CLIMATE POLICY

# Can Paris pledges avert severe climate change?

## Reducing risks of severe outcomes and improving chances of limiting warming to 2°C

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Current international climate negotiations seek to catalyze global emissions reductions through a system of nationally determined country-level emissions reduction targets that would be regularly updated. These "Intended Nationally Determined Contributions" (INDCs) would constitute the core of mitigation commitments under any agreement struck at the upcoming Paris Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) (*1*). With INDCs now reported from more than 150 countries and covering around 90% of global emissions, we can begin to assess the role of this round of INDCs in facilitating or frustrating achievement of longer-term climate goals. In this context, it is important to understand what these INDCs collectively deliver in terms of two objectives. First, how much do they reduce the probability of the highest levels of global mean surface temperature change? Second, how much do they improve the odds of achieving the international goal of limiting temperature change to under 2°C relative to preindustrial levels (*2*)? Although much discussion has focused on the latter objective (*3–5*), the former is equally important when viewing climate mitigation from a risk-management perspective.

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A comprehensive assessment of these questions depends on two important considerations. First, although the current negotiations seek to create a durable framework for mitigation action, the current round of INDCs extend only through 2025 or 2030 (*1*). Because temperature change depends on cumulative emissions over the entire century and beyond (*6*, *7*), the INDCs must be viewed as a first step in a longer process, with an important part of their contribution being the subsequent paths that they, and the Paris framework, enable. Assessing the implications of Paris therefore requires consideration of multiple possible emissions pathways beyond 2030. Second, because of uncertainties in the global carbon-cycle and climate-system response (*7*), the contribution of the INDCs to global temperature change needs to be assessed from a probabilistic perspective rather than a deterministic one (*8*).

Accordingly, we calculate probabilistic temperature outcomes over the 21st century for four global emissions scenarios meant to represent different possible future developments with and without INDCs. Our analysis indicates that the INDCs deliver improvements for both objectives—both reducing the probability of the worst levels of temperature change to 2100 and increasing the probability of limiting global warming to 2°C (see the figure). However, the degree to which either objective is achieved will depend on the level of ambition beyond 2030.

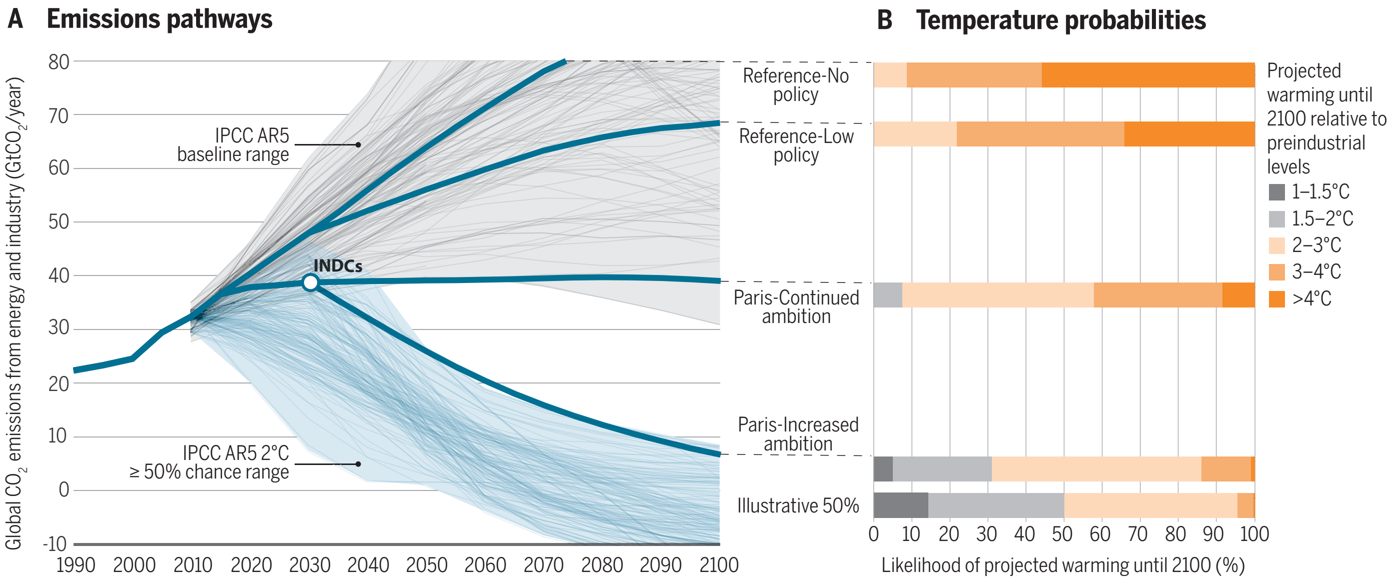


**Fig. 1: Global $CO_2$ emissions and probabilistic temperature outcomes of Paris.** (**A**) Global $CO_2$ emissions from energy and industry (includes $CO_2$ emissions from all fossil fuel production and use and industrial processes such as cement manufacture that also produce $CO_2$ as a byproduct) for the four emissions scenarios explored in this study. The IPCC AR5 emissions ranges are from (*12*). The IPCC AR5 baseline range comprises scenarios that do not include new explicit GHG mitigation policies throughout the century. The IPCC AR5 2°C ≥ 50% range comprises scenarios that limit global warming until 2100 to less than 2°C with at least a 50% chance. The faint lines within the IPCC ranges represent the actual emissions trajectories that determine the range (*12*). (**B**) Likelihoods of different levels of increase in global mean surface temperature change during the 21st century relative to preindustrial levels for the four scenarios. Although (A) shows only $CO_2$ emissions from energy and industry, temperature outcomes are based on the full suite of GHG, aerosol, and short-lived species emissions generated by the GCAM (*9*) simulations (see SM). The Illustrative 50% scenario in (B) corresponds to an emissions pathway that achieves a 50% chance of maintaining temperature change below 2°C until 2100 (see SM). Other 50% pathways could lead to a range of temperature distributions depending on cumulative $CO_2$ emissions and representations of other GHGs.

**EMISSIONS PATHWAYS.** To develop the emissions pathways (see the figure, part A), we use a global integrated assessment model [GCAM (*9*)], although our core findings do not hinge on the particular character of this model [see the supplementary materials (SM)]. Probabilistic temperature outcomes over the 21st century are then calculated using a global climate model [MAGICC (*10*)] in a setup representing the latest climate-sensitivity assessment of the Intergovernmental Panel on Climate Change (IPCC) (*11*).

Our analysis begins with two reference scenarios. The Reference–No policy scenario assumes no new greenhouse gas (GHG) mitigation actions throughout the 21st century and serves as a counterfactual against which to compare the other scenarios. The Reference–Low policy scenario illustrates a world in which there are no new GHG mitigation actions through 2030, and countries "muddle through" with weak policies beyond 2030 that achieve a 2% annual rate of improvement in $CO_2$ emissions per unit of Gross Domestic Product (GDP) ("decarbonization rate") (see SM and table S1).

The Paris–Continued ambition and Paris–Increased ambition scenarios illustrate potential implications of the INDCs. Both assume that parties meet their INDC goals through 2030 (see SM and table S4), but then assume different decarbonization rates beyond 2030. We do not take up the question of how likely individual countries are to achieve their INDCs, but rather assume that these goals are met and pursue the question of how that successful implementation shapes potential future options.

The Paris–Continued ambition scenario assumes that countries continue to decarbonize their economies beyond 2030 with the same annual decarbonization rate that was required to achieve their INDCs between 2020 and 2030. If their decarbonization rate is below a specified minimum (2% per year), they instead follow a path defined by that 2% minimum rate (table S1). In contrast, the Paris–Increased ambition scenario assumes a higher minimum decarbonization rate (5% per year) beyond 2030. This minimum rate is consistent with the average decarbonization rate required by the European Union and the United States to achieve their INDCs from 2020 to 2030 (SM).

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**TEMPERATURE PROBABILITIES.** Using the above scenarios, we estimate probabilistic temperature outcomes over the 21st century (see the figure, part B). The Paris–Continued ambition scenario reduces the probability of temperature change exceeding 4°C in 2100 by 75% compared with the Reference-Low policy scenario and by 80% compared with the Reference–No policy scenario. If mitigation efforts are increased beyond 2030, as in the Paris–Increased ambition scenario, the chance of exceeding 4°C is almost eliminated.

The INDCs hold open the possibility of maintaining temperature changes below 2°C, although none of our scenarios eliminates the possibility that temperature change could exceed 2°C. In the Paris-Continued ambition scenario, the probability of limiting warming to 2°C increases to 8% as opposed to virtually no chance in the two Reference scenarios. If ambition is scaled up after 2030—as in the Paris–Increased ambition scenario—the probability of limiting warming to 2°C increases to about 30%. If we assume even greater post-2030 emissions reductions, the probability of limiting warming to less than 2°C could be 50% or more. Indeed, many scenarios in the literature assume emissions through 2030 that are comparable to or higher than our Paris scenarios, yet limit warming to 2°C in 2100 with at least 50% probability, with many exceeding 66% (see the figure, part A) (*12*). These scenarios include rapid emissions reductions beyond 2030. Many also include negative global emissions in the second half of the century, based on large-scale deployment of bioenergy in conjunction with carbon capture and storage (*13–15*).

***"the contribution of the INDCs to global temperature change needs to be assessed from a probabilistic perspective rather than a deterministic one...."***

Two key factors should be considered when interpreting results of this analysis. First, to limit warming to any level, $CO_2$ emissions at the global level must ultimately be brought to zero (*6*). Although the two Paris scenarios provide meaningful benefits relative to the two Reference scenarios, if emissions are not brought swiftly to zero beyond 2100, the chances of extreme temperature change after 2100 could be much higher and the chance of limiting warming to 2°C much lower.

Second, the above analysis is based on one set of assumptions about key drivers of emissions such as technologies, regional population, and GDP. Although it is beyond the scope of this study to assess probabilities of achieving future emissions pathways, alternative assumptions are certainly possible (*14*), and the choice of assumptions might influence emissions pathways as well as precise probabilities associated with scenarios in this study. [Implications of alternative drivers are explored in figs. S5 to S8 and the (SM).] Nevertheless, key qualitative insights will remain the same: The Paris scenarios reduce probabilities of extreme warming and increase the probability of limiting global warming to 2°C this century, but depend on a robust process that allows pledges to be progressively tightened over time. ■

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## SUPPLEMENTARY MATERIALS

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