Carbon Budget

Estimating vanishing allowable emissions for 1.5 °C

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The remaining carbon budget for 1.5 °C has been a highly-discussed tool to communicate the urgency of efforts needed to meet the Paris Agreement. Now, research reassesses IPCC estimates, suggesting that ongoing near-flat emissions and methodological choices can make big relative differences to the tiny remaining 1.5 °C budget.

Time to avoid breaching the Paris thresholds is running out, but how much time do we have? Perhaps the most powerful climate communication message since the signing of the Paris Agreement has been the understanding[1] that each tonne of emitted carbon dioxide brings us incrementally closer to the 1.5 °C limit which the world has committed to at least pursue efforts to avoid. Budgets associated with different warming levels (most notably the 1.5 °C and 2.0 °C thresholds) have been calculated in the recent IPCC reports[2], by combining lines of evidence relating to recent warming and emissions rates with estimates of Earth system response parameters. However, these calculations (and their communicated uncertainties) can become outdated as new information becomes available, and they are subject to methodological assumptions. Now, writing in *Nature Climate Change*, Robin Lamboll and colleagues3 reassess assumptions in the methodology used to compute carbon budgets in the IPCC AR6 working group 1 assessment, finding that a number of these assumptions make significant relative changes to a 1.5 °C budget.

Their paper makes for uncomfortable reading for policy-makers, ostensibly halving the best estimate for the Remaining Carbon Budget (RCB) in the 2023 IPCC Sixth Assessment Synthesis Report from 500 remaining Gigatonnes of Carbon Dioxide to 250. 45% of this reduction comes from ongoing anthropogenic emissions since the IPCC reference date of 2020, where emissions have grown every year since the brief COVID dip [3]. The rest of the reduction comes from methodological updates relating to model choices and the estimate of warming due to gases other than CO_2.

Lamboll and colleagues conclude that the budget will most likely be exhausted in 6 years of current emissions, but this doesn't mean that 1.5 °C of warming will be achieved on that timescale. The warming we experience today has occurred due to a combination of historical emissions of greenhouse gases and aerosols together with natural processes (solar cycles and volcanoes) plus natural variability. As such, warming from greenhouse gases today is partially compensated by cooling from aerosols[4], and the strength of this masking is a key uncertainty. However, the technological shifts needed to reach net zero CO_2 emissions will also impact other gas emissions. Lamboll et al. suggest this will result in an additional warming of 0.1-0.2 °C at the time of net zero which needs to be subtracted from 1.5 °C before the RCB can be calculated. All of this means that if emissions remain at current levels and the masking effect remains constant, the RCB will be exhausted a few years *before* the 1.5 °C warming level is reached.

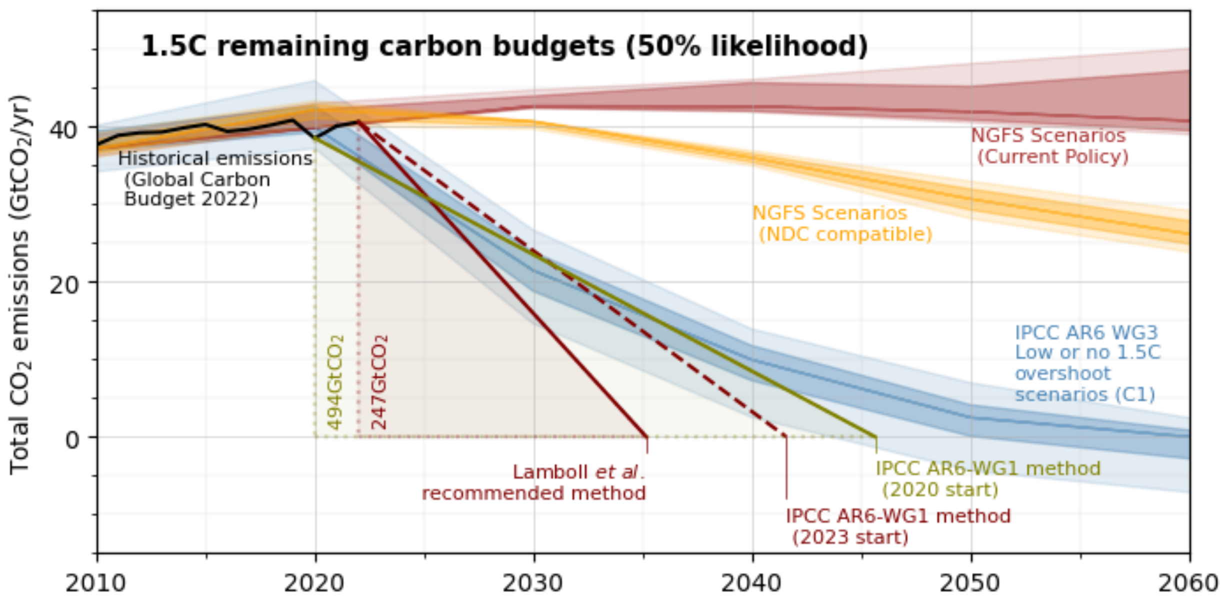

Figure 1: An illustration of the Remaining Carbon Budgets (RCB) detailed in the IPCC AR6 WG1 assessment [2] and in Lamboll et al. Budgets are illustrated by linear declines in CO2 emissions to zero from observed estimates in 2020 or 2023 [3], such that the integral of emissions under the line is equivalent to reported RCB. The Dashed red line shows the IPCC-AR6 RCB budget, minus emissions from 2020-2023. Scenarios are shown for context, where solid central lines, dark shading and light shading represent the median, (25-75) and (5-95) percentile ranges. Blue shaded scenario range is from the IPCC AR6-WG3 [5] scenario database, showing the distribution of scenarios which meet the C1 classification of low or no overshoot of 1.5C. Yellow and Red scenario ranges show NGFS scenarios [6] illustrating NDC compatible scenarios and Current Policy Scenarios respectively.

The budgets can be illustrated in an idealised way by considering a linear decline of CO_2 emissions from present day levels to zero (Figure 1). This framing illustrates that the original IPCC-WG1 budget (calculated from 2020) implied a net zero date of 2045 if emissions continued to fall post-COVID, a decline broadly in line with the most ambitious climate scenarios considered in AR6 with no or low overshoot of 1.5 °C. Lamboll's budget, however, is consistent with net-zero CO_2 being achieved in 2034 - this is vastly more ambitious than current implemented global climate policies and NDCs, but also significantly earlier than scenarios considered in AR6-WG3 which avoid significantly exceeding 1.5 °C (the majority of these reach net zero between 2050 and 2060 (Figure 1), in line with global adoption of mid-century net-zero targets [6]). So if Lamboll and colleagues are correct, mid-century net zero targets are insufficient to prevent an overshoot of 1.5 °C.

The implications depend on the accuracy of the new estimate. Aside from accounting for recent emissions, the largest factor in Lamboll's reduced budget was a revised estimate of historical aerosol emissions, which impacted the calibration of the simple climate model used in the calculation. However, understanding of how constantly evolving regional aerosol emissions drive global temperature response is still changing[7]. Lamboll also considered a second simple climate model, which simulated a 30% larger RCB than the model used in IPCC-WG1 (the results of the two models were averaged for the headline result). This is indicative that model assumptions play a significant role, and a comprehensive exploration of how calibration uncertainties map onto budget uncertainties has yet to be conducted.

The approach used by Lamboll is also not the only way to compute a carbon budget. The approach used here[8] represents the CO_2 portion of the RCB as a function of other quantities calculated in the IPCC report: the Transient Response to Cumulative Emissions and the Zero Emissions Commitment, using simple climate models to compute the non-CO_2 warming correction. This has the pragmatic advantage of improving the self-consistency of the IPCC report, but results are conditional on these structural assumptions. Meanwhile, other approaches for calclulating the RCB have been proposed[9–11] which account for the same processes with different calculation structures - and different results[12]

Given all this, how should the IPCC treat the RCB in future reports? The findings laid out by Lamboll and colleagues illustrate that any calculation, no matter how rigorous, is subject to change with revised data and understanding. By performing calculations in the preparation of assessment reports (rather than just assessing budgets in the published literature), the IPCC is conditioning its conclusions on a set of internally assessed assumptions which are liable to change or be challenged. Research papers that aim to publish revisions to IPCC statistics[3, 13] address this; however, such efforts risk confusing the self-consistent messaging of IPCC assessments if presented as semi-official ‘updates’ to the original reports.

This raises the need for the IPCC to consider internally how to keep data current with a cycle around 7 years and a rapidly evolving climate situation. In the case of the tiny remaining 1.5 °C budget, the paper by Lamboll et al. illustrates that calculation assumptions and the evolution of non-CO_2 gases can cause relative changes of the same order of magnitude as the budget itself. These problems will only be compounded for the authors of AR7, who (according to this study, at current emissions rates) will publish their synthesis report with an estimated remaining 1.5 °C budget of zero.

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