Navigating Towards 2035 Beautiful China: Assessing a Low-Carbon, Resilient, and Inclusive Energy Transition Pathway through Multi-Model Analysis

Environmental Defense Fund

CHINA ENERGY MODELING FORUM

Ji Gao[1] (Presenter), Yu Liu[2], Sheng Zhou[3], Hongbo Duan[4], Jianhui Cong[5], Yingying Liu[6], Lantian Zhang[6], Yongsheng Wang[7], Ying Qiu[1], Bei Zhao[1], Keyang Xue[1]

1. Environmental Defense Fund, Beijing, China; 2. Peking University; 3. Tsinghua University; 4. University of Chinese Academy of Science; 5. Shanxi University; 6. Beijing University of Technology; 7. Chinese Academy of Sciences Geography Science And Resource Institute

Introduction

Ahead of COP26 in Glasgow, China updated its NDC targets and pledged to peak its carbon dioxide (CO_2) emissions before 2030 and achieve carbon neutrality before 2060. It is crucial to understand the implications of achieving these two targets in such a short time frame on China's emission pathways, socioeconomic development, energy transition, and inclusive development. Given China's broad landscape with regional differences in current development status and resource abundance, it is also necessary to understand how each region would be impacted by China's low carbon transition.

Yellow River Basin (YRB), known as China's "energy basin" is an important ecological security barrier for China, as well as a crucial area for human activities and economic development. An inclusive energy transition will contribute to the sustainable development of YRB. In addition, the energy transition would likely lead to the rapid development of variable renewable energy (VRE). Hence, along with the study of decarbonization pathways in national and provincial levels, China Energy Modeling Forum (CEMF) have also delved into the research of Water-Energy-Food-Ecosystem nexus management in YRB, and prioritized sectors such as the power sector.

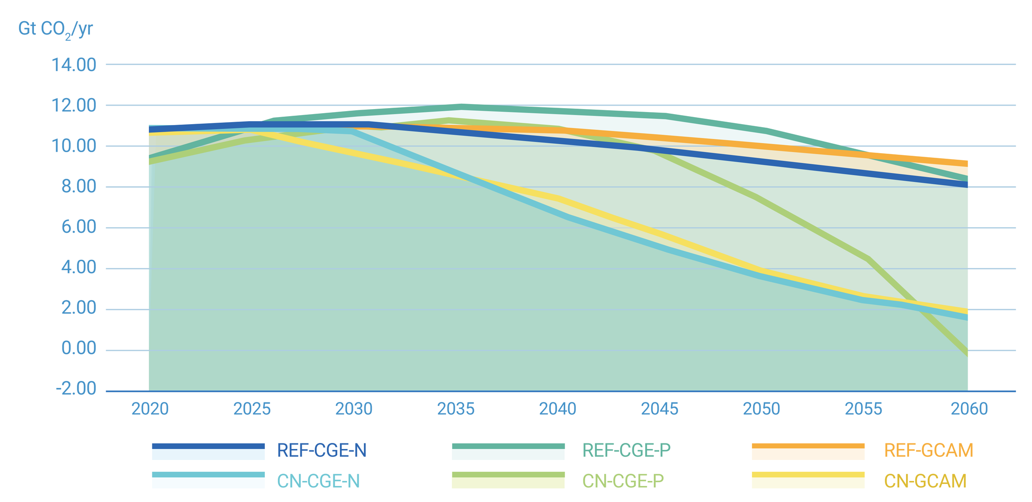
Methods & Models

Model	Note
CGE-N	Modeling China as a whole
CGE-P	Modeling China at the provincial level
GCAM	Modeling China as a whole
P-S-R	Modeling YRB at the provincial level
Input-Output Optimization Model	Modeling Shanxi Province
Water - Energy - Carbon Assessment (WECA) model	Modeling Shaanxi Province

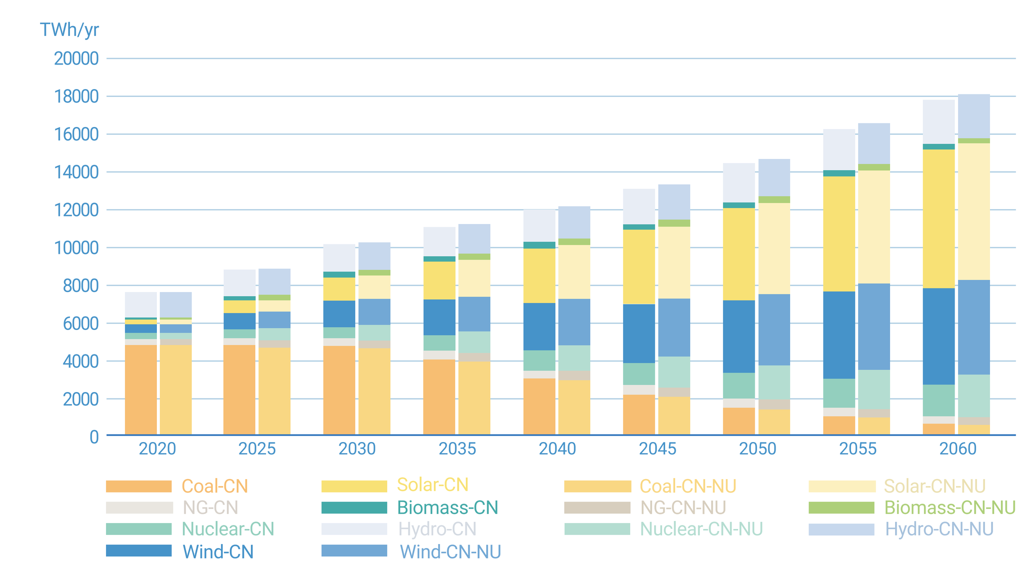
Scenario	Abbv.	Note
REF	REF	Baseline scenarios
Carbon Neutrality	CN	Carbon neutrality by 2060
Carbon Neutrality-hiNU	CN-NU	Carbon neutrality + high nuclear penetration
Business-as-usual	BAU	Baseline scenario
Low challenge - electricity - coal policy	Lec	Conservative approach, based on the energy resource endowment of Shaanxi, only achieve the dual carbon goals
Halve	Halve	Emissions halved compared to the 2030 peak by 2035
Great challenge - electricity - coal policy	Gec	Very high proportion of electricity substitution technologies + achieves dual carbon goals and the non-fossil energy share target
Great challenge - renewable energy policy	Ger	Extremely high proportion of renewable energy sources + achieves the dual carbon goals and the non-fossil energy share target
Carbon Peaking	CP	Both China and Shanxi province achieve carbon peaking in 2030
Water-Energy-Food Synergy	WEF	A holistic and integrated protection of water, energy, and food security

Results

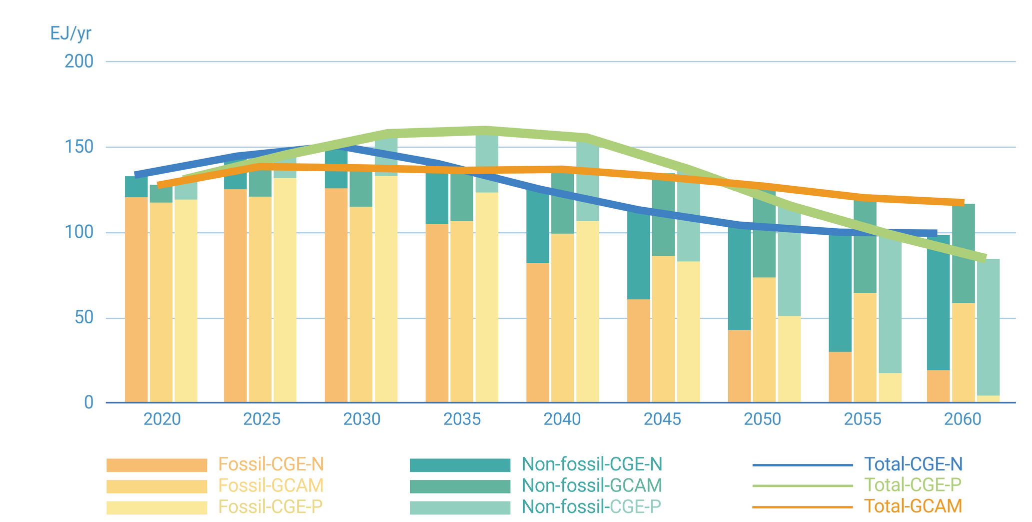
China's CO_2 Emission Pathways Across Models



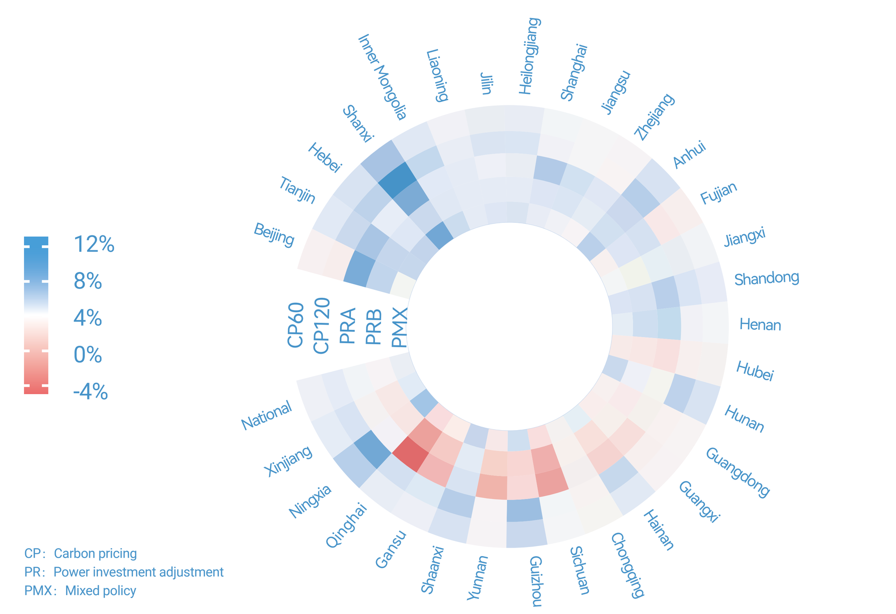
China's Electricity Generation by Fuel Type



China's Primary Energy Mix Across Models

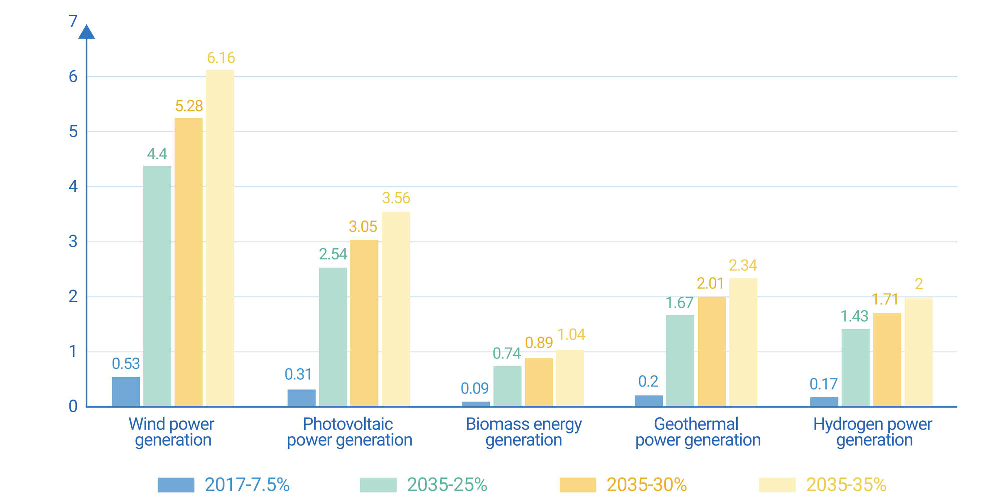


China's Economic Impacts of Achieving Carbon Neutrality Across-regions

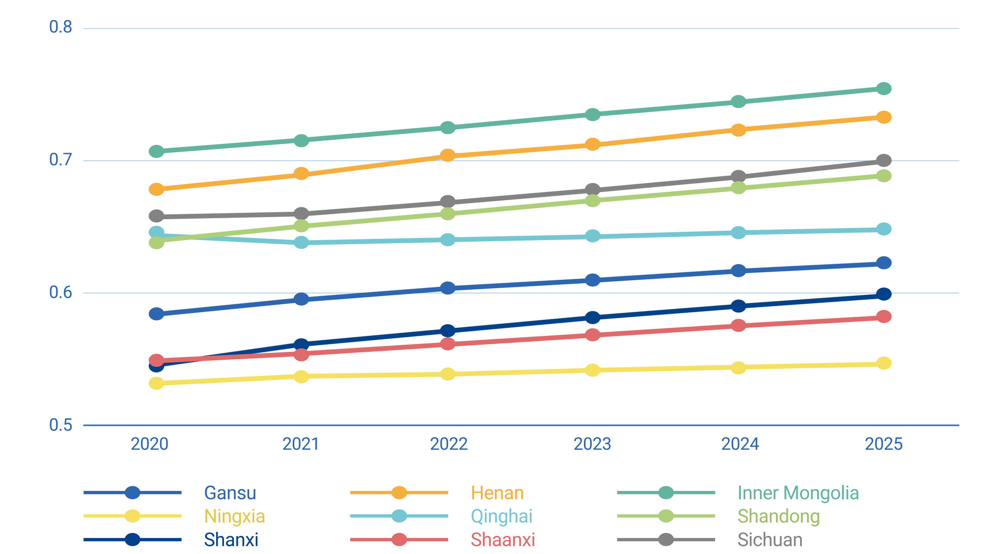


Shannxi's Water Assessment under Different Scenarios

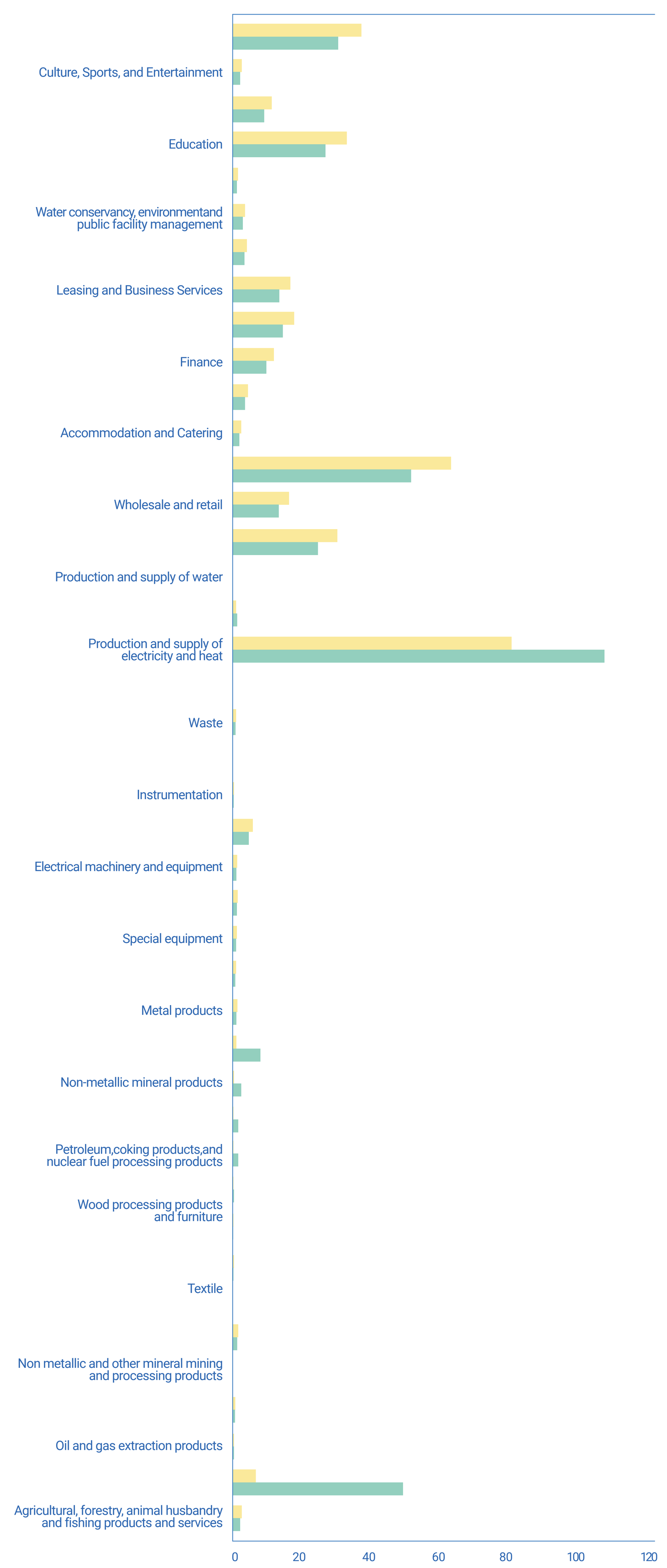
Estimated Number of Renewable Energy Employment in Shanxi Province in 2035 (Unit: ten thousand people)



YRB 9 Provinces' Water-Energy-Food Integrated Assessment Scores and Forecasts



Number of Employed Persons by Departments in Shanxi Province in 2035 (Unit: Ten thousand people)



9 Provinces of the YRB

Discussion

- **The limitation of multi-model comparison:** Different models have different assumptions of the cost and deployment projections of energy technologies. For example, models have different assumptions regarding cost and deployment projections for Carbon Capture, Utilisation and Storage (CCUS), yielding unalike results in the share of fossil fuels in primary energy consumption.
- **The challenges in integrating energy, economic, and environmental models:** Gathering accurate and comprehensive data on energy consumption, economic activities, and environmental factors can be challenging. Energy systems, economic structures, and environmental processes are highly complex and interconnected. Creating models that capture these complexities in a coherent manner is a significant challenge.
- **The absence of a comprehensive framework to assess inclusive development in the context of energy transition:** Inclusive development involves various dimensions, such as economic, social, and environmental aspects. Energy transition impacts all these dimensions, making it complex to quantify and assess comprehensively. Addressing these challenges requires a holistic and interdisciplinary approach, combining quantitative modeling with qualitative assessments and stakeholder engagement. It also involves ongoing monitoring and evaluation to adapt strategies and policies to ensure that energy transition benefits a broader spectrum of society.

Conclusion

- In baseline scenarios, China's energy-related CO2 emissions are expected to plateau around 2030. Under carbon neutrality scenarios, however, China can peak its emissions before 2030, even by 2025, with a peaking level below 11Gt.
- Relatively well-developed regions are less likely to experience GDP losses, whereas less-developed regions, especially those that rely heavily on the fossil fuel industry and lack renewable resources for development, will experience the worst impacts.
- Given the cost projections for CCUS technologies remain relatively high compared to that of nuclear, lessening the need for CCS can lead to a reduction in total mitigation cost. A more ambitious deployment of nuclear energy will mildly reduce the use of fossil fuels in the short-term, prior to carbon peaking, and reduce demand for renewables after peaking.
- For Shaanxi, improving CCUS technology and adopting corresponding advanced water treatment techniques can help reduce the impact on the water environment quality in major energy production cities. Each scenario shows significant synergistic effects on reducing water consumption, while the degree of synergy on water environment quality is the lowest. Considering the entire lifecycle, wind and solar energy have clear environmental advantages in the energy transition process. Large-scale applications will bring about significant synergies in energy conservation, emissions reduction, and water pollution reduction.
- The overall level of WEF development of YRB is relatively low, with a low growth rate, and inter-provincial disparities are gradually widening. The development level of the energy subsystem has improved significantly, but provinces with high energy production, such as Shaanxi, Ningxia, and Shanxi, have lower development levels in the energy subsystem due to their substantial energy exports.
- Shanxi Province will reach an employment figure of 150,000 in the renewable energy sector. However, the employment growth in the renewable energy industry struggles to compensate for the job gap in the coal and power industries. Labor migration shows a trend of moving from north to south, from west to east, and from inland to coastal areas. Resource-rich regions experience a significant outflow of labor, which may pose challenges to the transformation and development of these resource-dependent areas.