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Plausible mitigation targets

Whether the widely accepted 2°C limit for climate change is practically achievable depends partly on climate sensitivity, but predominantly on complex socio-economic dynamics.

Neil Edwards

Climate policy negotiations are a defining forum in the global geopolitical arena, where nations trade mitigation targets in the name of protecting the planet. But how much mitigation should we actually believe is possible? Governments need to know which targets are realistically achievable, while businesses need to understand the corresponding, potentially radical, changes in patterns of energy and resource consumption. Writing in this issue of *Nature Climate Change*, Rogelj and colleagues[1] use a risk-based modelling approach to explore plausible mitigation scenarios, taking into account both the processes linking greenhouse gas emissions to climate warming and the technical and economic aspects of reducing emissions.

Although a surprising degree of consensus has formed around the totemic 2°C threshold for globally averaged warming, the connection between warming and emissions is riddled with uncertainty and can only be determined probabilistically. This requires large numbers of simulations with simplified climate models tuned to reproduce the output of more comprehensive and costly models.

Yet this takes us only some way to pinpointing appropriate mitigation objectives. The principal uncertainty in future climate change is societal emissions, and these are strongly constrained by available technologies, markets and socio-political forces. Integrated Assessment Models (IAMs) can represent many of these factors but a consensus view, collating all published IAM studies, has been lacking. In the wake of the 2010 COP-15 Copenhagen summit, the United Nations Environment Programme (UNEP) commissioned just such a study to estimate the efficacy of the mitigation pledges offered[2]. The study combined a comprehensive synthesis of IAM results with a unified probabilistic analysis of physical climate uncertainty by reanalysing emissions trajectories using the simplified climate model MAGICC6[3]. With four boxes representing the atmosphere and a one-dimensional representation of the ocean, MAGICC6 cannot predict regional climate change but has been calibrated to faithfully reproduce global climate projections of the IPCC models.

Rogelj and colleagues[1] significantly extend and update the analyses in the UNEP report. They increase the total number of integrated model solutions considered from 126 to 193, allowing a much more detailed view of the critical high-mitigation end of the spectrum. They also push the envelope of their probabilistic analysis by characterizing the plausible mitigation trajectories that avoid particular levels of warming with more than 90% probability, in addition to the disturbingly un-ambitious >50% and >66% categories considered in the UNEP report. What they find makes salutary reading.

For a maximum temperature rise of 2°C before 2100, the 15–85% range of plausible pathways all show 2020 emissions well below 2010 levels, while emissions at 2050 are well below 1990 levels, with a median of 20 $GtCO_2e$ (CO_2 equivalent). Only three scenarios respect the 2°C threshold to 2100 with 90% probability, and all of those rely heavily on the use of bio-energy with carbon capture and sequestration (BECCS) to achieve net negative emissions in order to do so. Use of BECCS proves an important factor in allowing models to achieve stringent mitigation targets and to recover from more lax early emission constraints. However, even with BECCS, none of the studied scenarios respect the proposed tighter target of 1.5°C throughout the 21st century with more than 50% probability. Moreover, the researchers found that scenarios showing peak emissions around 2030 are more consistent with 'likely' (>66%) avoidance of 3°C warming before 2100 than 2°C.

Such an analysis has to be interpreted carefully, partly because of the relationship between allowed emissions at different times. Plausible trajectories that are in the highest range of emissions early in the period typically only satisfy temperature constraints by later reverting to the lowest range of emissions.

In practice, the limiting factors in achieving stringent climate targets may be the financial, business-model and social or indeed political innovation[4] needed to drive uptake of existing technology, rather than pure technical innovation *per se*[5,6]. If so, the data used to calibrate IAMs and the processes included in them may be inadequate. Nevertheless, Rogelj and colleagues have significantly advanced the state of the art by deriving a coherent, probabilistic consensus view of the plausibility of mitigation targets. IAMs are properly viewed as policy analysis tools rather than future prediction tools but what they can do is clarify which past behaviours must change if certain desired future outcomes are to be achieved. The burning question raised by this analysis is which technical assumptions and constraints, beyond reliance on BECCS, allow some of the models to achieve strong mitigation where others fail.

By combining comprehensive analyses of uncertainties in physical and socio-economic modelling, the study by Rogelj and colleagues represents an important step forward. However, the true joint uncertainty in future change may significantly differ from the sum of the two components. For instance a policy that aims to keep warming below 2°C may result in low net uncertainty even if climate sensitivity is uncertain. Modellers now need to address this by representing uncertain feedbacks between climate impacts and economic forces at the regional level, possibly using dimension reduction techniques that reduce the output of complex models to a small set of statistically predictable spatio-temporal patterns[7]. A number of projects[8–10] are moving in this general direction. Finally, the overall purpose of the UNEP report[2] was to assess the gap between likely achievable climate targets and the pledges of governments post-Copenhagen. A revision and update of that analysis would be another important contribution.

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