UNDERSTANDING "2°C" – And why 'slipping off 2' really matters

The *Copenhagen Accord*, struck in December 2009 by heads of state of the world's major economies, states:

> "...We agree that deep cuts in global emissions are required according to science, and as documented by the IPCC Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius, and take action to meet this objective consistent with science and on the basis of equity."

They also said:

> "...We call for an assessment of the implementation of this Accord to be completed by 2015, including in the light of the Convention's ultimate objective. This would include consideration of strengthening the long-term goal referencing various matters presented by the science, including in relation to temperature rises of 1.5 degrees Celsius."

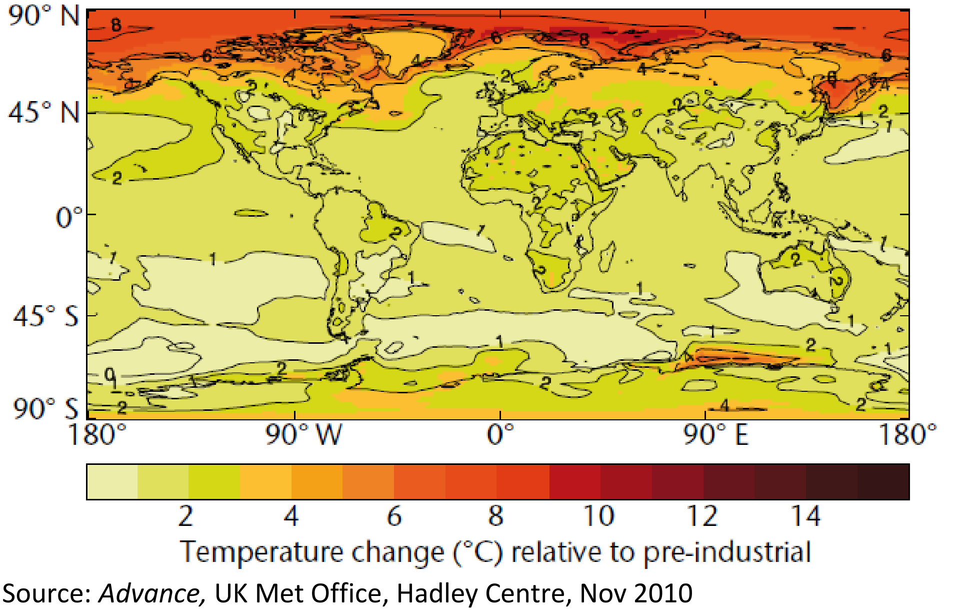
A year later, the *Cancun Agreements* reaffirmed this and added "that Parties should take urgent action to meet this long term (2°C) goal". Meanwhile the new UNEP *Emissions Gap* report (see footnote 3) showed that a gap of some 5-9 $GtCO_2e$ in 2020 exists between the emissions mitigation action that, thus far, has been pledged by countries (depending on the rules and interpretation of pledges) and what is needed to be on an emissions pathway that has a 'likely chance' of being consistent with 2°C.

These numbers, 2 degrees and 1.5 degrees, therefore have been taken up by the international media and interested publics around the world as being fundamentally meaningful, indeed somewhat iconic, in their own right. While they are a simple expression about what needs to be achieved to address global climate change, the simplistic use of numbers like these risks masking what is really being meant, and the seriousness of the issues at stake.

<u>Issue 1: Global averages don't reflect climate change 'on the ground'</u>

The first key point is that a number like 2°C represents a global average increase in near surface temperature compared with the global average in pre-industrial times (about 1750). It is important to recognise that this global average temperature is simply an indicator of the local changes in a wide range of observable quantities, e.g. precipitation. And importantly, a 2°C global average can translate to much higher temperature changes in some critical land masses in different latitudes and altitudes (see Figure 1 for the UK Met Office Hadley Centre's latest modelling results). Moreover, undesirable impacts will generally be driven by local climate changes (e.g. changes in rainfall patterns), and often changes in extremes in different seasons rather than the annual average values.

<u>Figure 1. Regional temperature increases versus a global average of about 2.1°C above pre-industrial</u>

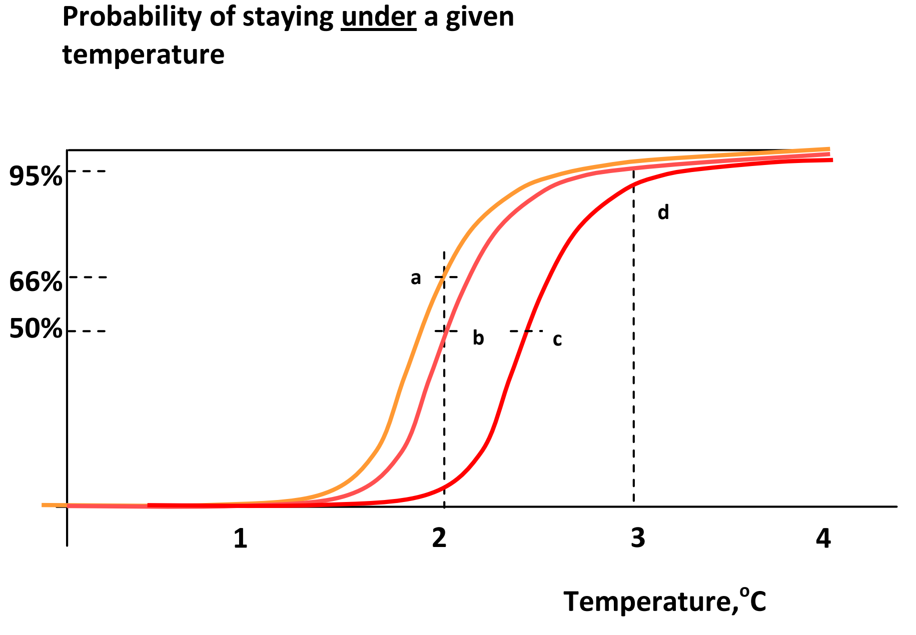


Source: *Advance,* UK Met Office, Hadley Centre, Nov 2010

Issue 2: It's really about probabilities – and what this means at different ends of 'the curve'

Secondly, a number like 2°C is not the full story of what temperature increases might occur for a given loading of greenhouse gases in the atmosphere. Importantly what is missing is the probability associated with this number. To convey this point, it has become customary for climate science to use terms such as 'medium chance' (a 50-66% probability) or 'likely chance' (higher than a 66% probability) when describing the relationship between emissions pathways and expected temperature rises. So a statement may be made that "a particular emissions pathway (defined by e.g. peak global emissions, peak year and annual rate of emissions decline following the peak) provides a *likely chance* (> 66% probability) of keeping temperatures under 2°C in the period to 2100." However, what is also critical to understand are the probabilities associated with the ends of the temperature probability curve for a given emissions pathway – so understand the risk of exceeding high temperatures or possibilities of staying under low temperatures. These points are set out in the sketch below. (Note that this is just a simplified, illustrative depiction to get some key understandings across, not a figure produced by a climate science model[1].)

Figure 2 Understanding the temperature and probability issue – A simple depiction



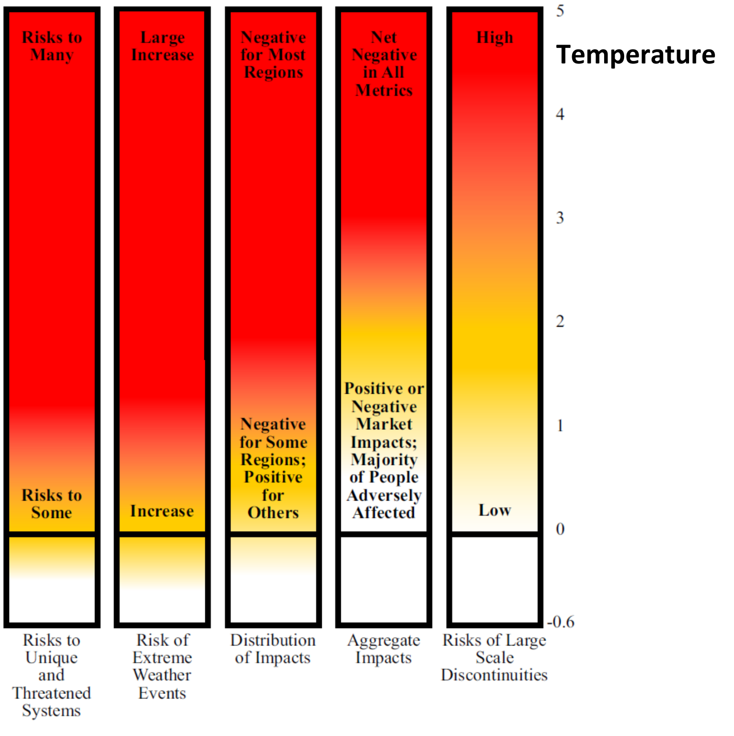
The three curves represent illustrative emissions pathways, each with different cumulative emissions over time. This implies a different aggregate greenhouse gas emissions load in the atmosphere associated with each line. The emissions load of the middle curve would be described (see point 'b') as resulting in there being a 50% probability of a 2°C global temperature rise (noting Issue 1, concerning local changes). The left hand curve, representing a different emissions pathway with a lower emissions load, provides a 66% probability at 2°C (point 'a'), so would be described as being among emission pathways providing a *likely chance* of meeting the goal to limit the global temperature increase to 2°C.

What is also important when comparing these first two curves is that the probability of the emissions load of the left hand (66%, 2°C) curve of keeping temperatures under 1.5°C, while low, is considerably higher than for the middle (50%, 2°C) curve. The third right hand curve is drawn to illustrate the critical point associated with the higher end of the probability curves. This depicted emissions pathway provides a 50% probability (medium chance) of keeping the temperature rise under 2.5°C (point 'c'). This illustrates that the risk of temperatures going over 3.0°C for this emissions pathway is much higher than for the middle curve, here about 10% compared with about 5% (point 'd') – but see footnote 1.

[1] In particular, more correctly, the uncertainty range increases with higher temperatures, so the curves to the right are more 'stretched' which additionally increases the probability of exceeding a tail. So rather than the 50% 2.5°C curve doubling the risk of exceeding 3°C, compared with the 50% 2.0°C curve (as depicted in Figure 2), this risk is more than triple.

Understanding this relationship between probabilities, including for other temperature increases, then helps with realising this point of the risks being taken associated with higher levels of warming. The graphic to the right (taken from the IPCC Fourth Assessment Report) points to concerns at various global average temperature increases.

Taking the right hand column for example, it can be seen just how risky it is to have doubled the risks of higher temperatures. Would anyone board a plane if told there was a 10% chance of it crashing?[2] Yet here, we are talking about, potentially, risks associated with the very survivability of planet earth for hundreds of millions of people.



In short, the "2^{o}C" issue is about so much more than just 2^{o}C.

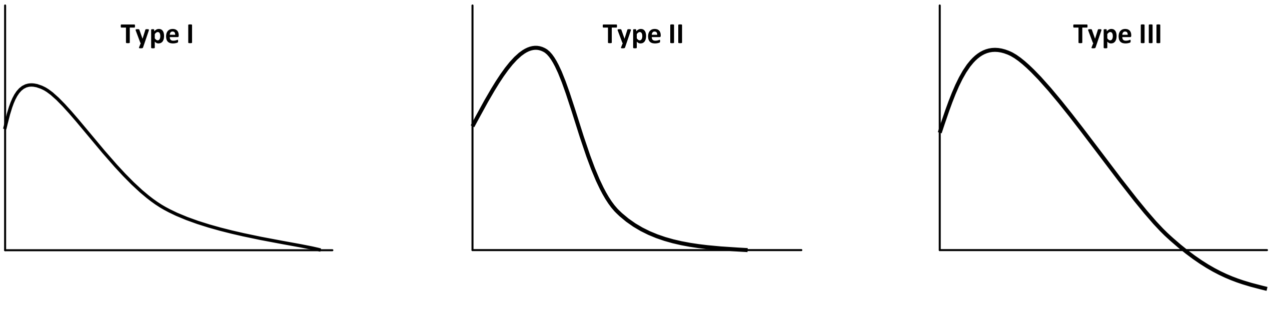
<u>Issue 3: Pathways to 2^{o}C</u>

A final key point about 2^{o}C is that there are multiple <u>theoretical</u> pathways to get there from here – as shown in the following three simple illustrations, chosen to make some key points.[3] They can be thought of as representing three different types of approaches to 2^{o}C, but not all equally compatible with 2^{o}C:

I. **peak sooner and 'lower', moderate-high emissions reduction rate thereafter to 2100** (where a likely chance to stay below 2^{o}C is still possible)

II. **peak later and 'higher', very high emissions reduction rate thereafter to 2100** (no likely options to stay below 2^{o}C have been modelled for such pathways)

III. **peak later and 'higher', high emissions reduction rate thereafter with substantial negative emissions prior to 2100** (a likely chance to stay below 2^{o}C is only possible if negative emissions technology proves to be feasible)



All of these types of approaches are represented within the full range of modelled emission pathway scenarios by international science groups looking at the question of pathways to 2^{o}C. However in assessing the practicality of these scenarios for similar probabilities of achieving 2^{o}C, the following key

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[2] Another comparison point for avoiding catastrophic failure is the calculated probable frequency of degraded nuclear reactor cores or core melt accidents. The US Nuclear Regulatory Commission (NRC) specifies that reactor designs must meet a 1 in 10,000 year core damage frequency, but modern designs exceed this. US utility requirements are 1 in 100,000 years – a risk of just 0.001%.

[3] This issue is set out in greater detail in "The Emissions Gap Report" published by UNEP in November 2010 available at **http://www.unep.org/publications/ebooks/emissionsgapreport/**

assumptions in Table 1 below need to be understood – and then weighed by policy makers, including as against the risks of not achieving 2^{o}C and what this means about the risks of higher temperatures.

Table 1. Illustrative examples of key assumptions about different emissions pathways and their implication for 2^{o}C

Type I	Type II	Type III	
• **Peak timing** ca. 2015 • **2020 emissions** 35 $GtCO_2e$ • **Global reductions in 2050** 40-50% cf 1990 • **Reduction rate after peak** 1% per annum • **Chance to stay below 2°C** Likely (>66%)	• **Peak timing** ca. 2020 • **2020 emissions** 44 $GtCO_2e$ • **Global reductions in 2050** 50-60% cf 1990 • **Reduction rate after peak** 2-3% per annum • **Chance to stay below 2°C** Medium (50 to 66%) There are no pathways of this kind modelled that give a "likely" chance to stay below 2°C	• **Peak timing** ca. 2020 • **2020 emissions** 44 $GtCO_2e$ • **Global reductions in 2050** 60-70% cf 1990 • **Reduction rate after peak** 3-4% per annum • **Quantity of negative emissions by sinks in 2100 (incl to offset residual emissions)** -6 $GtCO_2e$ (avg per year) • **Chance to stay below 2°C** Likely (>66%)	• **Peak timing** ca. 2020 • **2020 emissions** 48 $GtCO_2e$ • **Global reductions in 2050** 70-80% cf 1990 • **Reduction rate after peak** 3-5% per annum • **Quantity of negative emissions by sinks in 2100 (incl to offset residual emissions)** -25 $GtCO_2e$ (avg per year) • **Chance to stay below 2°C** Medium (50 to 66%)

Two issues here are worthy of some elaboration to help in judging what this comparative information means in practice:

Emission reduction rates

Important factors that determine the maximum emissions reduction rate are the typical lifetimes of machinery and infrastructure: decades or even up to centuries for building stock and urban infrastructure, around 40 years for power stations, 20 to 40 years for manufacturing equipment, up to 20 years for heating devices, and 10 to 20 years for passenger vehicles, but much longer for transport infrastructure. These lifetimes are critically important if mitigation strategies aim to avoid premature replacement of capital, which is often considered to be very expensive. There are different views about feasible emission reduction rates. The highest average rate of emission reductions over the next four to five decades found in the integrated assessment models literature is around 3.5 per cent per year. This would imply a decarbonisation rate (of decrease in emissions per unit of GDP) of more than 6 per cent per year. Historically (1969-2009), a decarbonisation rate of about 1% has been seen globally. In Table 1, while it might seem theoretically possible to create a modelled 'likely' Type II scenario by having a very high emissions reduction rate after the peak, in fact modellers have not found this to be feasible, given these practical constraints. To have a 'likely chance' also requires significant *negative emissions*, as shown in the first example of a Type III scenario in Table 1.

Negative emissions

Global net negative emissions occur when the removal of CO_2 from the atmosphere is greater than emissions into it. To achieve this models at present assume availability of "Bio-Energy combined with Carbon-Capture-and-Storage" (BECCS) technology. This involves using large amounts of biomass to generate energy (e.g. in place of coal) with the CO_2 emissions from that process captured and stored underground using Carbon-Capture-and-Storage (CCS) technology. As biomass takes up CO_2 from the atmosphere in the course of photosynthesis, if the oxidation products (CO_2) is kept out of the atmosphere and stored underground, BECCS in effect removes CO_2 from the air. The feasibility of BECCS is related to factors such as future land availability and biomass productivity for biomass energy systems, as well as the future development of carbon capture and storage technology. While BECCS is the single most important negative emissions technology, creating biochar and storing this in soils or using wood in very long life applications are other non-energy uses of biomass without releasing carbon back into the atmosphere. Other technologies, such as direct air capture of CO_2 have also been discussed in the literature.

A final note is that there are no modelled emissions pathway scenarios of Types I or II that provide a 'likely chance' of meeting a 1.5^{o}C goal. In all cases, the 1.5^{o}C goal requires significant negative emissions in the second half of the century which help temperatures to come back to 1.5^{o}C after overshooting this level shortly.

This article has been authored for Climate Strategies by Murray Ward (Principal, GtripleC), assisted considerably by a number of the authors involved in the UNEP "Emissions Gap" report, in particular, with respect to the detail in Table 1, by Joeri Rogelj, Michel den Elzen and Ramzi Elias.