# Supplemental Material


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**Supplementary Discussions**

The China in Global Energy Model (C-GEM) serves as a comprehensive analytical tool for assessing the impact of energy–environment–economic policies in China from a global perspective [1]. Compared with other Computable General Equilibrium (CGE) models, C-GEM has several distinctive features. It is calibrated using key economic and energy consumption data from official Chinese sources, ensuring that recent economic trends are accurately captured. Its regional segmentation not only distinguishes geographic areas but also considers differences in regional economic development and competitive trade relationships with China. Furthermore, C-GEM provides a detailed representation of both the energy sector and energy-intensive industries—a crucial factor for analyzing climate change impacts in developing regions. In the power sector, the model differentiates conventional technologies (such as coal, oil, gas, nuclear, and hydroelectric power) from advanced technologies (including wind, photovoltaic, and biomass energy generation), treating the latter as either perfect or imperfect substitutes. Additionally, C-GEM incorporates alternative advanced energy technologies like shale oil, biofuels, and coal gasification, accounting for their future potential based on regional cost differentials.

The C-GEM model incorporates key equations and parameters in its static and dynamic modules. In the static module, the production and consumption function $F$ is modelled as the nested CES function (Equations (S1) and (S2)), where $Y$ and $C$ represent the production and consumption products, and $i$ and $r$ denote sectors and regions, respectively. $L$, $K$, $R$, and $I$ in Equation (S1) represent labor input, capital input, resource input, and intermediate goods input, respectively. $M$ and $S$ in Equation (S2) denote market-available goods and services for consumption.

$$Y_{i,r} = F_{i,r}(L_{i,r}, K_{i,r}, R_{i,r}; I_{i,r,1}, I_{i,r,2}, \dots, I_{i,r,n}) \quad \text{(S1)}$$

$$C_{i,r} = F_{i,r}(M_{i,r,1}, M_{i,r,2}, \dots, M_{i,r,n}; S_{i,r,1}, S_{i,r,2}, \dots, S_{i,r,n}) \quad \text{(S2)}$$

In the C-GEM model's dynamic module, $r$ and $t$ represent region and time, with $ti$ denoting the model's time span of five years. In Equation (S3), $L$ represents labor, $\phi$ population growth rate, and $g$ the labor productivity growth rate. In Equation (S4), $K$ stands for capital, $\delta$ for the depreciation rate, and $I$ for current investments. Capital updates consider reinvestments and technological upgrades that enhance the efficiency of production facilities and infrastructure, thereby fostering economic growth and adaptation to new energy technologies. C-GEM also

assumes that energy efficiency improvements occur autonomously, reducing energy consumption by a certain percentage each year, represented by the $aeei$ rate (Equation (S5)). The term $e^{-aeei}$ reflects the cumulative effect of energy efficiency improvements over time, leading to a decrease in energy consumption independent of other economic factors. These updates enable the model to dynamically adjust to changing economic conditions and to simulate long-term economic and energy transitions.

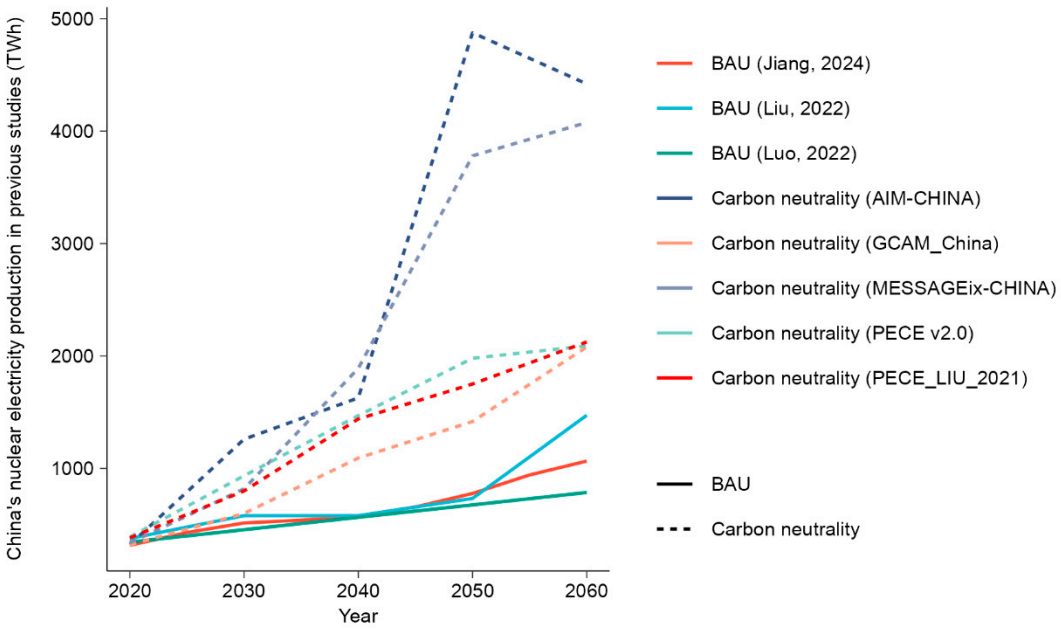
$$L_{r,t} = L_{r,t-1} \times (1 + \varphi_{r,t})^{ti} \times (1 + g_{r,t})^{ti} \quad \text{(S3)}$$

$$K_{r,t} = \left(1 - \delta_{r,t}\right)^{ti} * K_{r,t-1} + I_{r,t} \quad \text{(S4)}$$

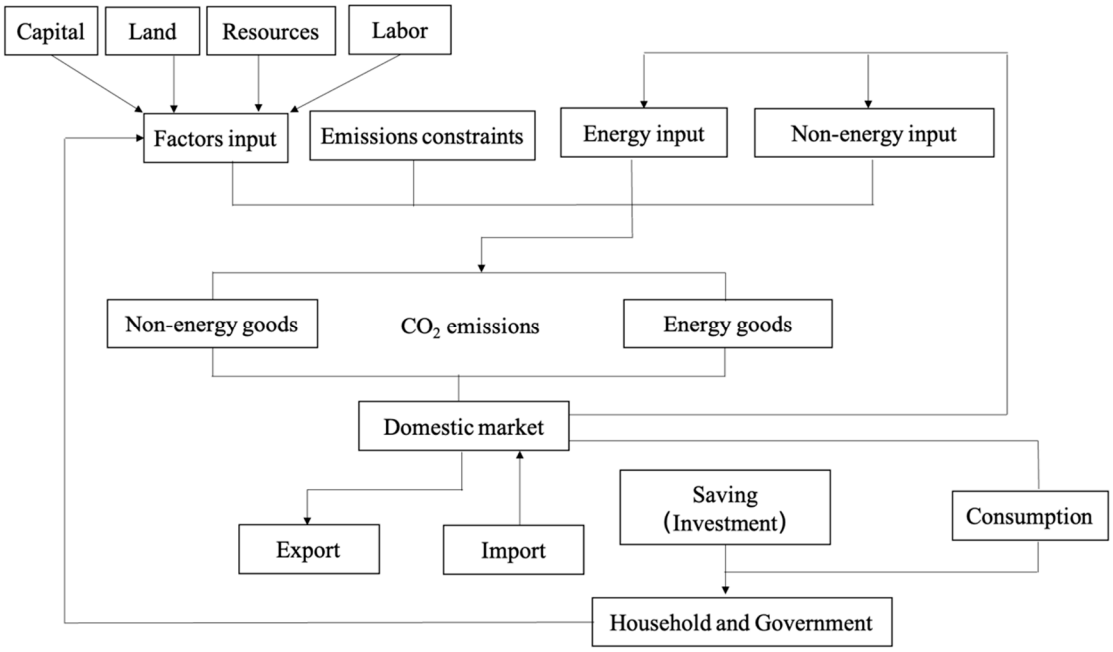
$$E_t = E_0 * e^{-aeei*t} \quad \text{(S5)}$$

The benchmark year data for the C-GEM model are modeled based on the latest GTAP 11 database [2], China's Input–Output Tables [3], and the China Energy Statistical Yearbook [4]. The GTAP's sub-database, GTAP-Power Database, further dissects the power sector, aiding in a more detailed depiction within the model. Key parameters in the static module, such as substitution elasticity, have been assigned based on extensive literature review and inter-model comparisons by the C-GEM modeling team. The labor–capital substitution elasticity is fixed at 1, while the substitution elasticity between labor–capital bundle and energy inputs ranges from 0.1 to 0.5. The substitution elasticity between the labor–capital–energy bundle and other intermediate inputs is set at 0.

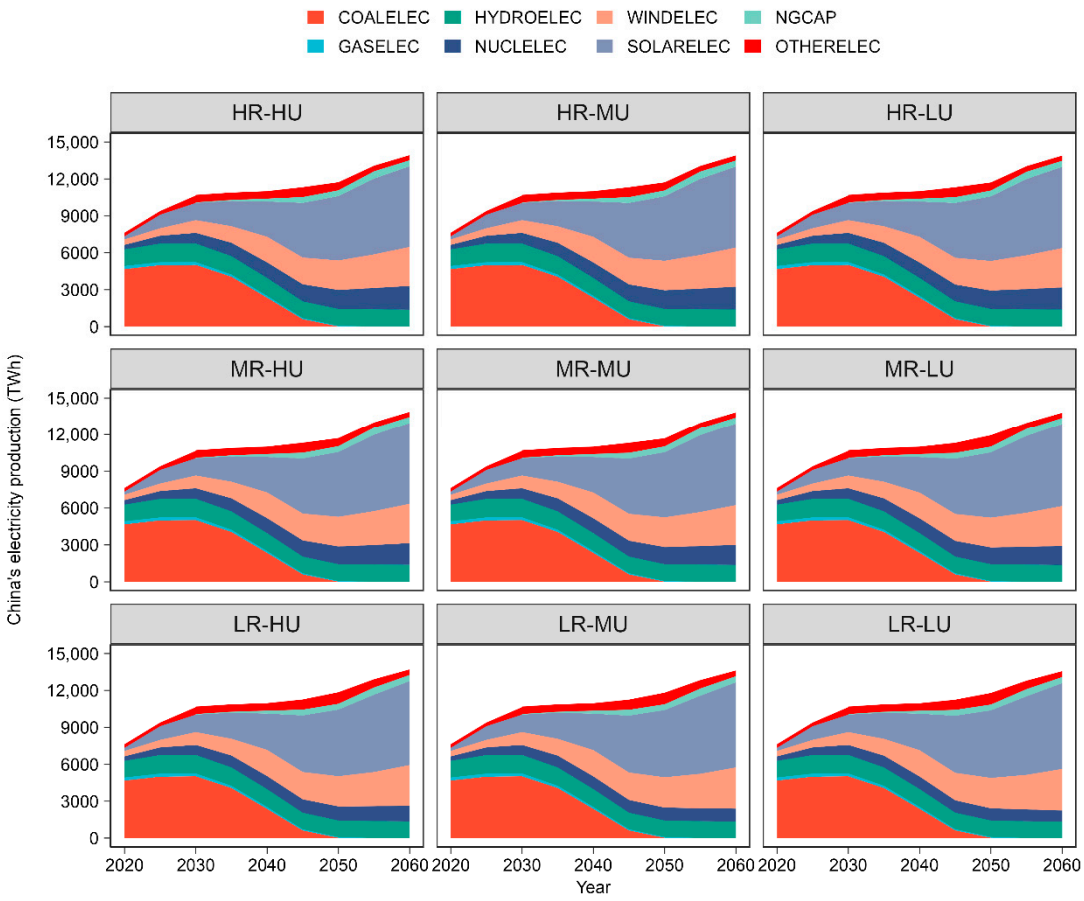
## Supplementary Figures



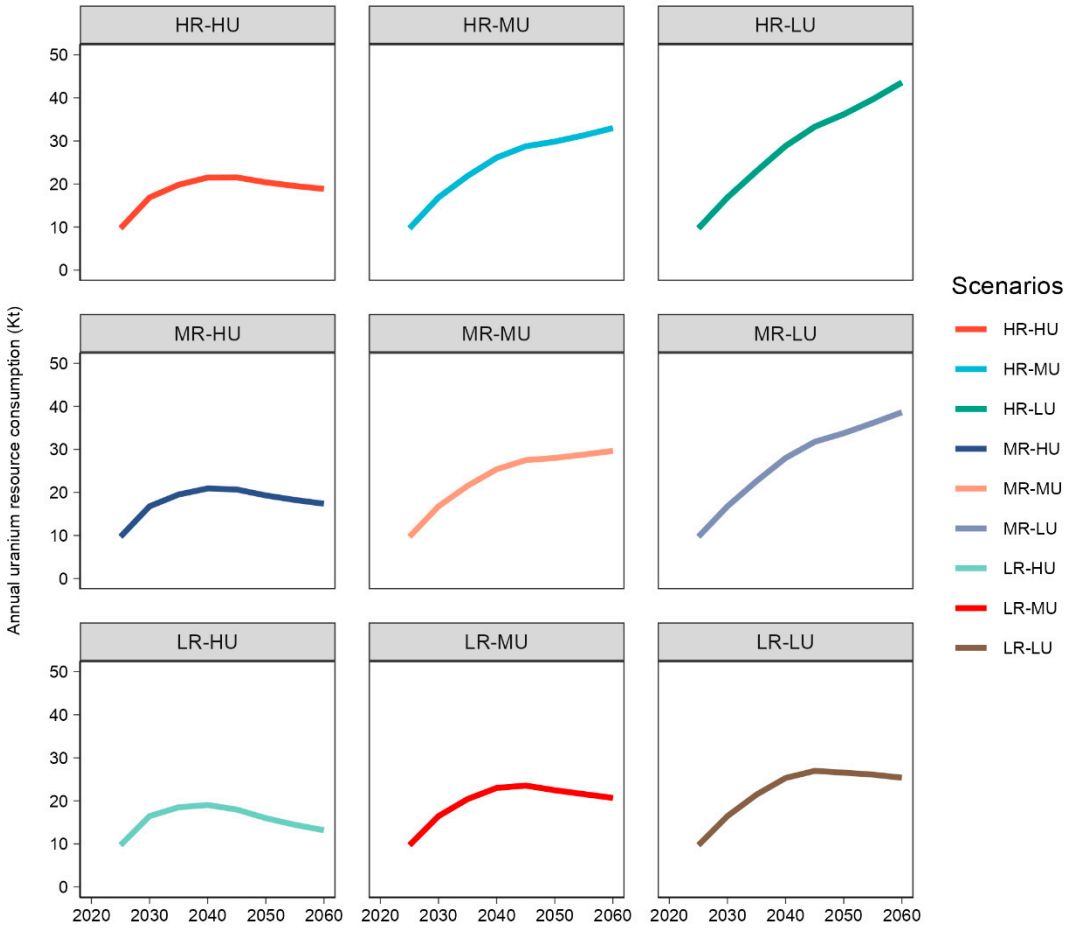

**Supplementary Figure S1. Projections made by different studies and models for nuclear power development in China from 2020 to 2060 [5-8].**



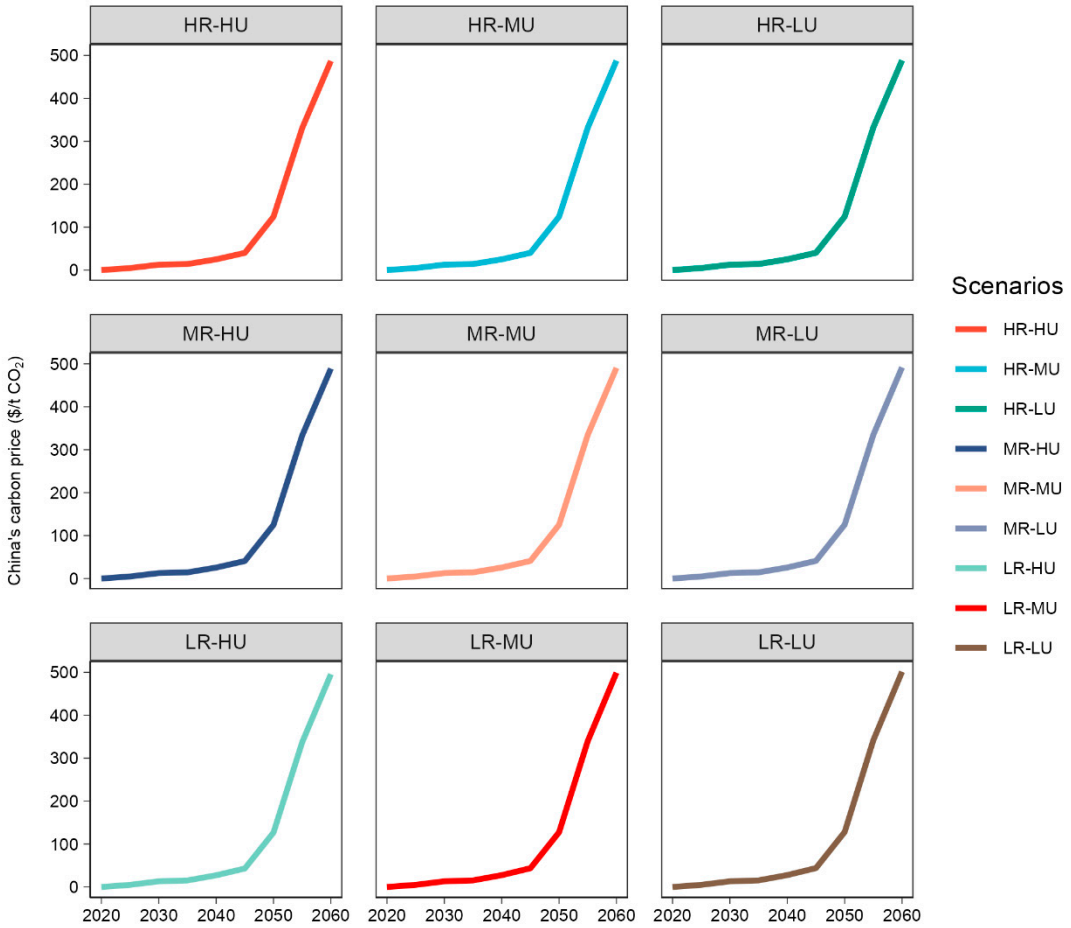

**Supplementary Figure S2. The basic model structure of the C-GEM model.**




**Supplementary Figure S3. China's electricity production structures under different scenarios for carbon neutrality target.**




**Supplementary Figure S4. China's annual uranium resource consumption from nuclear power generation under different scenarios for carbon neutrality target.**




**Supplementary Figure S5. China's carbon price under different scenarios for carbon neutrality target.**

**Supplementary Tables**

**Supplementary Table S1. Classifications of regions and sectors in the C-GEM model.**

| Regions | Sectors |
|---|---|
| China, CHN | Agriculture, AGR |
| United States of America, USA | Coal, COAL |
| Europe Union, EUR | Crude oil, OIL |
| Japan, JPN | Natural gas, GAS |
| Canada, CAN | Refined oil, ROIL |
| South Korea, KOR | Electricity and heat, ELEC |
| Australia–New Zealand, ANZ | Chemical rubber plastic production, CRP |
| Mexico, MEX | Non-metallic minerals, NMM |
| India, IND | Iron and steel, I_S |
| Brazil, BRA | Non-ferrous metals, NFM |
| Russia, RUS | Construction, CNS |
| South Africa, ZAF | Electronic equipment, ELE |
| Developing South East Asia, SEA | Textiles and Leather, TWL |
| Rest of Africa, AFR | Transport equipment, TEQ |
| Rest of Asia and Europe or Eurasia, RAE | Mining, MINE |
| Middle East, MES | Food products, FOOD |
| Rest of Latin America, LAM | Other industry, OTHR |
| | Transport, TRAN |
| | Commercial and public services, SER |

**Supplementary Table S2. Consumption of uranium resources for nuclear power development in China from year 2015 to year 2019 (billions of USD).**

| | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|
| Domestic and non-domestic (industry and government) uranium exploration and development expenditures | 0.68 | 0.51 | 0.23 | 0.16 | 0.18 | NA | NA | NA |
| Imported uranium expenditures | 1.90 | 1.30 | 1.13 | 1.14 | 0.98 | 1.27 | 1.24 | 1.26 |
| Total expenditures | 2.58 | 1.81 | 1.36 | 1.30 | 1.16 | NA | NA | NA |

**Supplementary Table S3. Uranium resource utilization efficiency for nuclear power generation in China.**

| | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|---|---|
| China's nuclear power generation (TWh) [4] | 210.5 | 247.5 | 277.1 | 330.1 | 344.7 | 383.2 | 395.4 | 433.4 |
| China's uranium demand (tU) [9] | 6072 | 5338 | 8289 | 9834 | 8352 | 10814 | 9563 | 11303 |
| China's Uranium resource utilization efficiency (tU/TWh) | 28.85 | 21.57 | 29.91 | 29.79 | 24.23 | 28.22 | 24.19 | 26.08 |

**Supplementary References**


1. Qi, T.; Winchester, N.; Karplus, V. J.; Zhang, D.; Zhang, X., An analysis of China's climate policy using the China-in-Global Energy Model. *Econ. Model.* **2016,** 52, 650-660.
2. Aguiar, A.; Chepeliev, M.; Corong, E.; van der Mensbrugghe, D., The Global Trade Analysis Project (GTAP) Data Base: Version 11. *J. Glob. Econ. Anal.* **2023,** 7, (2).
3. NBS. *China Statistical Yearbook*. National Bureau of Statistics of China. 2023. Available online: https://www.stats.gov.cn/sj/ndsj/2023/indexeh.htm (accessed on 13 March 2025).
4. NBS. *China Energy Statistical Yearbook*. National Bureau of Statistics. 2023. Available online: https://www.chinayearbooks.com/tags/china-energy-statistical-yearbook (accessed on 13 March 2025).
5. Luo, S.; Hu, W.; Liu, W.; Zhang, Z.; Bai, C.; Huang, Q.; Chen, Z., Study on the decarbonization in China's power sector under the background of carbon neutrality by 2060. *Renewable Sustainable Energy Rev.* **2022,** 166, 112618.
6. Jiang, H.-D.; Pradhan, B. K.; Dong, K.; Yu, Y.-Y.; Liang, Q.-M., An economy-wide impacts of multiple mitigation pathways toward carbon neutrality in China: A CGE-based analysis. *Energy Econ.* **2024,** 129, 107220.
7. Liu, S.; Jiang, Y.; Yu, S.; Tan, W.; Zhang, T.; Lin, Z., Electric power supply structure transformation model of China for peaking carbon dioxide emissions and achieving carbon neutrality. *Energy Rep.* **2022,** 8, 541-548.
8. Yu, S.; Fu, S.; Behrendt, J.; Chai, Q.; Chen, L.; Chen, W.; Cheng, X.; Clarke, L.; Du, X.; Guo, F. *Synthesis Report 2022 on China's Carbon Neutrality: Electrification in China's Carbon Neutrality Pathways*. Energy Foundation China. 2022. Available online: https://www.efchina.org/Reports-en/report-snp-20221104-en (accessed on 13 March 2025).
9. WNA. *The nuclear fuel report: global scenarios for demand and supply availability 2023-2040*. World Nuclear Association. 2024. Available online: https://world-nuclear.org/shop/products/the-nuclear-fuel-report-global-scenarios-for (accessed on 13 March 2025).