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

## 1 Introduction

China, as an emerging economy whose $CO_2$ emissions account for approximately one third of the global emissions, plays an important role in global climate change mitigation. However, existing research mainly focuses on the 2 °C scenario, with limited analyzes covering multi-dimensional differences between 2 °C and 1.5 °C goals, particularly for China (Duan et al., 2019).

In this circumstance, this study attempts to build a multi-model analysis framework to tell how China takes the global challenge of the shift from 2 °C goal to 1.5 °C strategy as its opportunity for the sustainable transition. By multi-model assessment, robust conclusions show dramatic emission reductions and key timelines realized in advance from 2 °C to 1.5 °C, which answers trajectories of targets consistently. Further findings from multi-model comparison indicate different patterns of emission pathways, including technology development, structural improvement and economic performance, due to different cross-model settings and assumptions. Actually, substantially different outcomes exist in the extant research on the integrated assessment of climate targets by IAMs (Bellamy and Geden, 2019; Veysey et al., 2016), which urgently requires multi-model analysis to explore the intrinsic mechanism of significances versus contributions and further generalizes to climate change mitigation on a global scale.

## 2 Multi-model frameworks

IAMs are born for climate change in 1970s, and the dynamic integrated climate economic model (DICE) is developed as the start of the era of IAMs (Nordhaus, 1979). By integrating the climate and economic systems, including environmental and energy variables, IAMs are then typically and broadly used for the analysis of climate change policy (Hope, 2005). In this work, we propose a multi-model analysis framework by incorporating several IAMs, i.e., AIM, GCAM, GEM-E3, IMACLIM, IMAGE, MESSAGE, POLES, REMIND, WITCH, CE3METL, IPAC and GCAM-TU, that set China as an independent region. Brief model features and descriptions are shown in Table 1.

**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)

## 3 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.

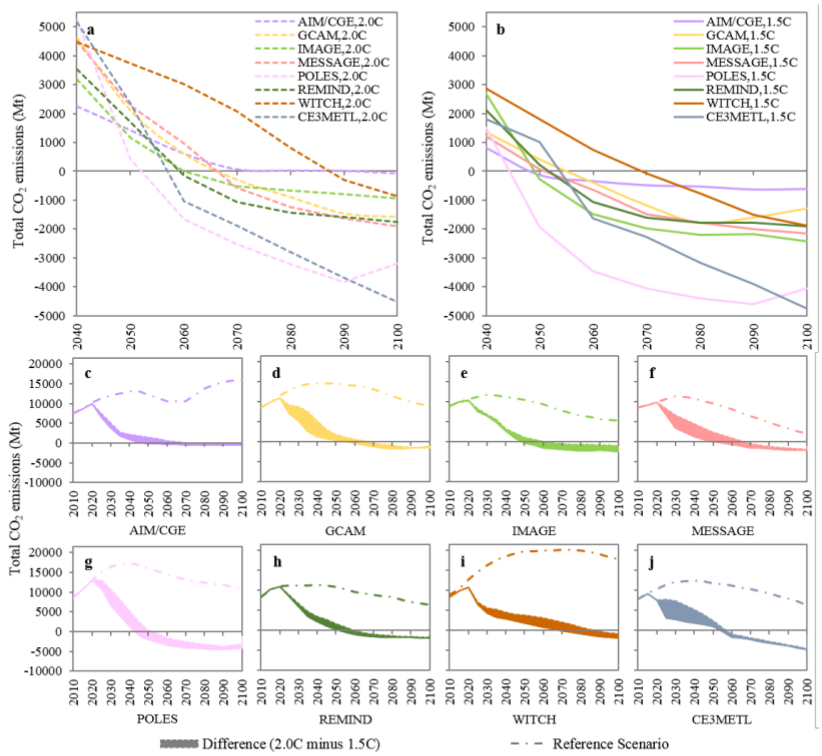

**Fig. 1**. Trajectories of China's long-term $CO_2$ emissions. (a) Total $CO_2$ emissions for 2040-2100 in 2 °C scenario by IAMs; (b) total $CO_2$ emissions for 2040-2100 in 1.5 °C scenario by IAMs; (c-j) total $CO_2$ emissions for 2010-2100 of 2 °C, 1.5 °C and reference scenarios (with the difference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

## 4 Conclusions

In terms of $CO_2$ emissions, under the strengthened warm-limiting target, model-robust conclusions on trajectories and budgets show that the peak and negative-emission shift can be reached in advance, and emissions in the early phase and long term will decline significantly. 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 consumption and increase policy costs. 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. Further, 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.

### References

Bellamy, R., Geden, O., 2019. Govern $CO_2$ removal from the ground up. Nat. Geosci., 1-3.

Duan, H., Zhang, G., Wang, S., Fan, Y., 2019. Integrated benefit-cost analysis of China's optimal adaptation and targeted mitigation. Ecol. Econ. 160, 76-86.

Hope, C., 2005. Integrated assessment models. Climate-change policy.

Leimbach, M., Bauer, N., Baumstark, L., Lüken, M., Edenhofer, O., 2010. Technological change and international trade–Insights from REMIND-R. The Energy J., 109-136.

Millar, R. J., Fuglestvedt, J. S., Friedlingstein, P., Rogelj, J., Grubb, M. J., Matthews, H. D., Skeie, R. B., Forster, P. M., Frame, D. J., Allen, M. R., 2017. Emission budgets and pathways consistent with limiting warming to 1.5 °C. Nat. Geosci. 10, 741.

Nordhaus, W. D., 1979. Efficient use of energy resources.

Sassi, O., Crassous, R., Hourcade, J., Gitz, V., Waisman, H., Guivarch, C., 2010. IMACLIM-R: a modelling framework to simulate sustainable development pathways. Int. J. Glob. Environ. Issues 10, 5-24.

van Vuuren, D. P., Lowe, J., Stehfest, E., Gohar, L., Hof, A. F., Hope, C., Warren, R., Meinshausen, M., Plattner, G.-K., 2011. How well do integrated assessment models simulate climate change? Clim. Change 104, 255-285.

Veysey, J., Octaviano, C., Calvin, K., Martinez, S. H., Kitous, A., McFarland, J., van der Zwaan, B., 2016. Pathways to Mexico's climate change mitigation targets: A multi-model analysis. Energy Econ. 56, 587-599.

Vrontisi, Z., Luderer, G., Saveyn, B., Keramidas, K., Lara, A. R., Baumstark, L., Bertram, C., De Boer, H. S., Drouet, L., Fragkiadakis, K., 2018. Enhancing global climate policy ambition towards a 1.5 °C stabilization: a short-term multi-model assessment. Environ. Res. Lett. 13, 044039.