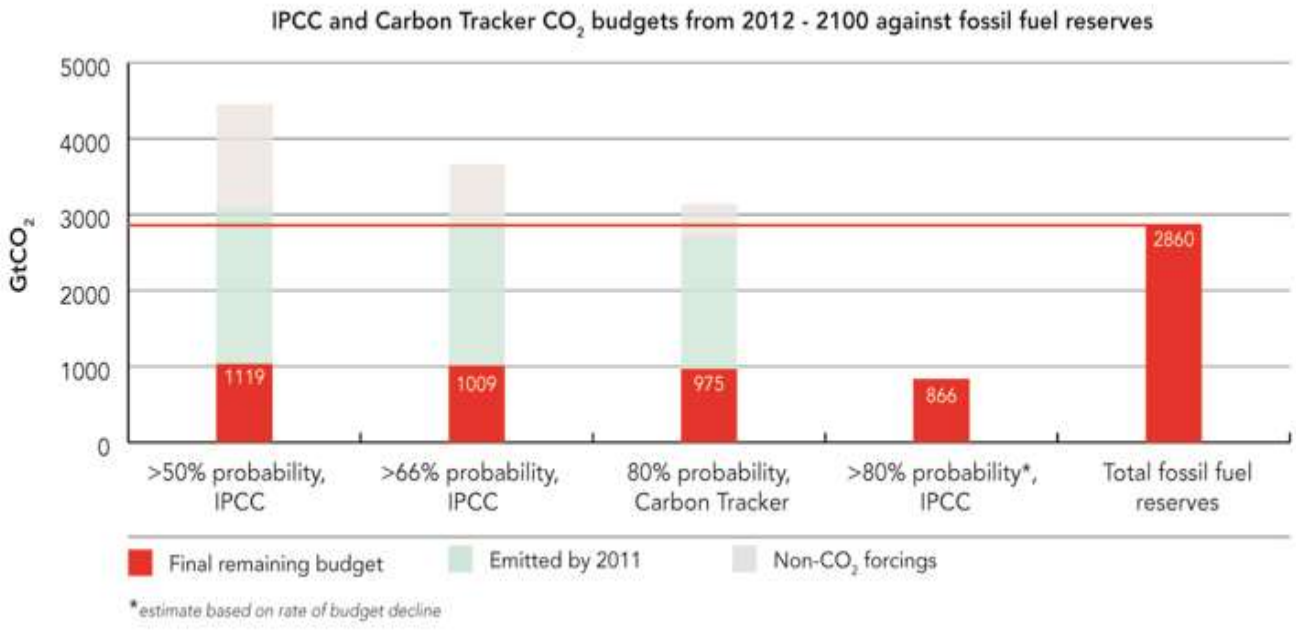
Things to look out for when using carbon budgets!

For any particular rise in temperature there is a budget for emissions of greenhouses gases (GHGs) which cannot be exceeded in order to avoid breaking this temperature threshold. As carbon dioxide (CO_2) is by far the most prevalent GHG, studies tend to focus on CO_2 only – hereafter referred to as carbon budgets.

This September the IPCC delved into the world of carbon budgets in their AR5 report, building on the carbon budget analyses of the IEA and Carbon Tracker. We released our first global carbon budget in 2012 with the Potsdam Institute, but for the sake of simplicity, comparisons in this document will only be made to our 2013 'unburnable carbon' report produced with the Grantham Institute at the London School of Economics.

The weight of credibility behind these contributing institutions and the powerful simplicity of comparing carbon budgets to fossil fuel reserves has pushed this approach up environmental and financial agendas. It also means that there has been increasing citation of carbon budgets over the past 12 months. With many variations between them, however, the budgets are easily misrepresented, or invalid comparisons can be made.

Below are the IPCC and Carbon Tracker's latest carbon budget figures (the IEA's carbon budgets do not extend to 2100 so can not be included in the comparison).



Below we outline the differences between the IPCC[1], IEA[2] and Carbon Tracker's[3] carbon budgets with a simple list of things to look out for when quoting carbon budgets.

1) What is the time period covered?

The carbon budget available to keep within a temperature rise increases as the time period within which we can achieve this increases. This is because a number of the Earth's systems naturally act as a 'carbon sink', meaning they absorb CO_2 from the atmosphere over time, buying us additional carbon emissions. The IEA's carbon budgets extend to 2050, while the IPCC go out to 2100 – Carbon Tracker's budgets include both time horizons.

2) What is the temperature increase targeted within which we must remain?

The IEA and IPCC budgets simply prescribe emissions to keep to the internationally agreed target of 2°C, beyond which the extent of the impacts of global warming are deemed unacceptable. Carbon Tracker also includes 1.5, 2.5 and 3°C scenarios. The higher the temperature limit modelled, the higher the carbon budget will be.

3) What is the probability of global warming keeping to the desired temperature level if you remain within the budget?

Global warming is projected using probabilistic models which combine a large number of factors and feedback mechanisms. As with any such approach, there are degrees of scientific uncertainty attached to the models, which produces a range of values based on the same agreed principles of how anthropogenic climate change is caused. If policymakers want a higher chance of achieving a particular outcome in terms of global warming (e.g. the agreed 2°C target) then they will need to apply a lower carbon budget.

4) In what metric is the carbon budget presented?

Carbon budgets can be in giga tonnes of carbon dioxide ($GtCO_2$), as used by the IEA and Carbon Tracker, or giga tonnes of carbon (GtC) which the IPCC prefers. The difference is stark - 1GtC = $3.67GtCO_2$ – so comparisons between the size of budgets can not be made between the two if the metrics are different. Crucially, these budgets all relate to just CO_2 emissions, rather than the suite of the six main GHGs, which would be represented in a common unit of CO_2e (carbon dioxide equivalent).

5) Does the carbon budget include emissions associated with land use?

While fossil fuel combustion and associated processes make up the bulk of anthropogenic CO_2 emissions, land use, land use change and forestry (LULUCF) also contribute. Carbon Tracker and the IEA exclude LULUCF from their carbon budgets, while the IPCC's comprises 'all anthropogenic sources', including agriculture, forestry and land use (AFOLU). Therefore, the IPCC's carbon budget as stated in the AR5 report will be slightly larger than the IEA and Carbon Tracker which include just fossil fuel combustion and other industrial sources. The contribution of AFOLU needs to be removed to facilitate an accurate comparison across budgets. Estimates of the CO_2 contribution from land use factors differ between studies, but as an indication of the additional input, the IEA believe LULUCF adds $136GtCO_2$ (13%) to the fossil fuel carbon budget to 2050.

[1] http://www.climatechange2013.org/images/uploads/WGIAR5_WGI-12Doc2b_FinalDraft_All.pdf
[2] http://www.worldenergyoutlook.org/publications/weo-2012/
[3] http://www.carbontracker.org/wastedcapital

6) What is the estimated cooling effect from emitted aerosols?

When fossil fuels are combusted, aerosols are emitted into the atmosphere as well as GHGs. These are estimated to have a net-cooling effect on the atmosphere – higher forcing from aerosols equals a higher cooling effect and a larger budget for carbon emissions. Carbon Tracker's carbon budget applied an amount of aerosols in line with the A1B scenario described in the IPCC Special Report on Emissions Scenarios – a relatively high -0.5Wm^{-2}. The IPCC's AR5 applied a forcing of -0.35Wm^{-2}, lower than previous reports amidst re-evaluation of aerosol absorption, which means the IPCC carbon budget will be lower than Carbon Tracker's in this criteria.

7) What are the assumptions made about efforts to mitigate other non-CO_2 greenhouse gases?

If one carbon budget model assumes greater success mitigating non-CO_2 greenhouse gases such as methane, this would decrease the forcing effect of these gases, increasing the budget available for CO_2 emissions to keep within a temperature increase. The IPCC's AR5 report assumes 'relatively high non-CO_2 forcing over the 21st century'. Carbon Tracker's work with the Grantham School also assumed more successful efforts to address non-CO_2 GHGs than previous models and calculations.

8) Updated understanding of the global warming potential of methane

The IPCC's AR5 report methane is 34 times stronger a heat-trapping gas than CO_2 over a 100 year time scale – this is 40% higher than its previous estimate of 25 in the AR4 report. This means that less budget will be available for CO_2 under models using this updated information.

9) What is the estimated climate sensitivity?

Climate sensitivity is defined as the equilibrium change in global mean surface temperature following a doubling of the atmospheric concentration of carbon dioxide, i.e. the temperature change associated with changes in CO_2 in the Earth's atmosphere. Carbon Tracker's budget uses an approach similar to Meinshausen et al. (2009) which assumes a climate sensitivity which has a median value of 3°C. The IPCC's AR5 also places the median at 3°C.

10) What difference does Carbon Capture and Storage (CCS) make?

Carbon Tracker modelled the impact of delivering the IEA's idealised scenario for CCS on extending carbon budgets. Due to the current status of the technology in terms of cost, liabilities and permits, it is not expected to become commercial on any scale until post-2030 under the IEA scenario. This means that there are many ongoing unabated emissions sources in the first half of this century. If CCS can be deployed at scale across existing and new point sources of GHGs then post-2050 it could make a major contribution to reducing the required budget. However the IEA note that this would require a major effort of thousands of installations, which are currently not financed or incentivised.

11) Does the carbon budget make assumptions about negative emissions technologies?

Successful deployment of negative emissions technologies at scale would increase the carbon budget available within a given temperature increase. Carbon Tracker's carbon budget analysis does not assume the widespread use of bio-energy with CCS (BECCS) or other possible negative emissions technologies such as geoengineering techniques. The IPCC's carbon budget appears to assume some success with these technologies in the second half of the 21st Century, resulting in an increase in their carbon budget against Carbon Tracker's. However there would be no impact on carbon budgets up to 2050 unless negative emissions technologies are assumed to come in earlier.

12) When will we break the budget for 2°C?

The IPCC and the International Energy Agency both provide decadal predictions of anthropogenic CO_2 emissions from fossil fuel combustion. Assuming a linear growth or decline between these 'checkpoints' allows us to estimate, on best evidence, when we will break 2°C as specified by carbon budgets.