

Setting a carbon budget to keep below two degrees

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We have already committed the planet to a certain amount of warming due to past carbon emissions. But efforts to reduce emissions now and over the next few decades will critically affect the degree of future warming.



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One way of determining how much we need to reduce carbon emissions is to use a 'carbon budget'. A budget lays out how much carbon we can burn in total if we want to keep to a certain amount of warming.

This was one of the headline messages of the recently released [Intergovernmental Panel on Climate Change \(IPCC\) Working Group I Fifth Assessment Report](#). For the first time, the IPCC described the limits to how much more carbon dioxide can be emitted to keep global temperatures below certain thresholds.

Concentrate on the total

The IPCC report highlighted the direct, almost proportional, relationship between cumulative carbon dioxide emissions from human activities and global temperatures. This is an important finding.

It means that staying below certain temperature targets depends not so much on the rate that we emit in any particular year, but what the grand total of emissions is. Consequently we must take into account all emissions that have taken place from the industrial revolution through to now, and add on all carbon dioxide that we emit in the future.

The bigger the grand total, the higher the eventual warming.

A carbon budget is like a household budget. You only have so much money to spend. How you choose to spend and invest your money will determine the available budget for your retirement and the legacy you provide for future generations.

This budget approach is attractive to policymakers because of its simplicity, and because it is not prescriptive on [how and when](#) the emissions quota needs to be met. However, the rate of emissions over time does make a difference to how

quickly cuts will need to be made.

Higher emissions this year, or in the next few years, imply more rapid cuts will be needed later. Lower emissions now imply more gradual future reductions.

Keeping below two degrees

The Fifth Assessment Report found the carbon dioxide emitted by humans so far is already about two-thirds of the quota allowable in order to have a two-in-three chance (66 per cent) of keeping temperatures below two degrees centigrade of warming from pre-industrial levels. This is if all sources of future warming are taken into account.

In the [2009 Copenhagen Accord](#) of the United Nations Framework Convention on Climate Change, governments around the world pledged to maintain temperatures below this threshold.

Beyond two degrees the risks to societies and ecosystems are judged to be unacceptably high.

The two degrees is based on the consideration of all scientific evidence, plausible natural and socio-economic impacts, mitigation requirements, and associated uncertainties. These considerations led to a prudent and still achievable temperature target, judged by governments to avoid dangerous impacts on ecosystems, economic development and food production due to climate change.

Up until 2011, the world has warmed by about 0.9°C since pre-industrial times.

To keep temperatures below the two degrees target, there is a limit to how much more carbon dioxide we can emit. How can this quantity be estimated?

From the relationship between global temperatures and cumulative carbon dioxide emissions, we can estimate the carbon budget or compatible emissions for any temperature target with a prescribed level of certainty. The lower the temperature target, the lower the emissions quota. The more certainty we want of staying below a certain temperature, the less we can emit.

Do other influences matter?

Carbon dioxide is only one influence on global warming, though it is the single most important one. Human emissions of other greenhouse gases such as methane and nitrous oxides also contribute to human-induced warming. Expected reductions in emissions of aerosols – particles such as soot – will also make a difference.

These components ‘live’ for a shorter time in the atmosphere than carbon dioxide. For instance, more than half of today’s carbon dioxide emissions will still remain in the atmosphere in 200 years time, while short-lived greenhouse gases and aerosols are removed within weeks to a few years through natural processes. This means the pathway of emissions (when they are released) is more important than the total cumulative amount in so far as their contribution to global warming.

However, carbon dioxide is the dominant force in future global warming (accounting for 80-90 per cent of the total impact by humans through the 21st century). So the proportional relationship between cumulative carbon dioxide emissions and global temperatures will continue to hold true to the end of this century.

Taking all this into consideration, the IPCC report found that for global temperatures to be likely to stay below two degrees (with a >66 per cent probability), the total amount of all carbon dioxide emitted since the late 19th century should be no more than 800 billion tonnes (800 gigatonnes of carbon). The permissible carbon budget increases to 880 gigatonnes of carbon if we accept only a one in three chance (>33 per cent) of staying below two degrees.

How much time is left?

By 2011 we had already emitted 531 gigatonnes of carbon. This is about two-thirds of the total emissions allowed to stabilise temperatures below 2 degrees.

This leaves only another 270 gigatonnes of carbon for future use.

With the current rate of carbon dioxide emissions at about 10 gigatonnes of carbon per year – and assuming an annual growth rate of 3 per cent, as seen over the last decade – the remaining carbon budget will be used up in less than 25 years.

If we want a greater chance than 66 per cent of limiting warming to two degrees, we would need to emit even less carbon dioxide. Conversely, if we accepted a lower probability of limiting the warming to two degrees, the budget would be higher.

The IPCC considered four possible emission scenarios. They call these Representative Concentration Pathways (RCPs).

Only one of the four pathways keeps us within the estimated quota of 800 gigatonnes of carbon in total, or 270 gigatonnes more. RCP2.6, as it's known, allows for declining emissions well into the second half of this century while still remaining under two degrees.

All the other emission scenarios considered in the report overshoot the emissions quota – and the associated warming – by a substantial amount.

If we're going to get on the RCP2.6 pathway, it will require strong mitigation, beginning now, and we may have to make our emissions negative later this century. That would require an energy system with zero emissions, plus additional technologies that directly remove carbon dioxide from the atmosphere and store it safely.

Risk assessment

An additional risk acknowledged in the IPCC report, but not accounted for in the carbon budget figures above, is that stored carbon and methane will potentially be [released from thawing permafrost](#). These are areas of frozen soil, predominantly in the Arctic and Tibetan plateau, that are projected to reduce with rising temperatures.

There is limited understanding of how much carbon will be released as permafrost thaws. But it could be large if strong warming occurs in these permafrost regions.

The IPCC estimated that the potential additional emissions from this source are in the range of 50–250 gigatonnes of carbon over this century if warming follows the RCP8.5 scenario. This means we will need an even more stringent future emissions quota to keep future temperature rise to the recommended two degree limit.

The conclusion of the IPCC is that only if substantial and sustained reductions in emissions are made, can we avoid potentially dangerous consequences of climate change.

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