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China’s challenges of warming limit: Strategic shift from 2 °C to well below 1.5 °C

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Introduction

Introduction

❖ **Broad framework: from 2 °C to 1.5 °C**

- Research on climate change of temperature increase has yielded rich achievements since the long-term goal is proposed by the Paris Agreement to limit the global average warming to well below 2 °C and further towards 1.5 °C with respect to the pre-industrial levels by the end of this century (Schleussner et al., 2016b).
- Existing studies mainly focus on 2 °C goal with topics including but more than the goal achievement, technology pathways, cost assessment and synergistic benefits (Duan et al., 2018b; Jordan et al., 2013), while studies about 1.5 °C goal remains sparse, particularly at the country levels (Vrontisi et al., 2018).
- The current global average temperature rise has already closed to 1°C, and the coming warming is likely to reach an even higher level (Otto et al., 2015), given continuous growth trend of global GHG emissions and the lock-in effect of the high-carbon economic development patterns (Rogelj et al., 2015a), which gradually shifts the focus of climate change research from 2 °C to an enhanced 1.5 °C goal (Hulme, 2016).

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❖ **Contributions: filling knowledge gaps from 3 aspects**

- First, understanding the significance of enhancing the temperature-increase limit from 2 ℃ to 1.5 ℃ is still lacking for China, while global-scale research shows that the strengthened warm-limiting target plays a formidable role in environmental, energy and economic systems. Here, we provide comprehensive details of systematic changes from 2 ℃ to 1.5 ℃ and make further discussions on potential strategies to address uncertainties.
- Second, limited evidence base for the dialogue with policy makers needs to be extended to the national level, because global governance depends on national actions, especially contributions from China, and that's why we focus on China and try to show its pronounced mitigation effect and promising transition effort.
- Third, the multi-model comparison, as an emerging research trend, facilitates the supporting method of robustness whereas with inadequate applications. In this study, we construct a multi-model analysis framework to gain reliable insights of goal-enhancing achievements and provide underlying implications for sustainability-developing approaches.

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Multi-model framework

Multi-model frameworks

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2.1 Participating models

Table 1. Basic information and brief summary of the participating IAMs

Abbreviation	Sources	Model type	Regions
AIM/CGE	(Calvin et al., 2012)	Dynamic-recursive CGE	32
GCAM	(Kim et al., 2006)	Dynamic-recursive PE	32
GEM-E3	(Capros et al., 2013)	CGE	One sector
IMACLIM	(Sassi et al., 2010)	CGE	12
IMAGE	(Bouwman et al., 2006)	Dynamic, PE	32
MESSAGE	(Messner and Strubegger, 1995)	Optimal GM	11
POLES	(EuropeanCommission, 1996)	Market PE	50
REMIND	(Leimbach et al., 2010)	Optimal economic GM	11
WITCH	(Bosetti et al., 2006)	Optimal economic GM	13 ~ 17
CE3METL	(Duan et al., 2013)	Aggregated optimal GM	One sector
IPAC	(Jiang et al., 2010)	Dynamic-recursive PE	9
GCAM-TU	(Wang et al., 2016)	PE	32

Note: CGE (computable general equilibrium), PE (partial equilibrium), GM (growth model)

Multi-model framework

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2.2 Multi-model comparison scenarios

Scenario settings in this study enables the assessment of strengthened targets towards 1.5 ℃ from 2 ℃, and we try to put all the IAMs at the same starting point by largely unifying the corresponding emission budgets under the given warming limits to make the cross-model outcomes comparable. Specifically,

- ✓ *2 ℃ scenario: mitigation efforts strengthened with globally uniform carbon price after 2020 to limit cumulative 2011-2100 CO_2 emissions to below 1000 $GtCO_2$ (corresponding to ~800 $GtCO_2$ from 2016-2100); >67% chance of staying below 2 ℃, consistent with the aim to stabilize well below 2 ℃.*
- ✓ *1.5 ℃ scenario: mitigation efforts strengthened with globally uniform carbon price after 2020 to limit cumulative 2011-2100 CO_2 emissions to 400 $GtCO_2$ (corresponding to ~200 $GtCO_2$ from 2016-2100); >67% chance of limiting 2100 warming to 1.5 ℃ (Vrontisi et al., 2018).*

As for national models that do not included in the ADVANCE project, i.e., the CE3METL and GCAM-TU, we design a highly comparable 1.5 ℃-consistent scenario, with the equivalent carbon emission budget to 760 $GtCO_2$ from 2016 to 2100; by using the blended principle defined by (Raupach et al., 2014), we then obtain China's available carbon space, i.e., 168.02 $GtCO_2$, in line with the expectation of the GCAM-TU.

Results

Results

3.1 Robustness in trajectories of targets

Enhancing the targets of limiting global warming towards 1.5 °C from 2 °C will lead to a significantly advanced carbon peaking and sharp reductions of total CO_2 emissions. It is mainly because that the achievement of warming-limit goals is tightly related to the emission trajectories, further implying corresponding emission budgets under different emission pathways (Millar et al., 2017; van Vuuren et al., 2011); in other words, the strengthened ambition of targets from 2 °C to 1.5 °C means increased constraints on emission trajectories and budgets (Vrontisi et al., 2018). Simultaneously, CO_2 emissions are mainly caused by energy consumption associated with long-term socioeconomic activities; therefore, by enhancing the global climate policy to limit temperature increase, the volume and structure of energy consumption will change accordingly in the energy system, with declining of the total demand and increasing of the proportion of non-fossil energy. In terms of the economic system, policy costs will also increase as the targets tighten.

Results

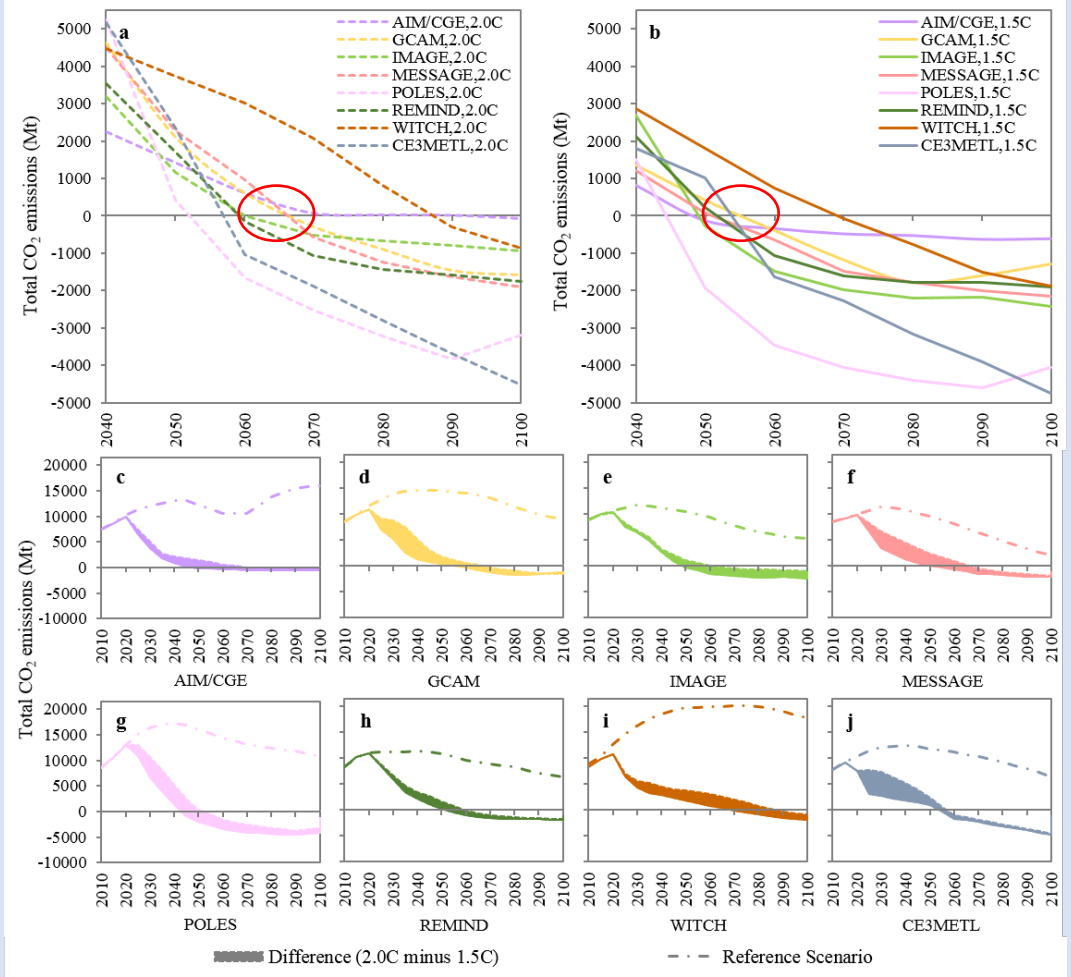

Fig. 1. Trajectories of China's long-term CO_2 emissions. (a) Total CO_2 emissions for 2040-2100 in 2 °C scenario by IAMs; (b) total CO_2 emissions for 2040-2100 in 1.5 °C scenario by IAMs; (c-j) total CO_2 emissions for 2010-2100 of 2 °C, 1.5 °C and reference scenarios (with the difference between 2 °C and 1.5 °C scenarios shaded) by IAMs, respectively (i.e., AIM/CGE, GCAM, IMAGE, MESSAGE, POLES, REMIND, WITCH and CE3METL).

Results

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Long-term CO_2 emissions

In the long term, the shift of the international temperature policy to below 1.5 °C will result in China's near-zero emission timeline significantly ahead of schedule.

- China's long-term emission trajectory, whether it is estimated in 2 °C (Fig 1a) or 1.5 °C (Fig 1b) scenarios, can realize negative emissions in all IAMs during the period of 2040-2100.
- Most of the zero emission timelines are distributed between 2060 and 2070 (Fig 1a), thereby realizing zero emissions around 10 years ahead of time compared with that under the 2 °C-consistent scenario.
- Global aggregated emissions before 2030 under the NDC scenario substantially exceed those under the 1.5 °C scenario by 19 $GtCO_2$ [15 $GtCO_2$, 22 $GtCO_2$] per year, leading to a 1.1 °C [0.9 °C, 1.6 °C] higher than the 1.5 °C threshold by the end of the century; the commitment of NDC pledges is far from achieving the warming-limit goal.
- The average level of emissions in 2 °C scenario can decrease by 80% of the emissions than that in reference scenario in 2050, and the corresponding result for the 1.5 °C scenario would further decrease by 18% (Fig 1c-j).

Results

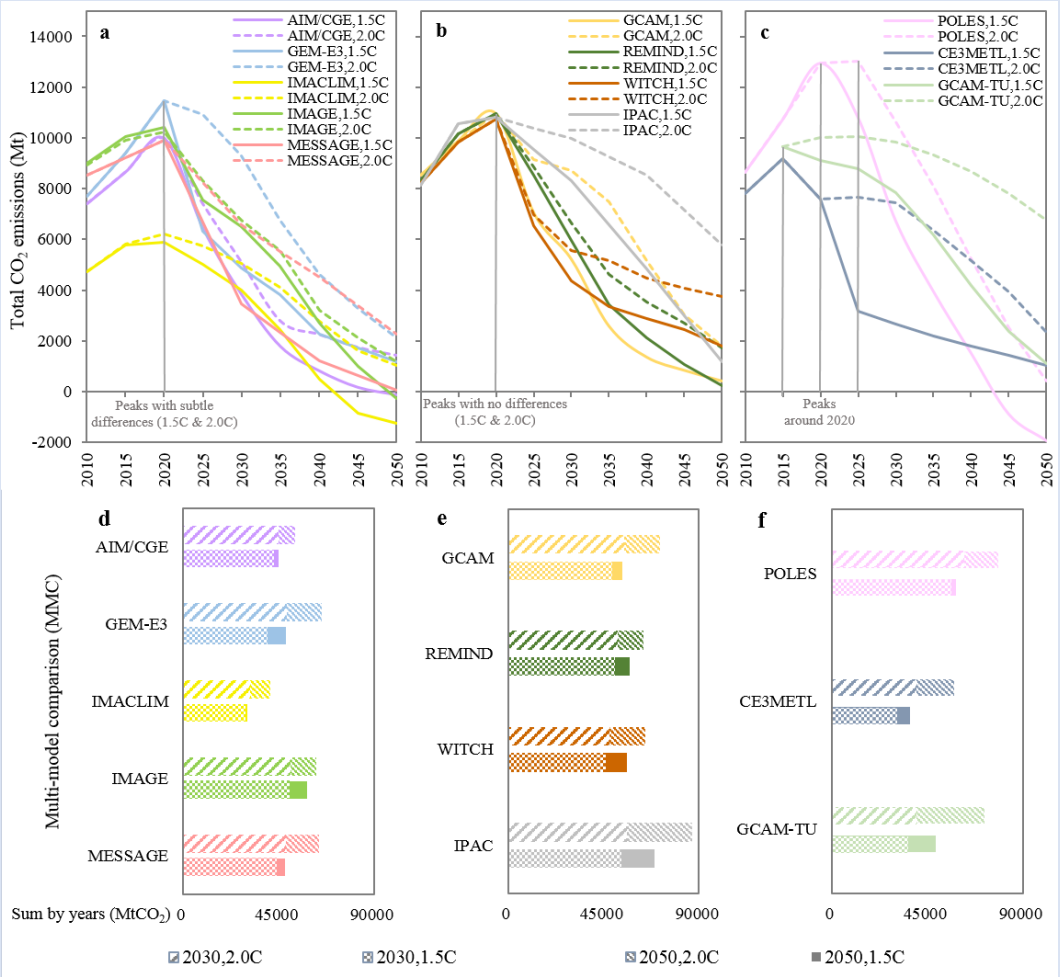

Fig. 2. Targets of China's short- and mid-term CO_2 emissions. (a-c) Total CO_2 emissions from 2010 to 2050 under both 2 °C and 1.5 °C scenarios across IAMs by peaking with subtle differences between 2 °C and 1.5 °C, with no differences, and around 2020 respectively; (d-f) comparisons on cumulative CO_2 emissions at the end of 2030 and 2050 for the 2 °C and 1.5 °C scenarios (with the sum by years represented by the length of pattern-filled bars).

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Short-term CO_2 emissions

The realization of the global climate policy to 2 °C and the shift to below 1.5 °C will lead to a ten-year early peak of China's CO_2 emissions relative to the committed 2030.

- Consistently provided by the assessment of IAMs with a probability of 67% (Fig 2a-c), China needs more earlier action than committed in NDC pledges, despite China has tried to reduce its emissions, supported by technology-innovative energy system and policy-incentive economic system.
- From the distances between lines (Fig 2a-c), especially the lengths of bars (Fig 2d-f), it can be seen that emissions by the end of 2030 in the short term and by the end of 2050 in the midterm are both significantly reduced. The further dramatical emission reductions under the 1.5 °C limit indicates the significance of the short-term control of GHG emissions.
- More particularly, under the 2 °C target, the proportion of short-term (i.e., by the end of 2030) cumulative emissions in mid-term (i.e., by the end of 2050) cumulative emissions is averagely over 50%, with the range of [55%, 85%], while under the 1.5 °C target, the proportion increases to a range of [85%, 97%].

Results

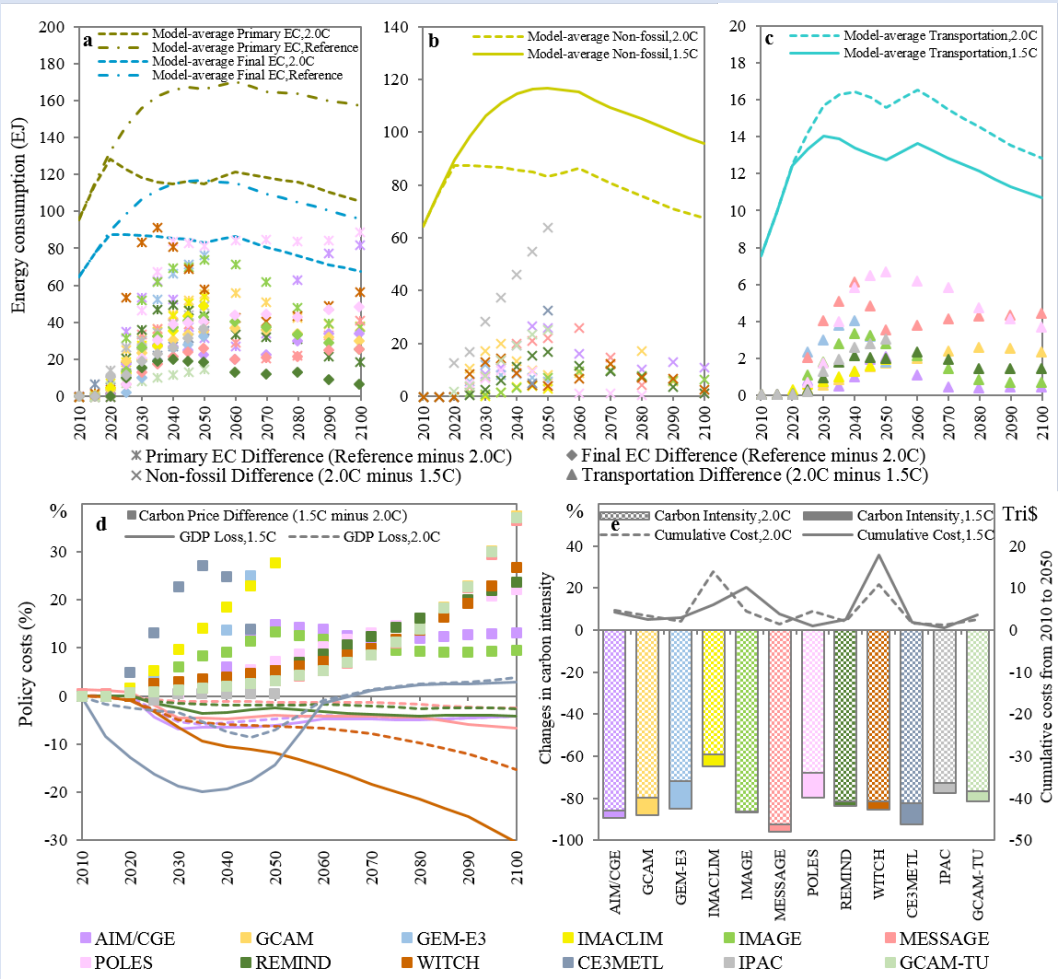

Fig. 3. Restructuring of China's energy system and economic system. (a) Primary and final energy consumption (EC), non-fossil EC (b) and energy consumption of transportation sector for the period of 2010-2100 under the 2 °C and reference scenarios across models in terms of model average and scenario difference; (d) carbon price difference and GDP loss for the period of 2010-2100 under the 2 °C and 1.5 °C scenarios; (e) cumulative costs (US $\$_{2005}$) from 2010 to 2050 and changes in carbon intensity under the two warming-control targets.

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Technology penetration

Contributions of CDR technologies and NETs are assessed to be different across models. There is a positive correlation between the competitiveness in costs and emission-reducing contributions.

- As shown by CE3METL, the rapid development of CCS-fossil and -biomass has significantly increases contributions to capture CO_2 around the timeline of 2045 (Fig 4a); and the strengthened climate target makes it greater for the improvement of CCS-capturing competence.
- Model estimates consistently show that competence of offsetting emissions by CCS-fossil will be weakened at the late stage (Fig 4b). The WITCH and CE3METL models show similar rising paths in removal of CO_2 emissions; while the others display parabolic shapes.
- The shift from 2 °C to 1.5 °C indicates more energy consumption with CCS in the short run, while fossil-CCS is dominant in the long term, given the relative superiority in technical efficiency (Fig 4c).
- Results in the WITCH and CE3METL models are consistent, while those of the AIM/CGE, GCAM and POLES models are different (Fig. 4d). The magnitude of energy consumption with CCS-biomass in the CE3METL is the smallest across models, while accomplishing the greatest CO_2 removal effect, especially during the second half of the century after 2050.

Results

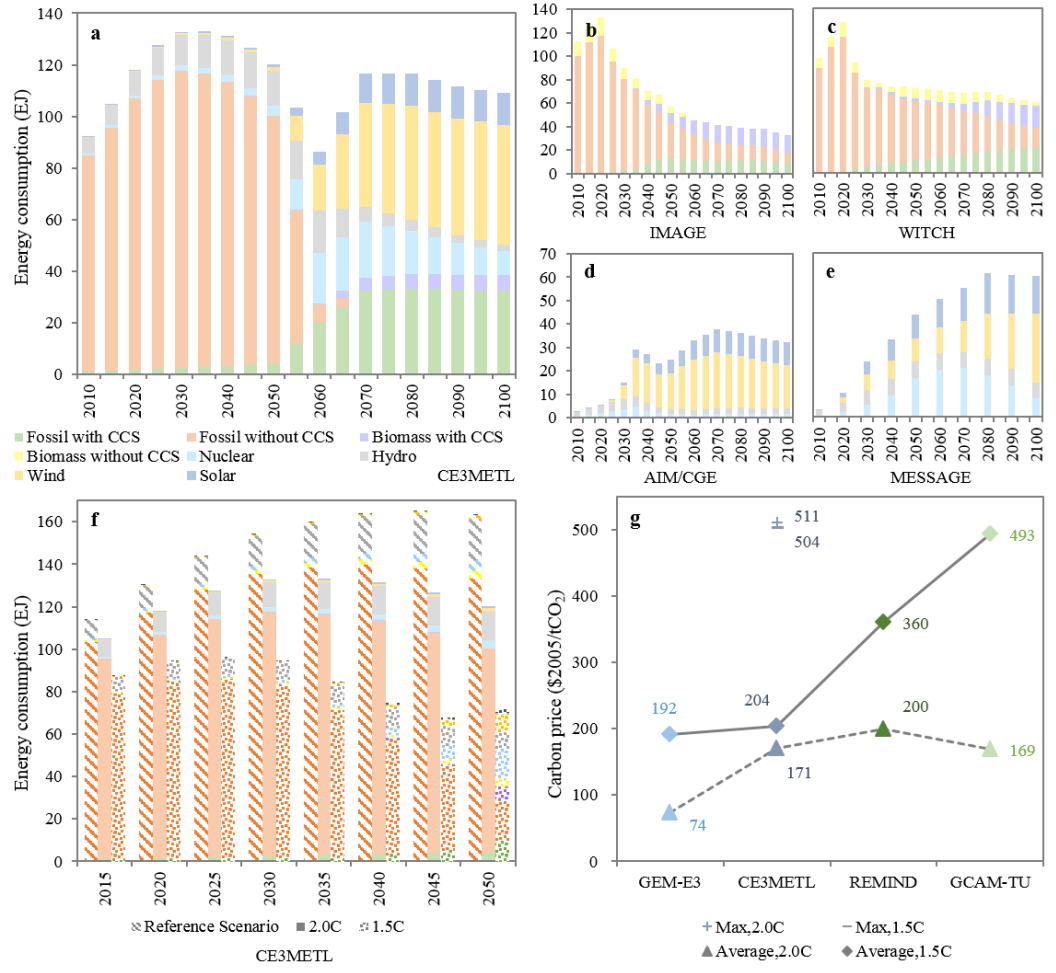

Fig. 5. Energy structure improvements and climate policy costs. (a) Evolution of energy structure for the period of 2010-2100 under the 2 °C scenario given the CE3METL; (b-c) cross-model performances of energy restructuring in terms of fossil and biomass energy and (d-e) in terms of renewables, for the period of 2010-2100 under the 2 °C scenario; (f) changes in energy consumption for the period of 2015-2050 by comparing the 2 °C and 1.5 °C scenarios with the reference; (g) average carbon price between 2010 and 2100 under the 2 °C and 1.5 °C scenarios across the GEM-E3, CE3METL (with extrema), REMIND and GCAM-TU.

Discussion

Discussion

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Underlying implications for transition pathways

- Given the current development trend and path design, China may achieve its short-term NDC pledges, but the long-term zero emissions, required by the 2 °C and 1.5 °C limits are still challenging and far from reach;
- This enhanced goal could be important driving forces for China's sustainable transition, including energy consumption control, energy structure upgrading, and sustainable economic development., and this is robust assessment across models.
  - **Technology deployment** The 1.5 °C goal will provide a valuable opportunity for the innovation and application of CCS technology, especially biomass. With less energy consumption but more negative CO_2 emissions, CCS-biomass performs to be an effective option to attain the given climate goals.
  - **Structural improvement** Competitions and conflicts between NETs and renewables can be appropriately avoided by misaligning their development windows.
  - **Policy support** The increase in carbon price for the 2 °C-to-1.5 °C shift implies a diminishing marginal cost, which emphasizes the importance of policy coverage and the timeline of policy implementation.

Conclusions

Conclusions

By developing an IAM-based multi-model analysis framework, this study explores the significance of limiting warming to below 1.5 °C from 2 °C for China, indicating that the challenge of the goal enhancement may drive China to sustainable transition.

- In terms of CO_2 emissions, under the strengthened warm-limiting target, model-robust conclusions on trajectories show that the peak and negative-emission shift can be reached in advance, and emissions in the early phase and long term need to be reduced dramatically.
- Some models find that enhancing the goal from 2 °C to 1.5 °C will perform better emission-reducing effect with prominent advantages of technologies.
- The enhancement in limiting warming will reduce the total energy. However, the energy system can be reconstructed through early-stage development of negative-emission technologies, e.g., biomass with CCS, and late-stage proportions of renewable energy to release the pressure of cutting energy demand.
- The reinforcing of climate goal from 2 °C to 1.5 °C corresponds to an increase of economic loss, in spite of a deceasing marginal cost.

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Thanks!

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