan because of the high proportion of the fossil fuels and the low proportion of renewable energy. Henan has the highest proportion of the cultivated area. Because of the limited amount of renewable energy reserves and land resources, renewable energy power in Henan cannot grow greatly. Fig5 shows the electricity consumption of Henan in the future. In 2050, the electricity consumption will be 647.7TWh, 632.9TWh and 556.8TWh in REF, CP30, and CPE respectively. The electricity import will reach 397.5TWh, 367.6TWh and 353.8TWh in REF, CP30 and CPE respectively.

Because elastic demand is used in the model, the increasing price of electricity reduces electricity consumption in low carbon scenarios. Compared with REF, Henan's consumption will decrease by 2.2% and 14% in CP30 and CPE. In CP30, the amount of Henan's renewable energy power increase by 75.3TWh to fill the gap which is caused by decreasing amount of fossil fuel power and electricity moving in. But in CPE, it can only increase by 9.5TWh. Meanwhile, the electricity moving in decrease by 76.1TWh. The stronger carbon emission constraint makes more provinces will need electricity moving in to replace fossil fuel power. In this situation, Henan cannot get enough electricity moving in with the constraint of electricity transportation capacity.

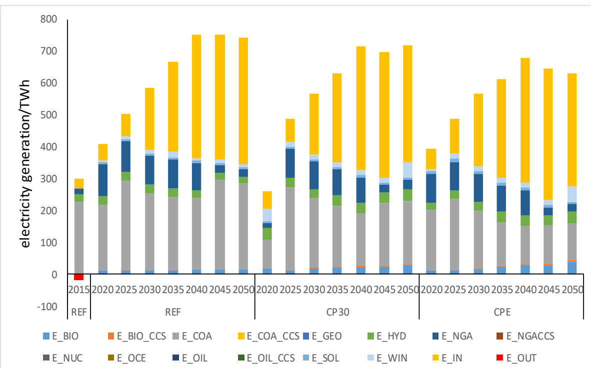

Fig 5 electricity consumption of Henan in the future

5. CONCLUSIONS

This study explores the electricity flow in the reference scenario and low carbon scenarios. In all scenarios, the provinces such as Inner Mongolia, Hubei and Sichuan with high proportion integration of renewable energy will be the major source of electricity output and the provinces in the southern and eastern China with larger population, higher GDP and higher electricity demand such as Henan and Guangdong will be the major targets of electricity input. In low carbon scenarios, more provinces will need electricity moving in or renewable energy power to fill the gap between the electricity demand and the reduction of fossil fuels power. At the same time, it is difficult for some provinces such as Henan which lack renewable energy reserves or land resources to integrate a high proportion of renewable energy. The model suggests optimizing inter-provincial electricity transmission capacity in low carbon scenarios.

ACKNOWLEDGEMENT

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