China's Tailored Power System: Integrating Renewable Resources, Innovative Technologies, and High-Resolution Modeling for Carbon Neutrality

Xiaoxiao Yan[1,2,3*], Gang Lin[1,2], Jingying Fu[1,2], Dong Jiang[1,2**]

1 Institute of Geographic Science and Natural Resources Research, Chinese Academy of Sciences; Beijing 100101, China

2 College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China

3 College of Geoscience and Surveying Engineering, China University of Mining and Technology-Beijing, Beijing 100083, China

* *Corresponding author Xiaoxiao Yan E-mail address: yanxiaoxiao@igsnrr.ac.cn*

* *Co-corresponding author Jiang Dong E-mail address: jiangd@igsnrr.ac.cn*

Abstract: With the intensification of global climate change and the strategic shift in energy structure, the large-scale development of renewable energy has become a global consensus. As the world's largest energy consumer, China faces significant challenges in its energy transition process toward achieving carbon neutrality. Projections suggest that by 2060, China's electricity demand will grow substantially, with wind and solar energy becoming the dominant sources of power. However, due to the uneven spatial distribution of energy resources in China—particularly the concentration of renewable energy resources in the northwest, while the east, with higher electricity consumption and population density, faces resource shortages—this imbalance has become a core challenge in constructing a new power system. On one hand, the uneven distribution of wind and solar resources, especially the limited construction of solar projects in the central and eastern regions, is a key issue. On the other hand, large-scale renewable energy integration and consumption continue to face challenges, especially due to the intermittency and variability of wind and solar power, which places increasing pressure on the grid. In response to these challenges, this study proposes a high spatial-temporal precision large-scale renewable energy deployment and power system optimization model. Based on a region-specific strategy, the model aims to improve energy utilization efficiency and optimize electricity consumption. Specifically, the application of renewable energy technologies such as photovoltaic systems in coal mining subsidence areas and floating photovoltaics can not only alleviate the pressure on land resources but also provide a new pathway for achieving carbon neutrality. This plan increases the proportion of renewable energy in a regionally tailored manner while addressing the issue of uneven resource distribution. By optimizing cross-regional grid construction, promoting distributed energy systems, enhancing energy storage technology, and strengthening smart grid management, it provides a feasible path for achieving carbon neutrality and contributing to the development of sustainable energy systems. This approach not only provides theoretical support for China's energy transition but also offers valuable insights for global energy system optimization

Keywords: Climate change; energy transition; renewable energy; power system optimization; carbon neutrality