NZCCC Climate Brief

No. 1, November 2011

The Challenge of Limiting Warming to Two Degrees

Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) was agreed in 1992 in Rio de Janeiro. Article Two of this Treaty states that the ultimate objective of this agreement is to stabilise atmospheric greenhouse gas (GHG) concentrations at levels sufficient to "prevent dangerous anthropogenic interference with the climate system." By May 2011, 194 countries, including all major emitters of GHGs, had ratified the UNFCCC.[1]

In 2010, in Cancun, Mexico, those countries agreed that, to meet that goal, global warming should not rise beyond 2°C above pre-industrial levels. They also agreed to consider a still tougher limit of 1.5°C in a future review.[2]

This New Zealand Climate Change Centre (NZCCC) Climate Brief[a] explains the scientific basis behind that agreement, and backgrounds the various emission and concentration targets used in climate change policy designed to achieve that 2°C limit.

The brief also sets out some of the possible consequences of failing to hold warming to 2°C, and summarises the impacts we might expect under a range of other warming scenarios. It closes with a look at the extent of emissions cuts needed to meet the Cancun goal, and the timelines required to achieve them.

The two degree limit

Scientific assessments have shown that, if we are to limit global warming to 2°C, we need a globally coordinated programme to reduce our net GHG emissions to near-zero during the 21st century.[3]

Two degrees may not sound like a big increase, but it represents a rate of global climatic change unparalleled in human history. Each increment of warming increasingly challenges our ability to adapt to it. Limiting warming to 2°C is possible, but requires rapid and sustained international changes to energy production and consumption patterns to cut emissions from transport, industry, agriculture, forestry, and waste.

What does "dangerous anthropogenic interference" mean?

What exactly is meant by "dangerous" is not specifically defined, but three criteria have been set out in the UNFCCC to guide decision-makers:[1]

- Allow "ecosystems to adapt naturally to climate change"
- Ensure that "food production is not threatened" and
- Enable "economic development to proceed in a sustainable manner."

Interpreting such broad criteria is not straightforward. Comprehensive research has refined climate change projections for different amounts of GHG emissions, and led to understanding of the impacts that climate change might have on ecosystems and society.

While quantifying the probability and severity of some impacts for specific locations remains difficult, the urgency for reducing GHG emissions has become well established.

That's partly because climate change impacts – and our ability to adapt to them – vary around the globe. Warming above 2°C will not be "dangerous" for all species and systems, but neither will everybody and everything be "safe" if we keep below it.

Many regions will suffer heat waves and face greater pressure on water supplies. At the same time more intense rainfall and sea level rise will threaten the viability of low-lying islands and deltas, even if warming is limited to 2°C.

There could be some benefits from limited warming. For instance, in cool or temperate places, there may be fewer cold-related deaths. Agriculture could enjoy longer growing seasons in temperate zones and supply of water to hydro-electric power plants in New Zealand can increase in winter months.[4]

A 2°C warming limit, then, is essentially a social and political judgement that tries to balance the global costs and technical feasibility of rapidly reducing GHG emissions against the very diverse impacts of unmitigated climate change across different societies, ecosystems, and economies.[5-7]

[a] NZCCC Climate Briefs are published by the NZCCC on behalf of its member organisations. The member organisations agree to the preparation of a brief on a particular topic, but do not individually provide sign-off approval of the text. Approval for publication is provided by the NZCCC Director, after considering scientific peer review comments on the draft text. This means any views expressed, and any perceived errors or omissions are the responsibility of the authors, and not of the member organisations of the NZCCC.

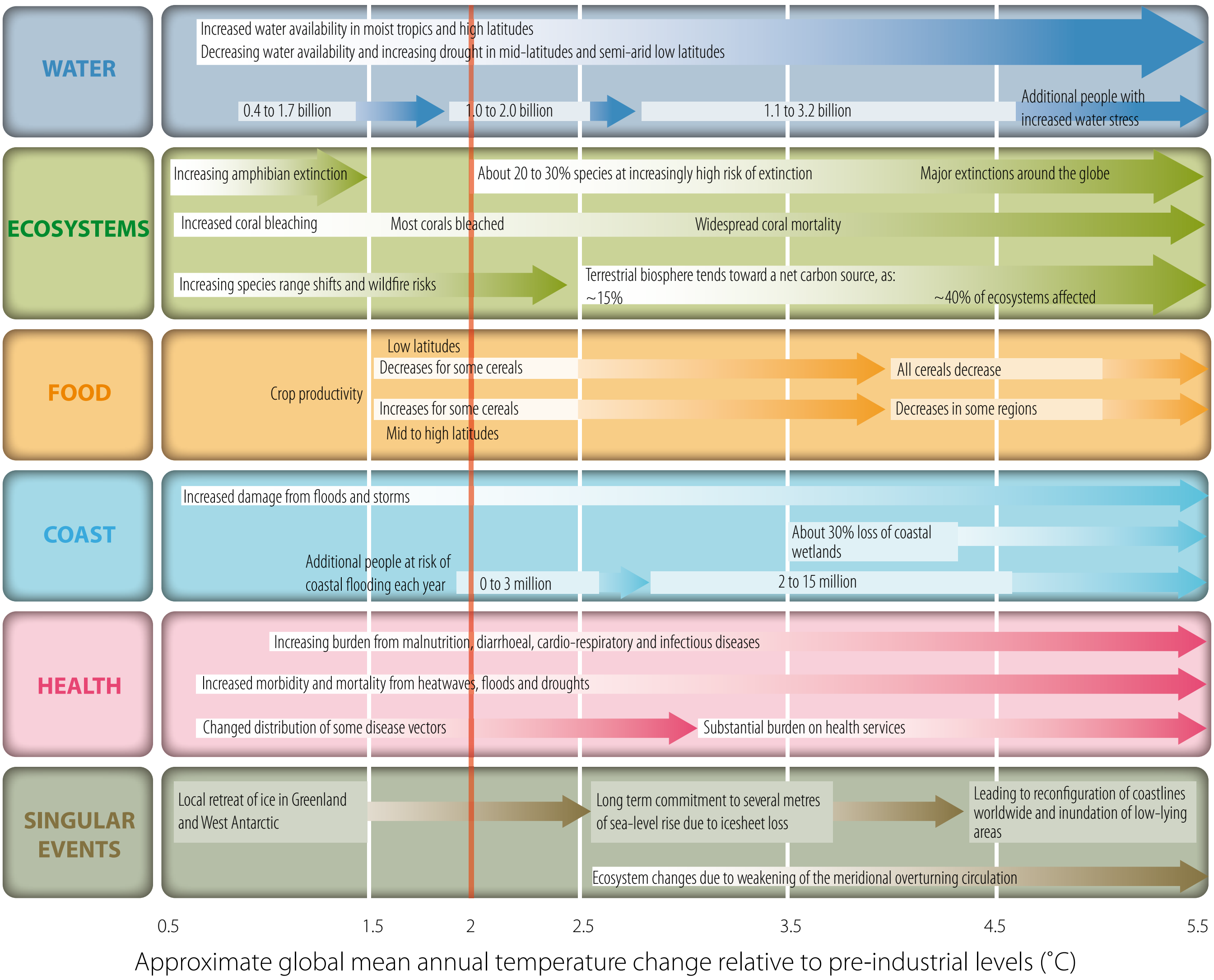

Figure 1. Selected impacts for a range of temperature increases and associated climate changes for different systems and sectors. Edges of boxes and placing of text indicate the range of temperature change to which the impacts relate. Arrows between boxes indicate increasing levels of impacts between estimations. Other arrows indicate trends in impacts. Graphic based on Parry (2009)[8] and draws on information from IPCC Fourth Assessment Report Working Group II Technical Summary (2007).[6]

In 2001, the Intergovernmental Panel on Climate Change (IPCC) assessed the extensive international research that had studied the vulnerability of many sectors and services to climate change, so as to inform policy decisions on what degree of human interference might be considered dangerous to the climate system. The IPCC distilled potential impacts into five key "reasons for concern."

In 2007, its next assessment found that new research meant those reasons had become stronger, because by then, scientists had more confidence in the evidence for them. Some risks were projected to worsen, or to start manifesting at lower temperature increases than first thought.

Figure 1 shows a summary of climate change impacts projected for different sectors and systems around the world. It shows that, while some sectors in some regions might benefit from initial warming, many other critically important aspects of human welfare, such as health and water supply, are likely to be negatively affected. Any warming above the current mean temperature is expected to cause significant and, in some cases, irreversible damage to some sensitive ecosystems.

Figure 1 alone doesn't show which impacts should be regarded as dangerous: rather, it shows that impacts increase with rising temperatures and other climate changes, and that different degrees of warming trigger different types of impacts.

Drawing a line between "dangerous", and "not yet dangerous" is a social and political judgement that science can only inform and support, not decide. Ultimately, the choice must somehow accommodate diverse political, social and cultural values around the world.

Drawing the temperature line

The world has already warmed by more than 0.7°C since the 1850s. Most of the observed increase in global average temperatures since 1950 is very likely due to the observed increase in anthropogenic (human-produced) GHG concentrations.[9]

Furthermore our climate system is still adjusting to the changes in GHG concentrations that have already occurred. Even if these concentrations were not to increase any further, the global average temperature is likely to increase by a further 0.6°C during this century.[9]

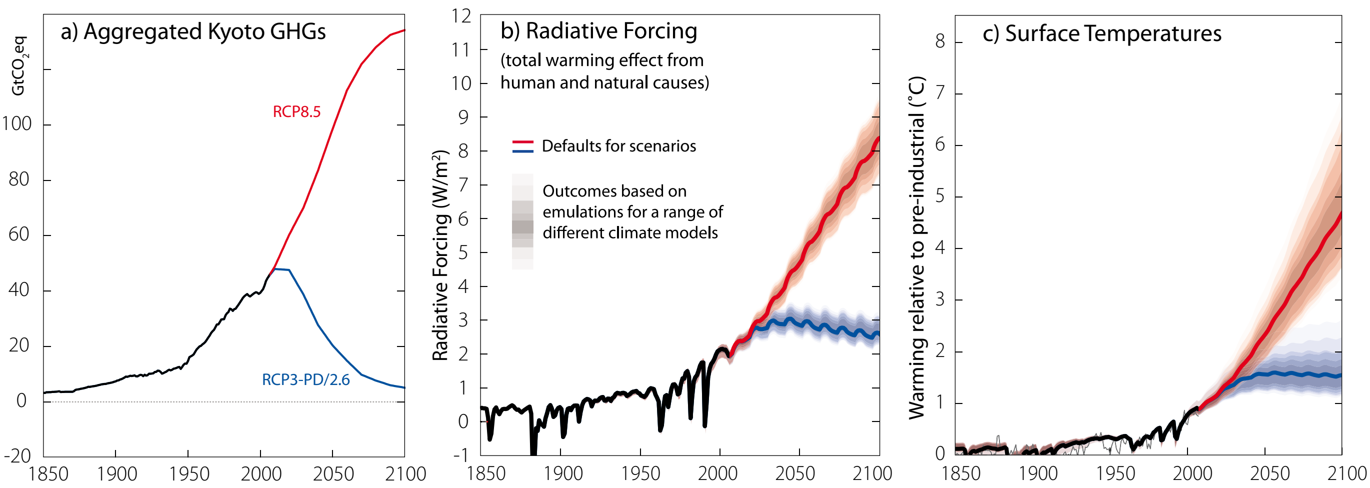

Figure 2. Greenhouse gas (GHG) emissions, radiative forcing and projected change in global average surface temperature for two different future pathways. Radiative forcing as shown here is the total warming effect exerted by increasing GHG concentrations, changes in aerosols and other human influences on the global climate, past volcanic eruptions (seen as marked irregular negative spikes in the historical record), and variation in output from the sun (resulting in small gradual changes as well as regular 11-year cycle). Data were kindly provided by Malte Meinshausen, based on Meinshausen et al. (2011).[10]

Climate scientists are confident that further increases in emissions of those gases will very likely lead to still greater climate changes over the 21st century and beyond. However, because the global climate system is very complex, it's impossible to quantify a precise global temperature increase for any given GHG concentration. Rather, climate science can only specify a range of possible outcomes.[9]

Climate scientists use sophisticated computer models to make projections of future warming. The models employ well-understood physical principles and climate observations, and can reproduce much of the climate changes and regional differences already observed during the 20th century. They allow scientists to project temperature increases and related changes in climate over time, based on different scenarios in which we either increase, curb or maintain our current GHG emissions.

Figure 2 presents two contrasting scenarios of future climate change:

The lower scenario depicts a world that takes strong action to rapidly reduce GHG emissions (RCP3-PD/2.6), while the higher scenario indicates a world that continues to use fossil fuels and inefficient production processes without any consideration of the associated GHG emissions and resulting climate change (RCP8.5).[10, 11]

These two scenarios have been selected from a wide range of possible futures, and shouldn't be seen as strict either/or options. Neither do they represent the extremes of a possible future – the future real world can lie between those two scenarios, but potentially even outside them.[12,13]

Climate scientists don't prescribe which scenario is most likely to play out. Instead, they advise decision makers of the likely impacts associated with each scenario, or any intermediate outcomes, and the decisions necessary to realise any goal we wish to achieve.

Temperature projections and associated climate changes can be combined with information about resulting impacts such as those shown in Figure 1. This helps communities understand the degree of climate change – and the severity of associated impacts – the situations that they might have to adapt to, and the types of impacts they wish to avoid.

What global GHG concentration limits warming to 2°C?

If GHG concentrations were to double from their pre-industrial concentration of 275ppm CO_2-equivalent (CO_2-eq) (see Box 1) to 550ppm CO_2-eq, the average global temperature would increase by about 3°C, within a likely range from about 2°C to 4.5°C, although changes outside this range can't be ruled out.[9, 14]

If warming of 2°C is considered the limit of acceptable change, we would need to constrain GHG concentrations to 450ppm CO_2-eq as a best estimate. However, we cannot say that the warming for such a limited increase in GHG concentrations would be *exactly* 2°C, because of the uncertainties of climate science. There's a roughly 50 per cent chance that the world will warm by more (and possibly much more[14]) than 2°C even if global GHG concentrations are stabilised at 450ppm CO_2-eq.

Given this even chance, the "correct" GHG concentration target depends on how much we want to avoid exceeding the limit of 2°C. If we want to give ourselves an even chance to stay below 2°C, the best scientific estimates suggest 450ppm CO_2-eq is a reasonable long-term target. If we want more certainty – say, at least a 90 per cent chance that temperatures will not increase beyond 2°C – then the increase in GHG concentrations would have to be kept to well below 450ppm CO_2-eq.

What can we control?

Humans can't control the *concentration* of GHGs directly, but we can control our GHG *emissions*. If we do nothing to constrain them, global GHG emissions are projected to increase by 20-90 per cent by 2030. That would produce at least a doubling – and possibly more than a tripling – of GHG concentrations in the atmosphere by the end of the 21st century.[15]

Box 1. Carbon dioxide-equivalent (CO_2-eq) concentrations (based on IPCC 2007[3])

Greenhouse gases (GHGs) differ in their warming influence on the global climate system, due to their different ways of absorbing and re-emitting heat near the Earth's surface and their different lifetimes in the atmosphere. The same global average warming effect could be caused either by higher concentrations of carbon dioxide (CO_2) but lower concentrations of other GHGs, or by lower concentrations of CO_2 and higher concentrations of other GHGs.

To reduce confusion and complexity, scientists use the notion of "Carbon dioxide-equivalent" (CO_2-eq) concentration to describe the total warming effect exerted by all GHGs and aerosols arising from human activities.

Using this notion, the global concentration of all GHGs and aerosols before the industrial revolution (in the mid-18th century) was about 275ppm CO_2-eq. By 2005, this had risen to about 375ppm CO_2-eq due to increasing emissions of CO_2 from the burning of fossil fuels and clearance of forests, and emissions of other gases such as methane, nitrous oxide and synthetic gases from agriculture, industry and waste management, together with a cooling effect from aerosols.

By 2100, without dedicated efforts to reduce GHG emissions, the total concentration of all GHGs and aerosols is expected to rise further to between 650 and more than 1500ppm CO_2-eq, which would result in long-term warming of at least 3°C, but possibly more than 6°C.

By comparison, GHG concentrations would have to be limited to about 450ppm CO_2-eq to give an even chance of global warming not exceeding 2°C in the long term.

CO_2 is removed only very slowly from the atmosphere – once atmospheric concentrations increase above natural levels, it takes a very long time for them to drop again. Without measures to actively remove it, such as afforestation, 20 per cent or more of the rise in CO_2 concentrations from human activities will still remain in a thousand years' time.

As long as the net emissions of CO_2 and other very long-lived GHGs remain significantly above zero, their concentrations will continue to increase. To stop this, emissions will need to peak and then decline to levels much lower than today's (see Figure 2 and the emissions for scenario RCP3-PD/2.6). The sooner that peak and decline happens, the lower the level at which concentrations will ultimately stabilise.

What, by how much and by when?

If we want to hold GHG concentrations to 450ppm CO_2-eq or less, global emissions would need to peak by about 2020, then fall to much lower levels over subsequent decades. However, the timing of the emissions peak is not absolutely fixed, as it depends on the cost and availability of future technologies, including whether CO_2 can be actively removed from the atmosphere.[16] Most recent studies agree that global net emissions would need to fall to around 50 per cent or less of 2000 levels before 2060, and to much lower levels again by 2100.[16, 17]

Any delay in global emissions reductions would demand even more rapid – and drastic – global emissions reductions later to achieve the same long-term outcome. If global emissions peak by 2020, emissions would then need to be reduced by about three per cent a year, every year, for the next several decades. If global emissions peak later, in 2030, they would then have to be reduced even more rapidly to meet the same long-term goal (see Box 2).

While putting off emissions cuts might seem to save money in the short term, it increases costs in the future up to a point where those costs could become prohibitive. This is mainly because delays would encourage more capital investment – in the order of tens of trillions of US dollars over the next two decades – in long-lived carbon-intensive infrastructure such as power plants and networks, transport systems, and urban settlements. This capital infrastructure would have to be retired prematurely or would require wholesale structural changes to achieve the necessary rapid emissions reductions later on.[18-23]

One way to understand the necessary scale and urgency of emissions reductions, while retaining some flexibility around their timing, is through the concept of cumulative emissions targets (see Box 2).

Global issue, regional response

Cutting our collective global emissions by 50 per cent by 2050 is a considerable challenge. Furthermore, meeting it isn't simply a matter of all countries reducing their emissions by the same amount.

To make reductions of this magnitude, all major emitters will have to play some part, as the top 20 emitters produce almost 80 per cent of total global emissions.[28]

The UNFCCC stipulates that developed countries should take the lead in reducing emissions, but targets and expectations vary greatly: to what extent do we hold countries responsible for historical emissions, or their future emissions growth? Should we consider their economic status? Or make a special case of the unique costs of, and opportunities for, the emissions reductions they face, depending on the structure of their economies and their access to renewable energy resources?

Some allocation mechanisms take these different perspectives into account. While they differ in details, they come to a relatively robust agreement on some key points. For instance, to stabilise global GHG concentrations at about 450ppm CO_2-eq by 2100:[15, 29]

- Developed countries would need to reduce their collective emissions by 25-40 per cent below 1990 levels by 2020, and by 80-95 per cent by 2050
- Developing countries would need to reduce their collective emissions by 15-30 per cent below what they would otherwise have been in 2020.

However, the distinction between "developed" and "developing" countries is simplistic, given the wide diversity of economic conditions and technological development among developing countries. If the 2°C goal is to be met, major emerging economies will need to make substantial cuts in their emissions. The poorest countries, on the other hand, will have very little to contribute.

In general, the less one group of countries does to reduce its emissions – or the later they do it – the more other countries would have to do to reduce theirs (or the sooner they must begin) to achieve the same long-term outcome. Sharing responsibility for reducing emissions fairly amongst individual countries therefore becomes a question of ethics, economics and politics, as well as social and technological development.

Despite international agreement on a target of no more than 2°C of warming, pledges of emissions reductions to date fall well short of what science estimates is needed.

As of 2011, pledges to reduce emissions by 2020 from developed countries range from about -10 to -15 per cent below 1990 levels. Some developed countries have set aspirational goals for 2050: the largest reduction is 80 per cent, but many are weaker. Pledged reductions from developing countries are more difficult to quantify, since they are not expressed in absolute terms, but relative to economic and emissions growth that would occur in the absence of climate policies.[30, 31]

Nevertheless, achievement of all these current pledges combined would still allow expected global average warming to exceed 3°C above pre-industrial levels in the long term.[30, 31]

While opportunities to limit warming to 2°C or less still exist, they are rapidly diminishing.[16]

Box 2. Cumulative emissions targets

Some of today's CO_2 emissions will still be contributing to warming in a thousand years' time. This is because, contrary to other GHGs, CO_2 does not disappear entirely, but is merely redistributed over time between the atmosphere, ocean, vegetation and soils. This persistence means that, if we are only concerned about long-term warming, it doesn't matter so much *when* emissions occur – what matters is the *total quantity* of CO_2 we can emit over the next few decades (to about 2050 or 2060) without pushing GHG concentrations to a level where total warming would eventually exceed 2°C.[24]

This provides a new perspective on the challenge for global climate policy, which can inform the setting of emissions targets for specific years.

Humans can emit about another 1000 gigatons (Gt) of CO_2 between 2000 and 2050 to have a good chance (about 75 per cent) of limiting long-term global average warming to 2°C.[25] About 350 Gt of CO_2 have already been emitted during the first decade of the 21st century, and the current emissions rate is about 34-35 Gt CO_2 per year.[26] This means that, at current emissions rates, the remaining global emissions budget of 650 Gt CO_2 would be exhausted within the next 20 years. After that, it would have to drop to – and remain at – zero to retain the same chance of holding warming to no more than 2°C. Higher cumulative CO_2 emissions make it more likely this level of warming will be exceeded.

Cumulative emissions targets cannot apply to shorter-lived gases such as methane, but demonstrate the massive overall reduction in global CO_2 emissions needed if the world wishes to limit the risks of warming beyond 2°C. They also show us that we still have choices: the world can continue for another short while at its current emissions rates, but would then have to make extremely rapid reductions, or it could initiate emissions reductions earlier and enable a smoother transition to a low-carbon future in the long-term (Figure 3).

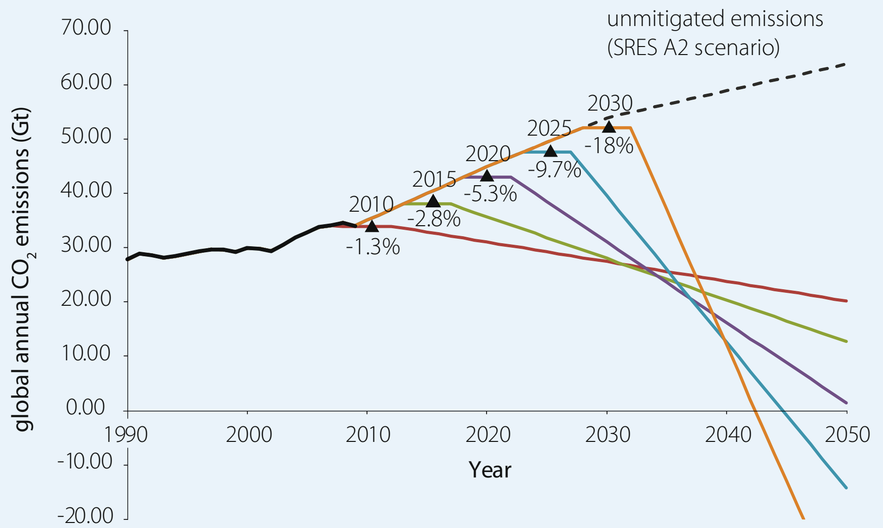

Figure 3. Alternative scenarios for global CO_2 emissions to 2050. The percentage figures indicate the amount (relative to 1990) by which global emissions would need to be reduced, per year, every year, after their peak to remain within the same cumulative emissions budget. All scenarios meet the same cumulative emissions budget of 1445 Gt CO_2 between 2000 and 2050, which gives a roughly 50/50 chance of limiting long-term temperature increase to 2°C.[25] Scenarios that peak earlier could afford a more gradual reduction in emissions later; scenarios that delay emissions reductions in the near term would require a much more rapid and eventually infeasible global reduction in emissions after 2030 to achieve the same long-term outcome. Based on Meinshausen et al. (2009)[25], historical emissions data from Friedlingstein et al. (2010)[26], future unmitigated emissions from IPCC (2000).[27]

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Published in November 2011
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New Zealand Climate Change Centre

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