

What counts for our climate: Carbon budgets untangled

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A new study published in *Nature* identifies relevant factors that affect estimates of remaining carbon budgets, and thereby untangles the differences to make estimates more easily comparable, which will help decision-makers in using them. From a climate policy perspective, the bottom line remains the same: Even if the remaining carbon budget for limiting warming to 1.5°C increases by one-half, there will be only 10 years more time before emissions have to be reduced to net zero.

"Bringing CO₂ emissions from industry to transport to net zero requires urgent action—a couple of years more or less to achieve this do not make a difference for the actions we have to take now," says Elmar Kriegler from the Potsdam Institute for Climate Impact Research (PIK) in Germany, one of the study's authors. "Yet, untangling different carbon budget calculations is more than just an academic issue. It tells us about the risks." One main insight of the study is that feedbacks in the Earth system, such as permafrost thawing that releases the powerful greenhouse gas methane, might be a major underestimated factor for carbon budgets.

"Available carbon budget estimates often neglect permafrost thawing and other slow Earth system feedbacks that could lead to further heating of the planet. This means that our wiggle room might be even smaller than we thought," explains Kriegler. "Spelling out the implicit underlying assumptions in carbon budget calculations such as this one is important for supporting policy-makers to make informed choices."

Earth system feedbacks and other factors to be considered

Another example for differences between carbon budget estimates is the way they use temperature measurements. Some estimates refer to Earth's surface air temperature (SAT). Measured 1.5 meters above the ground,

this is basically the temperature people experience. However, some carbon budget estimates include sea surface temperatures in their yardstick to measure warming. Since sea surface temperature rises more slowly than air temperature, it appears as if more CO₂ can be emitted before the 1.5 degrees Celsius limit is breached. Yet these budgets would also come with clear climate consequences: a relatively hotter Earth. In their paper, the authors recommend to choose SAT for estimating the remaining carbon budget.

In a key equation they derived for current and future estimates of the remaining carbon budget, the scientists include five factors. One of them, the future warming from non-CO₂ emissions depends strongly on policy choices about non-CO₂ gases that will still be emitted. The less we heat the planet with non-CO₂ gases like methane, the larger will be our remaining budget for CO₂ emissions. Besides Earth system feedbacks, the largest uncertainty relates to the estimate of how strongly the climate warms in response to cumulative emissions of CO₂. Further uncertainties relate to the measured range of the historical human-induced warming and the amount of additional warming after CO₂ emissions have reached net zero. The authors point to the upcoming Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) as an important milestone to narrow these uncertainties.

The authors' approach builds on the reasoning in the Special Report on 1.5 degree warming by the IPCC that they co-authored. The report gave central estimates of the remaining CO₂ emissions budget from 2018 onward of 420 GtCO₂ for a 66 percent probability of limiting warming to 1.5°C and 580 GtCO₂ for a 50 percent probability. Different assumptions about future non-CO₂ emissions can change these estimates by 250 GtCO₂ up and down. Those estimates would need to be reduced by the amount of CO₂ outgassing from permafrost thawing and other unrepresented Earth system feedbacks, which are tentatively estimated to be at least 100 GtCO₂. "We do not know exactly how big the budget is

in the end due to future choices about Non-CO₂ emissions and uncertainties in natural systems. But we know enough to be sure it is past time to enact deep reductions in greenhouse gas emissions," says Kriegler.

Keeping up to date to make informed choices

"All factors in our equation are expected to undergo updates as science progresses—some of these updates will make carbon budgets smaller while other will make them slightly larger," says Joeri Rogelj from the Grantham Institute at Imperial College London, lead-author of the study. "However, by making these regular updates explicit, they can be communicated transparently. It is important that policy makers are kept up to date on the latest science, with the next report of the IPCC in 2021 expected to consolidate our knowledge about the remaining carbon budgets to limit warming to 1.5°C and well below 2°C."

"Choices today will determine whether we will have a decent chance of limiting warming to 1.5°C and our study does not change this bottom line," Rogelj adds. "If anything, the severity of expected climate impacts in a world heated beyond 1.5°C and our better understanding of the various factors that can affect the size of the remaining [carbon](#) budget calls for a precautionary approach with decisive climate action in the next five to ten years to limit the risks and keep options open, no matter which direction estimates of the remaining [carbon budget](#) might wobble."

More information: Estimating and tracking the remaining carbon budget for stringent climate targets, *Nature* (2019). [DOI:](#) [10.1038/s41586-019-1368-z](https://doi.org/10.1038/s41586-019-1368-z)

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