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Economic analysis and impact assessment of electricity supply and demand-side emission reductions in China under carbon neutrality goals

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Highlight

- Regions are categorized based on electricity supply and demand characteristics.
- The distribution of natural resources across regions is considered in the analysis.
- Carbon emission constraints are applied in the modeling of carbon neutrality goals.
- Energy intensity sensitivity is used as an assessment metric for emission reduction.

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Methodology

- This study employs the LEAP-NEMO framework to minimize total social cost. The model characterizes detailed energy demands across key sectors and generation parameters, subject to constraints such as carbon limits and unit capacities. Powered by solvers like CBC, the framework conducts scenario analysis to evaluate optimal future carbon pathways and their associated mitigation costs under diverse strategies.

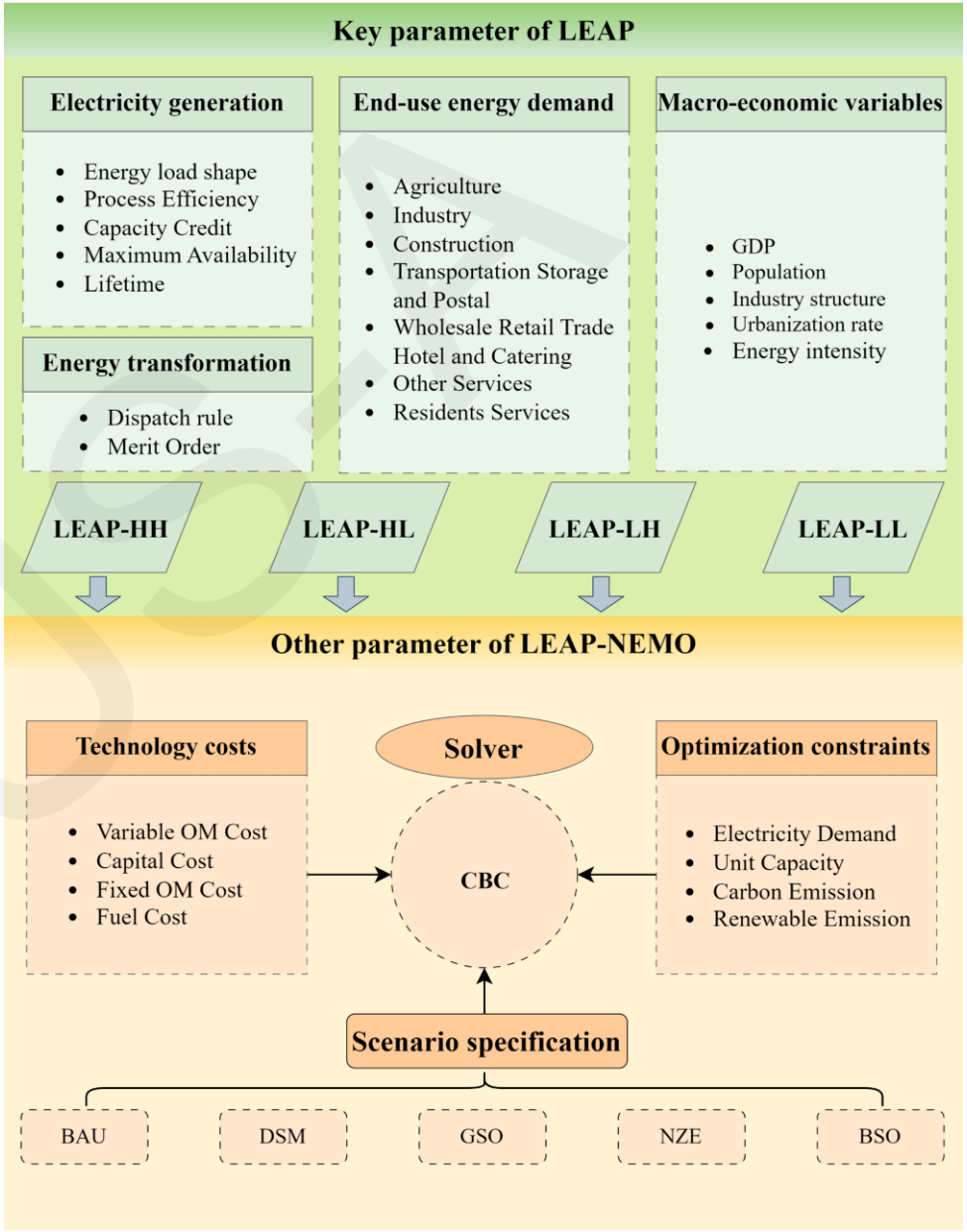

Fig | The modeling framework and key input of LEAP-NEMO

Conclusion I

- Renewable energy development plays a pivotal role in China's electricity structure transformation, as the accelerated adoption of wind and solar energy aligns with international objectives for sustainable development and clean energy transition. Considering the differences in resource conditions across regions, energy strategies should be tailored to local circumstances. In resource-constrained areas, priority should be given to nuclear power and other established generation methods to address electricity supply shortages.

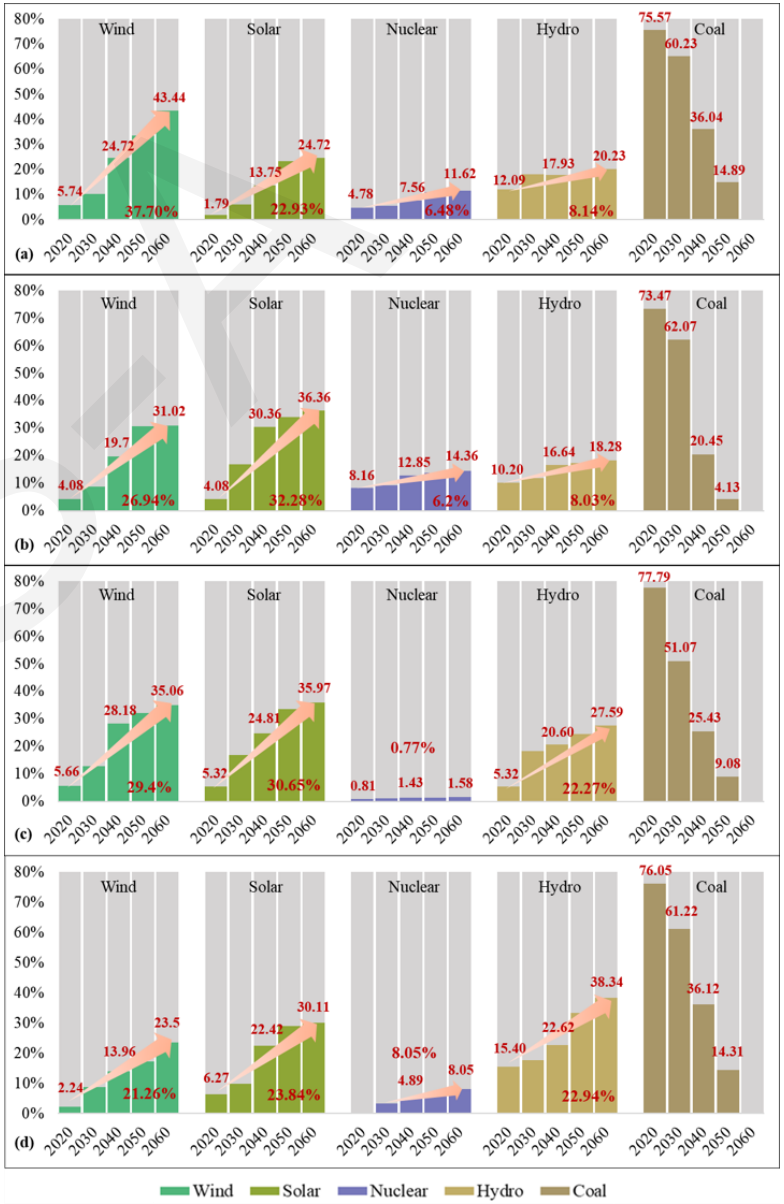

Fig | Changes in the power generation structure of four regions from 2020 to 2060

Conclusion II

- From an industrial development standpoint, industries within the LH region may encounter transformative pressures or potential decline, necessitating strategic development of emerging economic drivers and industrial restructuring to prevent deindustrialization traps. Conversely, the industrialization efforts in the remaining three region categories are ongoing, emphasizing the need for integrating technological innovations to promote clean industrial growth. Moreover, urbanization is expected to steadily increase residential electricity demand across all regions, necessitating a sustainable electricity supply to meet this demand.

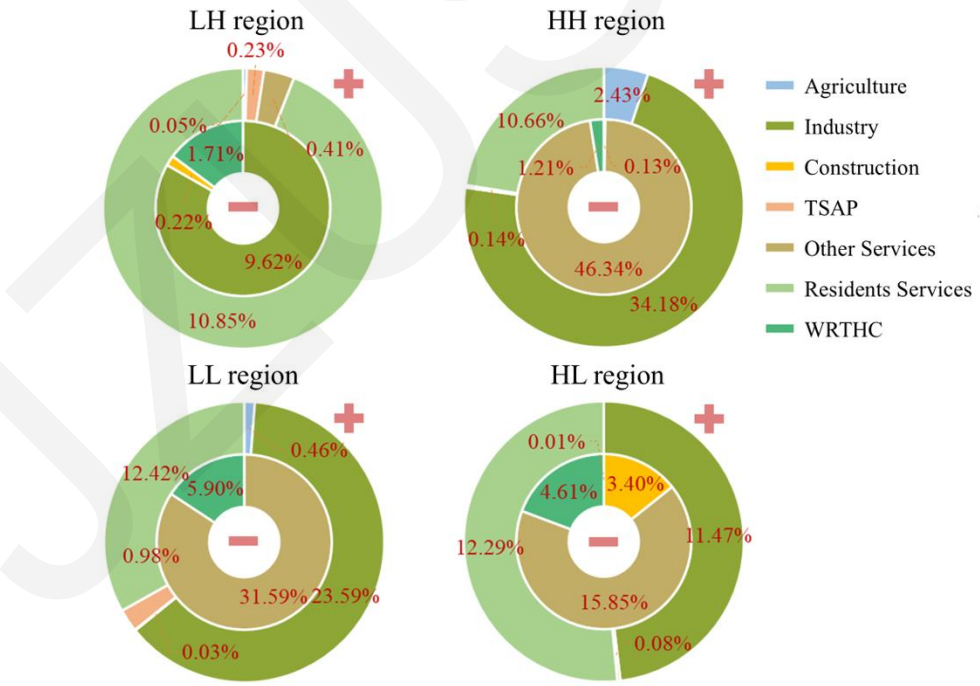

Fig | Changes in electricity consumption share by demand-side industries from 2020 to 2060 in four regions

Conclusion III

- Postponing the peak year increases short-term marginal cost of carbon reduction and the cumulative unit costs. What's more, achieving carbon peaking as early as possible is economically and technologically prudent to avoid compounding costs from climate extremes and ecological restoration. Regional heterogeneity in marginal costs and cost growth rates across power system typologies necessitates differentiated strategies. Specifically, the HL region which exhibites both high marginal costs and rapid cost escalation requires enhanced national policy support and prioritized investments.

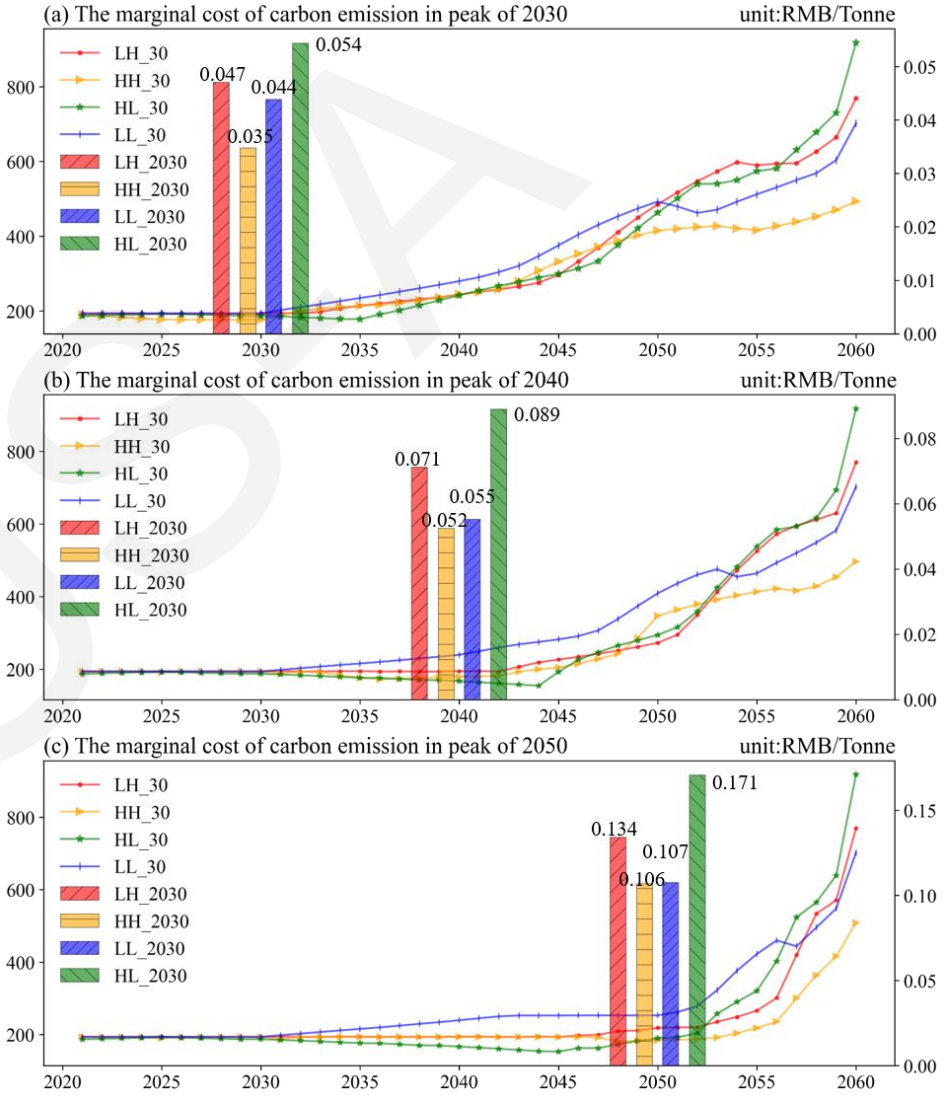

Fig | Marginal cost and cost growth rate of carbon reduction under different peak years

Conclusion IV

- The impact of energy intensity reduction rates varies across regions, necessitating strategic adjustments tailored to regional disparities. Specifically, the LH, HH, and HL regions should focus on achieving cost optimization with an energy intensity reduction rate of 1.5%, while the LL region might benefit from a 2% reduction rate. Additionally, regions with high energy generation should aim to sustain their energy intensity reduction rate beyond 2050, requiring the proactive development and implementation of adaptable strategies. In contrast, low generation regions will need continued policy support to maintain their reduction rates.

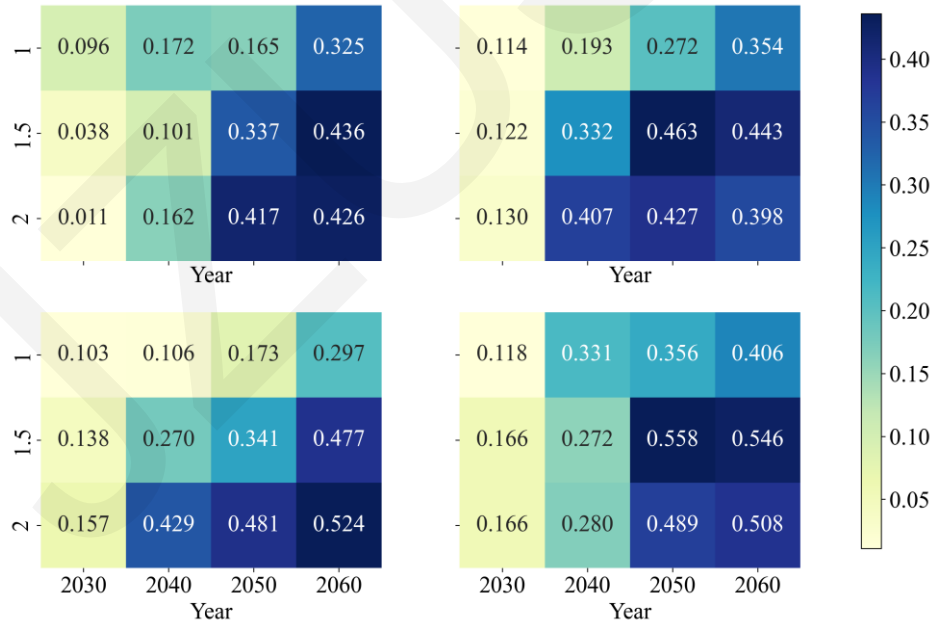

Fig | Sensitivity heatmap of energy intensity and cost changes from 2020 to 2060