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Likely emissions pathways in the 21st century

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Estimating probabilities over the likelihood of different greenhouse gas emission pathways can guide policymakers' strategies in areas ranging from climate adaptation to macroeconomic and financial policy. Such probability estimates also imply that preventing harmful climate change needs urgent and unprecedented action.

Recent research has used a variety of techniques to constrain the set of likely emissions and temperature outcomes for the 21st century. While methodologies differ, the results collectively seem to provide strong evidence that warming by 2100 will likely be in the 2-3 degree range, with either very high (4-5 degrees) or low (<2 degrees) warming much less likely.

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Malte Meinshausen et al. (2022), in "Realization of Paris Agreement pledges may limit warming just below 2°C," use nationally determined contributions (NDCs) and net zero pledges for 2030-2050 to estimate possible warming in 2100 (see Figure 1). Using only information from the 2030 NDCs implies warming of, on average, 2.6°C. Considering also countries' various net-zero pledges (beyond 2040) can limit warming just below 2°C. Nevertheless, the authors do not assess the likelihood of countries meeting their emissions commitments. The paper uses a bottom-up aggregation of NDCs and pledges and a two-fold technique of extending 2030 pledges into the future. Up until 2050, the authors extrapolate the likely emission growth path of the years 2025-2030. For the years up to 2100, a statistical tool inferring missing emissions data is used.

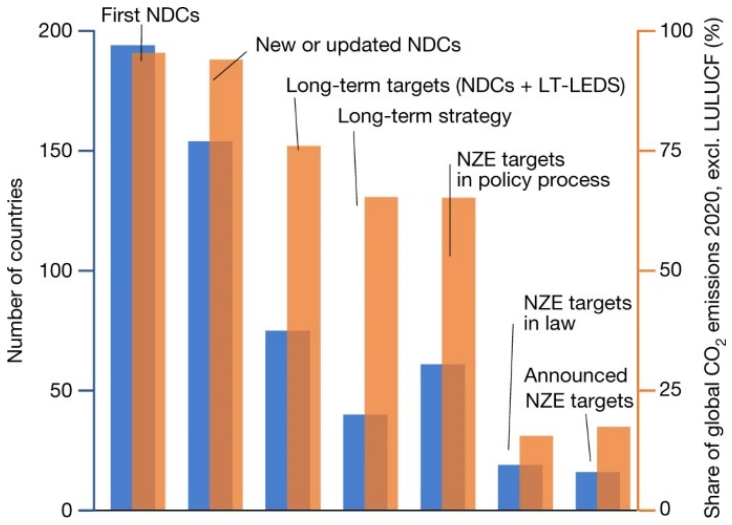

Figure 1: NDCs and Net Zero targets considered by Meinshausen et al. (2021)

Kevin Rennert et al. (2021), in "The Social Cost of Carbon: Advances in Long-Term Probabilistic Projections of Population, GDP, Emissions, and Discount Rates," integrate probabilistic demographic models with distributions over economic growth and emissions based on structured expert surveys. They estimate warming of 2.6°C in 2100 (with a confidence range of 1.8 – 4°C), similar to SSP2 – 4.5. Unlike scenario-based approaches, the authors quantify uncertainties in the future trajectories of population, GDP and emissions and can provide probabilities over alternative emissions pathways.

Greenhouse gas emissions are not only impacted by demographic changes and GDP growth. The global trajectory until 2100 will be a function of technological developments, government policies, financial markets, individuals' preferences, and community action. Yet, socio-political-technical processes are mostly treated as exogenous in climate change modelling.

Frances Moore et al. (2022), in "Determinants of emissions pathways in the coupled climate–social system," incorporate both socio-political-technical feedbacks and endogenous climate policy in a stylized model. They explicitly model the social and political dynamics that give rise to climate policy. They find that there will very likely be an acceleration of climate policy implementation over the next 15 years. As a result, the distribution of temperature levels should fall 2 to 3 degrees by 2100. Climate policy is a factor in virtually all 100'000 model runs - even the highest estimates produce lower warming than the RCP7 "business-as-usual" baseline of 3.9°C.

Zeke Hausfather and Frances Moore (2022), in "Net-zero commitments could limit warming to below 2 °C," summarize emerging evidence that the distribution of warming over the 21st century can be substantially constrained and has a high likelihood of being between 2 and 3 degrees above pre-industrial. More rapid warming is possible, if accelerating decarbonization is more difficult and expensive, or if the sensitivity of the climate system is larger than anticipated.

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