Met Office

How can we limit warming?

The amount of warming we will see in future is directly linked to how much carbon we emit. This means we can estimate what our global 'carbon budget' is to have a good chance of staying below any given temperature. This helps governments understand what needs to be done to limit warming to given levels, such as the "well-below 2 °C" goal. However these budgets have a large range, due largely to uncertainty in the response of global temperature to carbon emissions. If the climate is more sensitive to carbon than currently thought, budgets will be lower and vice-versa. Extra processes considered in more complex Earth system models also contribute to uncertainty in budgets.

How much carbon have we got left to stay below 1.5 °C and 2 °C?

Up to the start of 2017 we've emitted 2075 (±205) gigatonnes (1 gigatonne = 1 billion tonnes) of carbon dioxide ($GtCO_2$)[1] since pre-industrial times. Using figures from the IPCC's AR5, figure 1 shows how much carbon budget, and time, we have left to stay below 1.5 °C and 2 °C.

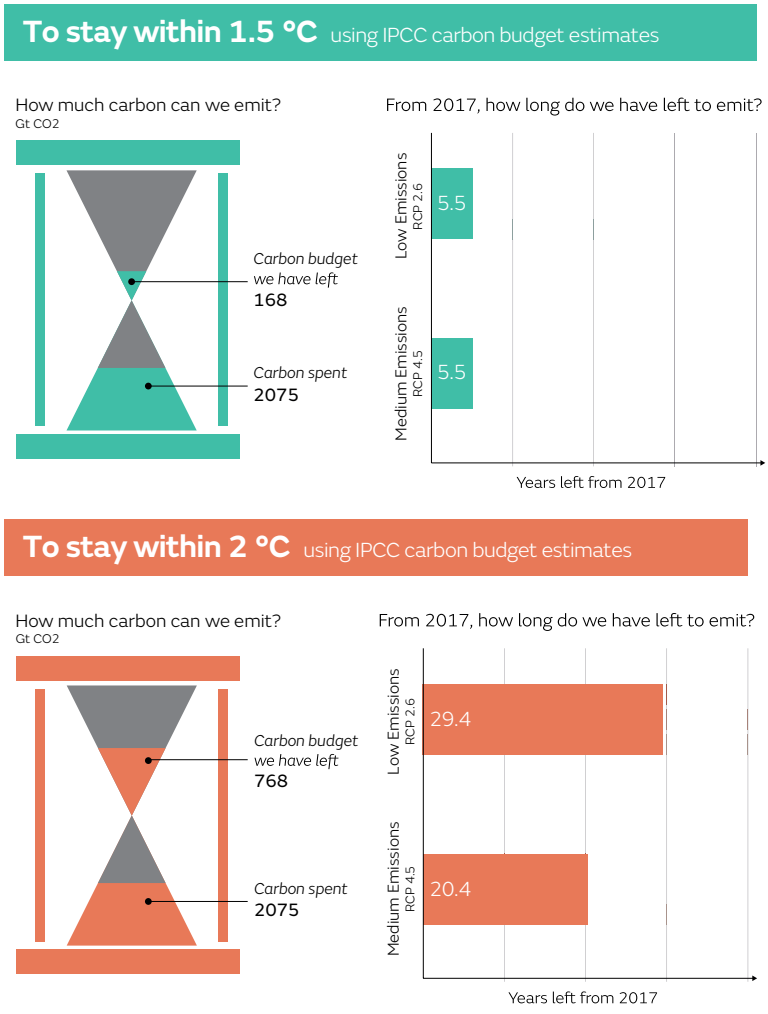

Figure 1 - Shows how many years of current emissions from the start of 2017 onwards would use up the IPCC's carbon budgets for a 66% chance of staying within 1.5 and 2 °C. This is based on global carbon budgets as of 2011 from table 2.2 in the IPCC AR5 Synthesis Report combined with emissions data from 2011-2016 from the Global Carbon Project. The 66% probability refers to the % of climate model simulations that keep within that temperature goal. It is not equivalent to the IPCC definition of >66% i.e. 'likely'. There are many ways to define carbon budgets and this is just one such representation in a quickly developing area of climate science.

How can we be sure on the size of the budget?

There are several factors that might affect the size of carbon budgets in the above figure, including:

- understanding the exact relationship between carbon dioxide and temperature rise;
- accounting for exactly how much carbon we have already emitted;
- including future changes in other greenhouse gases, such as methane;
- the impact of factors not currently included in estimates, such as thawing permafrost;
- which global temperature datasets are used to show the warming we have seen so far.

[1]Le Quere et al, 2016. Global Carbon Budget 2016.

What does the latest evidence show?

Recent research has put forward conflicting evidence to show carbon budgets may be either larger or smaller than previously thought.

For example, one 2017 paper[2] updates carbon budgets based on recent global temperature observations and suggests that warming in our climate may be less sensitive to carbon emissions. It concludes that we may have up to 20 years before we use up the carbon budget to stay below 1.5 °C.

Meanwhile, the next generation of climate models being developed at centres around the world will include for the first time many complex Earth system processes that will affect carbon budgets. One example is the impact of warming on wetland and permafrost regions, which currently store vast quantities of carbon comparable to all the worlds living vegetation. This could be released if these areas warm further, which would then increase the warming effect and drive a reduced global carbon budget for any given temperature goal.

Additional contributions from natural ecosystem processes may also reduce carbon budgets. For example as CO_2 concentrations increase, additional plant growth will be limited by the supply of nitrogen. Therefore the natural nitrogen cycle will act to limit the effectiveness of elements of the carbon system that absorb or store CO_2 such as the forests and oceans.

Recent Met Office research shows that including these additional processes could reduce the carbon budget for a >66% chance of 2 °C by over 100 GtC – equivalent to approximately a decade or more of current global emissions of carbon. This will also be the case for the 1.5 °C carbon budget but the reduction will be less.

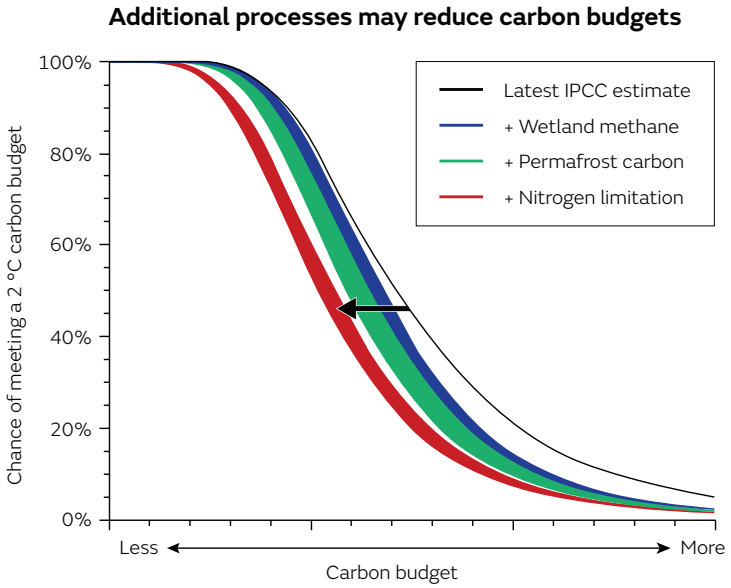

Figure 2 - Shows the chance of meeting a 2 °C carbon budget is reduced when additional processes such as methane release from wetlands and carbon from thawing permafrost are accounted for. The exact reduction has not yet been quantified and remains an active area of research within the Met Office Hadley Centre.The exact reduction has not yet been quantified and remains an active area of research within the Met Office Hadley Centre.

What does this tell us about staying below 1.5 °C and 2 °C?

Despite the current range of carbon budget estimates, they all show a consistent picture – that limiting warming to 2 °C or less remains a challenging goal.

All carbon budgets suggest stringent emission reductions will be necessary over the coming decades as well as net zero emissions in the 2070s if we want to meet the "well-below 2 °C" goal.

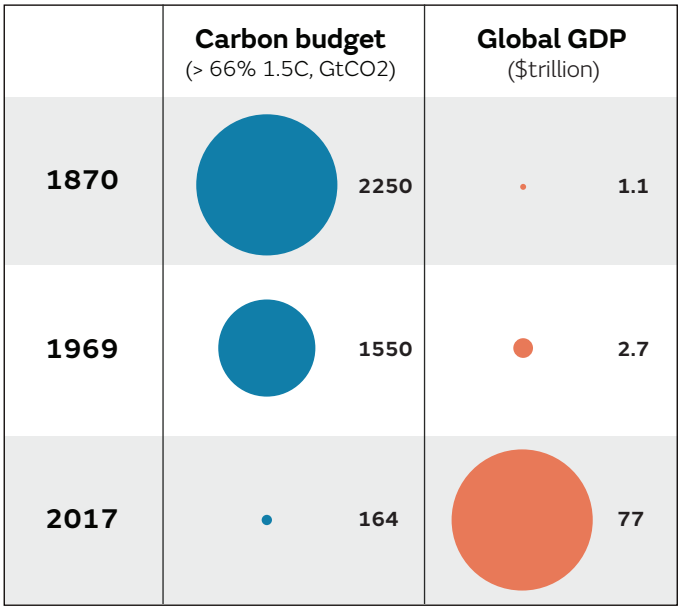

Figure 3 - Shows the increasing size of our global economy against a dwindling carbon budget available for a >66% chance of staying below 1.5 °C above pre-industrial levels, illustrating the scale of the challenge to limit global warming. The carbon budget data is from the same source as Figure 1 and the historical global GDP data is from 'Historical statistics of the World Economy: 1-2008 AD" and the 2017 GDP data from World Bank growth forecasts.

[2]Millar et al, 2017. Emission budgets and pathways consistent with limiting warming to 1.5 °C.