

Recent Climate Change Science, Global Targets and the Global Climate Emergency

An Issues Paper
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Introduction and Summary

Climate change impacts are occurring faster and with more severity than predicted only several years ago. At the same time, the world's emissions are increasing at rates greater than predicted, and the alarming rates of emissions reductions required to avoid dangerous levels of climate change are becoming more apparent. The time-frames within which we can take effective action are shrinking rapidly, and now appear to be so tight as to require that we take world-wide emergency action, or prepare to face catastrophic levels of climate change.

This paper considers:

- some key findings of recent climate science
- some key climate indicators, and how they have been tracking recently
- whether a rise in the average global temperature of 2 degrees Celsius above pre-industrial levels is an appropriate threshold for 'dangerous' climate change
- what targets for atmospheric CO₂e concentrations (ie, atmospheric concentrations of greenhouse gases) are necessary to limit the temperature rise to 2 degrees, and (alternatively) to stabilise the temperature at less than 1 degree above pre-industrial levels
- what targets for global emissions reductions, and other actions, are necessary to achieve these atmospheric CO₂e concentrations targets, and
- the way in which time-lines in the climate change arena are shrinking:
 - the impacts of climate change are getting worse more rapidly than predicted
 - key climate indicators are providing great cause for concern
 - the magnitude of the emissions reduction task is becoming more apparent.

Key questions for consideration are set out at the end of each section of the paper. In summary, they are:

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All views expressed in the paper remain the responsibility of the author. Comments and questions concerning the paper can be directed to the author on kewells@wellex.com.au.

1. Is a rise in the average global surface temperature of 2 degrees above pre-industrial levels the appropriate threshold for 'dangerous' climate change? If not, what would a more appropriate threshold be?
2. Is a target for atmospheric greenhouse gas concentrations of 450 ppm CO₂e appropriate, or should the world be aiming for a more stringent target? If so, what should this be?
3. Are global emissions reduction targets which are consistent with achieving atmospheric greenhouse gas concentrations of 450 ppm CO₂e appropriate, or should the world be aiming for more stringent global emissions reduction targets? If so, what should these be?
4. Achieving the more stringent targets for atmospheric greenhouse gas concentrations is likely to require not just deep emissions cuts, but action in other areas, such as, from later in this century, negative emissions. Should we expand the current policy debate to encompass and address these issues?
5. Given the shrinking time-frames indicated by the latest scientific analysis in this area, is it reasonable to characterise the current climate situation as a climate emergency? If not, why not, and when *would* it be reasonable to characterise the climate situation as an emergency?
6. If it is a climate emergency, what should we do differently to address it?

1. Recent climate change science

Most climate change policy around the world is based on IPCC science, and most recently, the IPCC's 2007 report (AR4). The IPCC's 5-yearly reports give a clear indication of where the broad international scientific consensus on climate change lies. They are therefore a valuable reference point in such a complex field. However, the consensual process involved in producing IPCC reports tends towards a 'lowest common denominator' approach, in order to gain global agreement. The IPCC process of review is also a lengthy one which tends to exclude scientific findings published during the preceding one or two years. In addition, the IPCC's emissions-related modelling scenarios have not been updated since the early 2000's.

In a less-rapidly-moving area, this might not matter too much. However, in the climate change arena, the science is moving extremely rapidly. As a consequence, AR4 does not reflect key aspects of the most recent published science on climate change. Key examples of this include:

- Summer sea-ice in the Arctic is decreasing in extent and mass far more rapidly than predicted
- The Greenland and West Antarctic ice sheets are melting more rapidly than predicted
- Sea level rise is now predicted to be in the order of up to at least 1.4 metres this century, rather than the maximum of 0.6 metres articulated in AR4
- The world's great carbon sinks (land and ocean) are becoming less efficient, more rapidly than predicted

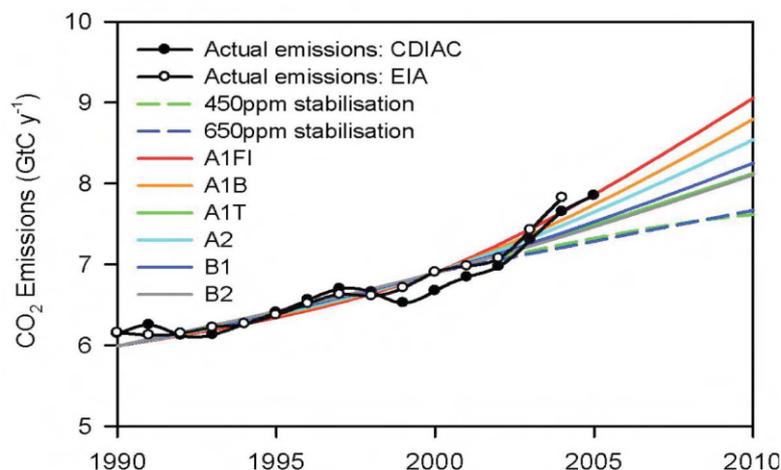
These examples are discussed in more detail in Appendix One.

2. Recent climate indicators

In addition, a range of key climate indicators is providing great cause for alarm. In brief, the data now available raise concerns that the climate system may be responding more quickly than climate models indicate. For example:

- The global mean surface temperature increase for the period 1990 – 2006 was in the upper part of the range projected by the IPCC in its 2001 report ²
- The observed sea level for the same period rose faster than the rise projected by the IPCC in 2001 ³
- Growth in *CO₂ concentrations* since 2000 has been very high. Since 2000, there has been the most rapid 7-year increase in atmospheric CO₂ since the beginning of the industrial revolution. ⁴
- Most importantly, growth in *CO₂ emissions* from 2000 to 2007 exceeded the highest rate projected by the IPCC in 2001. The growth rate of emissions was 3.5% per year, an almost four fold increase from 0.9% per year in 1990 – 1999. ⁵

Figure 1: Growth in CO₂ Emissions



Source: Raupach et al. 2007, PNAS; Meinshausen; see as well van Vuuren & Riahi (forthcoming)

The consequence of these trends is that the world is currently on track to meet A1 FI, the most fossil-fuel-intense of the IPCC's 2001 scenarios; an utterly catastrophic 6-degree rise over the next 90 years.

² Rahmstorf, S. et al, 2007, 'Recent Climate Observations Compared to Projections', *Science*, Vol. 316, 709

³ Ibid

⁴ In 2007 the annual mean growth rate of atmospheric CO₂ was 2.2 ppm per year; up from 1.8 ppm in 2006, and above the 2.0 ppm average for the period 2000-2007. The average annual mean growth rate for the previous 20 years was about 1.5 ppm per year. This increase brought the atmospheric CO₂ concentration to 383 ppm in 2007, 37% above the concentration at the start of the industrial revolution (about 280 ppm in 1750). The present concentration is the highest during the last 650,000 years and probably during the last 20 million years. *Global Carbon Project (2008): Carbon Budget and Trends, 2007*, www.globalcarbonproject.org, accessed 09/03/09; Canadell, J. G., Le Quéré, C., et al, 2007, 'Contributions to Accelerating Atmospheric CO₂ Growth from Economic Activity, Carbon Intensity, and Efficiency of Natural Sinks', *Proceedings of the National Academy of Sciences*, Vol 104, 18866-18870

⁵ Global Carbon Project (2008), *ibid*; Canadell and Le Quéré, *ibid*. See also Raupach, M. R. et al, 2007, 'Global and Regional Drivers of Accelerating CO₂ Emissions', *Proceedings of the National Academy of Sciences*, Vol 104, 10288-10293. Canadell and Le Quéré attribute this growth in emissions to a growing global economy, an increase in the carbon emissions required to produce each unit of economic activity, and a decreasing efficiency of carbon sinks on land and in oceans. 'Together, these effects characterise a carbon cycle that is generating stronger-than-expected climate forcing sooner than expected.'

3. Dangerous climate change

3.1 Is 2 degrees C the appropriate threshold for 'dangerous' climate change?

Most climate policy around the world is currently aimed at keeping the rise in the average global surface temperature to 2 degrees Celsius above pre-industrial levels, on the understanding that an increase of more than 2 degrees would constitute 'dangerous' climate change. This implies that a rise of 2 degrees or less would be, if not desirable, at least acceptable.⁶

However, there are two increasingly strong arguments *against* accepting that a global temperature increase of more than 2 degrees should be the threshold for 'dangerous' climate change.

First, recent scientific developments indicate that a rise of only 2 degrees could, in fact, lead to catastrophic climate change for many parts of the planet, and perhaps the planet as a whole. For example, as outlined in Appendix One, with a 0.8 degree in temperature rise to date, we appear to be close to the loss of the Arctic's summer sea-ice, with the range of potential consequences including the accelerated melting and disintegration of the Greenland Ice Sheet, and the more rapid release of methane from the northern tundra.

Second, it is apparent, even without the most recent science, that 'dangerous' climate change is relative term, and that a rise of less than 2 degrees above pre-industrial levels would lead to enormous economic, social and environmental loss across the planet.

For example, Joel Smith, Stephen Schneider and colleagues have recently carried out an update of the IPCC's 2001 'burning embers' diagram, which gives some guidance as to what the IPCC might regard as 'reasons for concern' in the context of dangerous climate change. Their work examined the risks likely to result from various rises in the global mean temperature *relative to 1990 levels*. (By 1990 the world had already experienced a rise of approximately 0.5 degrees above pre-industrial levels.) They concluded, amongst other things, that:

- A rise in the global mean temperature of less than 2 degrees Celsius above 1990 levels poses significant risks to many unique and threatened systems, including many biodiversity hotspots. There are likely to be substantial impacts and/or moderate risks *at current temperature levels*, and potentially severe or widespread impacts and associated increases in risks from about 1 degree above 1990 levels (ie, about 1.5 degrees above pre-industrial levels).
- A rise of less than 2 degrees above 1990 levels also poses a significant risk of extreme weather events. Again, there are substantial impacts and/or moderate risks *at current temperature levels*, and potentially severe and/or wide-spread impacts and associated increases in risks from about 1 degree above 1990 levels (ie, about 1.5 degrees above pre-industrial levels).

⁶ 'Dangerous climate change' is a term which arose from the 1992 United Nations Framework Convention on Climate Change (the UNFCCC), which called for 'stabilisation of greenhouse gases to prevent dangerous anthropogenic interference with the climate system'. However, the Convention did not define what this meant. The judgement that a rise of more than 2 degrees in the average global surface temperature constitutes 'dangerous' climate change has since gained considerable currency worldwide. This judgement has some scientific basis, but is also a consequence of social, economic, political and moral value judgements about what constitutes 'danger', and what are acceptable impacts. See for example, Schneider, S. and Lane, J., 2006, 'An Overview of Dangerous Climate Change', in *Avoiding Dangerous Climate Change*, Cambridge University Press., U.K..

- A rise of *less* than 1 degree above 1990 levels (ie, *less* than about 1.5 degrees above pre-industrial levels) is likely to result in reductions in water supply for between 0.4 and 1.7 billion people.⁷

It is also clear that a rise of less than 2 degrees above pre-industrial levels would lead to enormous loss within Australia. For example, Preston and Jones looked at the impacts of various temperature rises on Australia, and concluded that a rise of less than 1 degree above pre-industrial levels would lead, amongst other things, to:

- the loss of between 10 -40% of the snow-covered area in the Australian Alps
- a 70% increase in droughts in NSW
- an 18% increase in annual days above 35 degrees in South Australia, and a 25% increase in the NT.

Preston and Jones also concluded that a rise of between 1 and 2 degrees above pre-industrial levels would lead, amongst other things, to:

- Murray-Darling river flows falling by 10 – 25%
- a 7 – 35% decrease in Melbourne’s water supply
- the bleaching of between 60 – 80% of the Great Barrier Reef every year
- significant species extinction in internationally significant environments in North Queensland and Western Australia
- 1,200 – 1,400 more heat-related deaths per year in major population centres
- an increase in the number of people at risk from dengue fever from 0.17 million to 0.75 – 1.6 million
- an increase in peak electricity demand in Adelaide and Brisbane of 4 – 10%
- an increase in the 100-year storm surge height around Cairns of 22%; the area flooded will double
- a 25% increase in 100-year storm tides along the eastern Victoria coast.

Their table on the likely impacts of different levels of temperature rise on key aspects of Australia’s environment is set out in Appendix 2.⁸

Clearly, these sorts of impacts will have a range of severe consequences across Australia, economically, socially and environmentally.

3.2 Alternatives to 2 degrees

With these sorts of considerations in mind, climate scientists are now starting to advise that 2 degrees is not an appropriate threshold for ‘dangerous’ climate change, and that we should be aiming for a lower threshold. For example:

⁷ Smith, J. and Schneider, S., 2009, ‘Assessing Dangerous Climate Change Through an Update of the IPCC ‘Reasons for Concern’, *Proceedings of the National Academy of Sciences*, published online before print, Feb 26, 2009, 10.1073/pnas.0812355106

⁸ Preston, B. and Jones, R., 2005, ‘*Climate Change Impacts on Australia and Benefits of Early Action to Reduce Global Greenhouse Gas Emissions*’, CSIRO, Australia

- James Hansen and colleagues, in 2007, argued that the temperature rise should be limited to 1.7 degrees above pre-industrial levels, on the basis that potential changes above this level would be highly disruptive.⁹
- Subsequently, after further work on climate sensitivity, Hansen and his colleagues called for an initial CO₂ target of 350 ppm, followed by a stabilisation target for CO₂ of 300 ppm. (Note that Hansen's call relates to CO₂ only, and not to the broader suite of greenhouse gases which is the subject of current international negotiations. Without taking into account the warming contributed by other greenhouse gases, a target of 350 ppm CO₂ would lead to a long-term warming of around 1 degree above pre-industrial levels if climate sensitivity is close to the IPCC 'best estimate' of 3 degrees Celsius. However, if the other greenhouse gases are taken into account, the resulting warming would be closer to 1.5 degrees above pre-industrial levels.)¹⁰
- Bill Hare, from the Potsdam Institute for Climate Impact Research, has similarly concluded that because of the dangers inherent in a rise of 2 degrees, we should aim to stabilise the climate as far below 2 degrees above pre-industrial levels as possible, and that this will need to involve peaking the temperature at close to, if not below, 2 degrees above pre-industrial levels, and reducing the temperature as rapidly as possible after that, to below 1 degree above pre-industrial levels. He points out in particular the risks involved in a rise of between 1.5 and 2 degrees, and argues that the amount of time the climate system remains in this temperature region should be minimised if it cannot be prevented.¹¹

These views are controversial, not least because of the degree of difficulty attached to achieving them. Amongst other things, the world has already experienced a rise of 0.8 degrees. We are also committed to another approximately 1.6 degrees, principally as a consequence of the thermal inertia of the oceans and the masking effect of aerosols on the warming caused by greenhouse gases. As a consequence, if we were to stop all emissions tomorrow, we would be likely to face an unavoidable 2.4 degrees of warming.¹²

This means that to stabilise the global average temperature at less than one degree above pre-industrial levels, as some are now advocating, would ultimately require *lowering* the temperature substantially *below* the level we are already committed to.

The size of this task would be enormous. According to Hare, stabilising the temperature at less than one degree would require a multi-century commitment to action which covers:

- the rapid reduction of global CO₂e emissions down to 85% below 1990 levels by 2050
- a halt to deforestation well before 2030, and large-scale efforts to store carbon in soils through progress toward sustainable agriculture, forestation and reforestation, and
- from the 2050's, large-scale negative emissions of CO₂ (ie, the removal of CO₂ from the atmosphere) for two centuries. (Without this it will be impossible to draw down atmospheric concentrations sufficiently quickly, owing to the long life of this gas.)¹³

⁹ J. Hansen et al., 2007, 'Dangerous Human-made Interference with Climate: A GISS modelE Study,' *Atmospheric Chemistry and Physics*, Vol. 7, 2287–2312

¹⁰ Hansen, J. et al, 2008, 'Target Atmospheric CO₂: Where Should Humanity Aim?', *Open Atmospheric Science Journal*, Vol 2, 217-231; Hare, W., 'A Safe Landing for the Climate', *2009 State of the World*, Worldwatch Institute, 13-29; personal communication with Professor David Karoly, University of Melbourne, 200309

¹¹ Hare, *ibid*

¹² Ramanathan, V., and Feng, Y., 2008, 'On Avoiding Dangerous Anthropogenic Interference With the Climate System: Formidable Challenges Lie Ahead', *Proceedings of the National Academy of Sciences*, Vol 105, 14239-14240. Ramanathan and Feng estimate that the observed increase in concentrations of greenhouse gases in the atmosphere since the pre-industrial era has committed the world to a warming of 1.4 – 4.3 degrees Celsius, with a mean estimate of 2.4 degrees.

¹³ Hare, *op. cit.* note 10

With this level of action, according to Hare, the global temperature increase should peak below 2 degrees around mid-century, and begin a slow decline, dropping to present levels by the last half of the 23rd Century, and to 1990 levels by the end of the 24th Century.¹⁴

In considering these ideas, however, it is worth recalling that one of the main reasons we find them controversial is that we are not used to considering, in a realistic fashion, the devastation that a rise of 2 degrees or less is likely to bring with it.

Issue for consideration: 2 degrees and ‘dangerous’ climate change

Most climate change policy around the world is currently aimed at limiting the rise in the average global temperature to 2 degrees above pre-industrial levels, on the understanding that an increase of more than 2 degrees would constitute ‘dangerous’ climate change.

The judgement that 2 degrees is the appropriate threshold for ‘dangerous’ climate change has some scientific basis, but is also a consequence of social, economic, political and moral judgements about what is ‘dangerous’, and what impacts are acceptable. It is apparent on the most recent science that a rise of less than 2 degrees is likely to prove disastrous for a significant proportion of the world’s peoples and species, and perhaps for the globe as a whole, and that it would put key Australian ecosystems and parts of our society and economy at high risk.

Issue:

Is a rise in the average global surface temperature of 2 degrees above pre-industrial levels the appropriate threshold for ‘dangerous’ climate change? If not, what would a more appropriate threshold be?

3.3 What global targets are likely to be needed?

Two types of targets are at issue here:

- a global target for atmospheric concentrations of greenhouse gases (expressed as a target for atmospheric CO₂e concentrations¹⁵), and
- global emissions reduction targets.

a) A target for atmospheric CO₂e concentrations

There has been considerable discussion internationally about what constitutes an appropriate target for atmospheric CO₂e concentrations.¹⁶ Much of the political discussion over the last five years has

¹⁴ Hare, op. cit. note 10

¹⁵ ‘CO₂e’ refers to carbon dioxide equivalents, and is short-hand for the 6 greenhouse gases covered by the Kyoto Protocol.

¹⁶ In 2005, the IPCC’s best estimate of the *total* atmospheric CO₂e concentrations for all long-lived GHG’s was about 455 ppm. (In 2007 it was 460 ppm.) After taking into account the impact of aerosols and other human-induced climate forcing agents, the ‘*net*’ forcing in 2005 was around 375 CO₂e (similar to atmospheric CO₂ concentrations, which in 2005 were 379

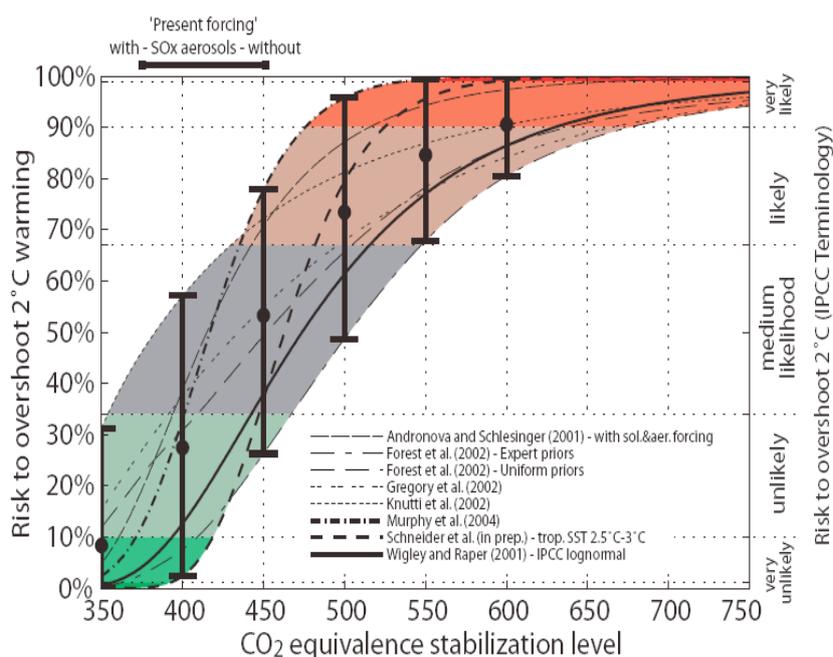
centred around the appropriateness of targets of 450, 550 and 650 ppm CO₂e. Targets of less than 450 ppm CO₂e have generally been seen as desirable, but completely unrealistic, politically and economically, and targets of more than 650 ppm CO₂e have generally been recognised as being completely inadequate in terms of preventing catastrophic climate change.

Scientifically, it is now widely accepted that a target of 450 ppm CO₂e is necessary if the world is to have a chance of limiting the temperature rise to 2 degrees, and that a 550 ppm CO₂e target would be likely to lead to a 3-degree rise, and a 650 ppm CO₂e target to a 4-degree rise.¹⁷

However, over the last few years scientists have begun to question whether even the 450 ppm CO₂e target is sufficient.

Firstly, a target of 450 ppm CO₂e would actually only provide about a 50% chance of limiting the temperature rise to 2 degrees. Put another way, it would give the world a 26 -78% risk (mean 47%) of *exceeding* a global temperature increase of 2 degrees. A target of 400 ppm CO₂e, on the other hand, would give the world a 2-57% risk (mean 27%) of exceeding 2 degrees, and a target of 350 ppm CO₂e would give the world a 0 -31% risk (mean 8%) of exceeding 2 degrees.¹⁸

Figure 2: The risk of overshooting a 2 degree C target



Hare and Meinshausen (2004)

ppm). IPCC, 2007, *Climate Change 2007: Synthesis Report: Summary for Policymakers*, Cambridge University Press, U.K.; Hare, op. cit. note 10; data from the National Oceanic and Atmospheric Administration (The NOAA) Annual Greenhouse Gas Index.

¹⁷ IPCC, *ibid*; Meinshausen, M., et al., 2006, 'Multi-gas Emissions Pathways to Meet Climate Targets', *Climatic Change*, Vol 75 (1), 151-194 (Meinshausen 2006a); Meinshausen, M. 2006, 'What Does a 2C Target Mean for Greenhouse Gas Concentrations? A Brief Analysis Based on Multi-Gas Emission Pathways and Several Climate Sensitivity Uncertainty Estimates', in *Avoiding Dangerous Climate Change*, Cambridge University Press, U.K., 253-279 (Meinshausen 2006b)

¹⁸ Meinshausen 2006b, *ibid*. Note that discussions about appropriate GHG concentrations targets often assume a peak in concentrations before subsequent stabilisation at a lower figure. This is particularly the case for the more stringent concentrations targets. In relation to the 400 ppm CO₂e stabilisation target, Meinshausen envisages peaking concentrations at no more than 475 ppm CO₂e, and subsequently reducing them to 400 ppm CO₂e.

Consequently, even if one considers that a goal of limiting the global temperature rise to 2 degrees is adequate, a target of 450 ppm CO₂e clearly is not, and constitutes, at the very least, extremely poor risk management.

Secondly, it is apparent that a target of less than 450 ppm CO₂e will be necessary if one is attempting to tackle the more onerous task of trying to stabilise the temperature at less than 2 degrees above pre-industrial levels. In January 2009, a Communication from the European Commission to the European Parliament noted that: 'In the light of some new research findings, an increasing number of scientists are calling for the level of greenhouse gases in the atmosphere to be stabilised at a significantly lower level than previously recommended, ie, as low as 350 ppmv CO₂e. It is imperative to secure an ambitious outcome in Copenhagen that leaves the door open for a lower stabilisation effort.'¹⁹

Amongst those scientists are Hansen and his colleagues, who in 2008 concluded that based on the paleoclimate evidence and ongoing global changes, 385 ppm CO₂ (the level of CO₂ in the atmosphere at that time) was already too high to maintain the climate to which humanity, wildlife and the rest of the biosphere are adapted. They argue that if the world is to avoid catastrophic rates of climate change, we should aim for an initial target of 350 ppm CO₂, with a stabilisation target of 300 ppm CO₂.²⁰

As previously mentioned, Hare has concluded that we should aim to peak global temperature at close to, if not below, 2 degrees, and reduce it as rapidly as possible after that to below 1 degree. He argues that CO₂e concentrations of 400 ppm and ultimately 300 ppm are necessary to achieve this.²¹

Issue for consideration: A target for atmospheric CO₂e concentrations

Mainstream climate change policy around the world is aiming, at most, for a target of 450 ppm CO₂e. in order to limit the global temperature rise to 2 degrees. However, this will give us, *at best*, a 50% chance of avoiding a rise of more than 2 degrees.

Recent analysis indicates that:

¹⁹ 'Communication from the European Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Towards a Comprehensive Climate Change Agreement in Copenhagen', Jan 2009, <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52009DC0039:EN:NOT>, accessed 260209

²⁰ Hansen, op. cit., note 10. As noted above, these figures are for CO₂, not CO₂e. It is difficult to make direct comparisons between CO₂ and CO₂e, because the relationship between the two changes over time as the proportions of CO₂ and the various non-CO₂ gases in the atmosphere change. AR4 compares CO₂ and CO₂e concentrations for various stabilisation scenarios, and implies that:

350 – 400 ppm CO₂ corresponds with 445 – 490 ppm CO₂e
400 – 440 ppm CO₂ corresponds with 490 – 535 ppm CO₂e, and
440 – 485 ppm CO₂ corresponds with 535 – 590 ppm CO₂e.

AR4 does not examine scenarios involving CO₂ concentrations of less than 350 ppm. IPCC, 2007, *Climate Change 2007: Mitigation: Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Summary for Policymakers*, Cambridge University Press, U.K.

²¹ Hare, op. cit., note 10

- To have a fair (approximately 75%) chance of limiting the global temperature rise to 2 degrees, a target of 400 ppm CO₂e is likely to be necessary
- To have a high (approximately 90%) chance of limiting the global temperature rise to 2 degrees, a target of 350 ppm CO₂e is likely to be necessary
- To stabilise the global temperature at less than 1 degree, a target of 300 ppm CO₂e may well be necessary. (Note, however, that this area needs further analysis, globally)
- These targets would all require an initial overshooting of the target, and working down to subsequent stabilisation at the target.

Issue:

Is a target for atmospheric greenhouse gas concentrations of 450 ppm CO₂e appropriate, or should the world be aiming for a more stringent target? If so, what should this be?

b) Targets for global emissions reductions

Once an appropriate target for atmospheric CO₂e concentrations has been determined, it is necessary to set an emissions reduction trajectory and global emissions reduction targets which will ensure the atmospheric CO₂e concentrations target is met.

(National emissions reduction targets then need to be allocated amongst nations to ensure that those global emissions reduction targets are achieved. This is where most international debate has been focussed to date. However, this paper does not deal with the allocation of national targets.)

Global emissions reduction targets for 450 ppm CO₂e

The IPCC has noted – and most signatories to the UNFCCC have acknowledged - that in order to achieve an atmospheric CO₂e concentration of 450 ppm (ie, in order to have approximately a 50% chance of limiting the global temperature rise to 2 degrees), global CO₂e emissions need to:

- peak before 2020 (and global CO₂ emissions need to peak by 2015), and
- be reduced to at least half of their 1990 levels by 2050.²²

Global emissions reduction targets for 400 ppm CO₂e and less

The global emissions reductions necessary to meet global GHG concentrations of less than 450 ppm are less well-understood, and are not addressed in AR4. Hare notes that a number of recent scenarios have been constructed which demonstrate that it is technically and economically feasible to reduce CO₂ emissions fast enough so that GHG concentrations can be limited to around 400 ppm CO₂e, or to lower in the longer term. Under these scenarios it is likely that peak warming would occur close to, if not below, 2 degrees Celsius, and in some cases temperatures might slowly decline beyond the 21st Century.

²² IPCC, op. cit., notes 16 and 20. Note also the Communication from European Commission, op. cit., note 19. AR4 puts the 2050 reduction for the range 445 – 490 ppm CO₂e at 50 – 85% below 2000 levels.

All these scenarios require:

- rapid fossil fuel CO₂e emissions reductions of between 40 to 60% by 2050
- rapid reductions in deforestation, and
- negative CO₂ emissions by the last quarter of the 21st Century at the latest.²³

Hare also looks at the pathways necessary to reach even lower atmospheric CO₂e concentrations. He notes that:

- No technically and economically feasible pathway published to date brings warming to below 1 degree Celsius above pre-industrial levels.
- A few pathways could bring warming to below 1.5 degrees Celsius by the 23rd Century if the negative CO₂ emissions at the end of the 21st Century in these scenarios were sustained for at least 100 years. (Without this, warming would be likely to remain well above 1.5 degrees Celsius for many centuries.)
- The pathway required to provide greater confidence around avoiding a 2-degree rise and to reduce warming rapidly to below 1 degree would require:
 - a more rapid reduction in emissions by 2050 than in the most recent scenarios, which have already been at the limits of what models indicate is feasible based on present technological assessments (CO₂e emissions would need to be reduced to around 85% of their 1990 levels)
 - a halt to deforestation well before 2030, and large scale efforts to store carbon in soils through progress toward sustainable agriculture and regrowing forests, and
 - after the 2050's, the capture from the atmosphere and permanent storage of about 9 billion tons of CO₂ per year for more than 200 years in order to draw total GHG concentrations down to below 300 ppm CO₂e.²⁴

He notes also that while some of these pathways require much more drastic action than others, the beginnings of each of the pathways are very similar, in that they all require immediate action to peak global emissions by, or before, 2020.²⁵

Issue for consideration: Targets for global emissions reductions

Mainstream climate change policy around the world is aiming for global emissions reductions targets which are, at best, consistent with achieving an atmospheric greenhouse gas concentration target of **450 ppm CO₂e**. As noted above, the IPCC has indicated that to achieve that target, global CO₂e emissions will need to peak by 2020 (with global CO₂ emissions peaking by 2015), and be reduced by at least 50% by 2050.

However, following this path will give us, at best, a 50% chance of avoiding a rise of more than 2 degrees.

Recent analysis indicates that:

²³ Hare, op. cit., note 10. Note that some of the more stringent mitigation scenarios for CO₂e stabilisation levels in AR4 also include negative emissions, using technologies such as biomass energy production utilising carbon capture and storage (BECS). IPCC, op. cit., note 20

²⁴ Hare, op. cit., note 10

²⁵ Hare, op. cit., note 10

- to achieve an atmospheric greenhouse gas concentration of **400 ppm CO₂e** (which would provide approximately a 75% chance of limiting the global temperature increase to 2 degrees), global CO₂e emissions would need to peak by 2020 and be reduced by 40 to 60% by 2050. In addition, the world would need to take a range of other very stringent measures (see next box)
- to achieve an atmospheric greenhouse gas concentration of **350 -300 ppm CO₂e** (which would provide a 90% chance or more of limiting the global temperature increase to 2 degrees, and would also provide a chance of subsequently stabilising the temperature at less than a one degree rise), global CO₂e emissions would need to peak before 2020 and be reduced by about 85% by 2050. In addition, the world would need to take a range of other very stringent measures (see next box). Note that this area needs further analysis, globally.

Issue:

Are global emissions reduction targets which are consistent with achieving atmospheric greenhouse gas concentrations of 450 ppm CO₂e appropriate, or should the world be aiming for more stringent global emissions reduction targets? If so, what should these be?

Issue for consideration: Other measures necessary to achieve stringent targets for atmospheric CO₂e concentrations

The mainstream policy debate in this area currently has a significant focus on emissions reductions, and some focus on avoided deforestation.

Recent analysis suggests that in order to meet the more stringent targets for atmospheric CO₂e concentrations (ie, 400 ppm CO₂e and less), it will be necessary for the world not just to make strong emissions reductions, but for it to:

- halt deforestation rapidly and engage in large-scale efforts to store carbon in soils, and
- from the second half of this century, capture large amounts of CO₂ from the atmosphere and store it permanently (ie, negative emissions).

Issue:

Should we expand the current policy debate to encompass and address all of these issues?

4. Shrinking time frames

It is apparent on a number of fronts that the time-frames within which the world can address climate change are shrinking rapidly.

These fronts include:

- the increasing speed at which impacts are occurring, and their unanticipated severity
- the alarming progress of a whole range of key climate change indicators, and
- our increasing understanding of the magnitude of the task ahead of us, and the rates of change necessary to meet even mainstream targets for atmospheric CO₂e concentrations and global emissions reductions.

Exacerbating matters still further is the fact that all of this is occurring against a long-term global back-drop of substantial population and consumption growth.

The first two of the fronts listed above have been discussed already, in Parts 1 and 2 of this paper. The third is discussed below.

4.1 Our understanding of the magnitude of the emissions reduction task

Over the past decade, the world's understanding of the emissions reduction task facing it has grown significantly. For example, the inclusion of carbon-cycle feedbacks in AR4 significantly reduced the anthropogenic carbon budgets associated with particular concentrations of CO₂e.²⁶ In addition, as noted above, we now have empirical data on the high rates of growth in global emissions since 2000.

The latest McKinsey report on global abatement opportunities gives one indication of what the detail of the task might look like.

It finds (amongst other things) that, focusing principally on technical measures because of the inherent difficulty in achieving behaviour change, the *potential* exists to reduce GHG emissions by some 35% from 1990 levels by 2030. This would be broadly consistent with an emissions pathway that would see the atmospheric concentration of GHG's peak at 480 ppm, and then start decreasing, stabilising eventually at 400 ppm. However, capturing the full abatement potential is a major challenge, and would entail change on a huge scale.

In addition, it finds that delays in action of even 10 years would mean missing the 2-degree target. The modelling undertaken for the study shows that if concerted global action is delayed until 2020, it would be challenging to achieve even a 550 ppm stabilisation path, even if more expensive technical measures and behavioural changes were also implemented.²⁷

4.2 The need to peak emissions by 2015

This 'peaking' theme is also evident in AR4, which, as noted above, concluded that the world has until 2015 to peak CO₂ emissions if we wish to aim for a target for atmospheric CO₂e concentrations of 450 ppm CO₂e (the lowest of the atmospheric GHG targets being considered by the mainstream climate change agenda).

²⁶ Anderson, K. and Bows, A., 2008, 'Reframing the Climate Change Challenge in Light of Post-2000 Emission Trends', *Philosophical Transactions of the Royal Society*, Vol 366, 3863-3882, referring to the findings of AR4.

²⁷ McKinsey and Company, 2009, *Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve*, www.mckinsey.com/index_9.asp, accessed 26/02/09. The report assesses more than 200 GHG abatement opportunities across 10 major sectors and 21 world regions between now and 2030. It looks at abatement opportunities which would reduce GHG's at a cost of up to 60 Euros per tonne CO₂e of avoided emissions, and are possible with technologies that are either available today or offer a high degree of certainty about their potential in a 2030 time horizon.

Given the rate at which emissions are currently growing, peaking global emissions by 2015 appears to be an exceptionally difficult task. However, Meinshausen has also commented that if this peak is delayed, even until 2020, the world will need to embark upon far steeper rates of emissions reductions than if the peak occurs by 2015, and it may prove too difficult to achieve the rates of change necessary to stabilise at 450 ppm CO₂e.²⁸

4.3 Rates of emissions reductions

Furthermore, recent work by Kevin Anderson and Alice Bows, from the Tyndall Centre for Climate Change Research in the UK, demonstrates that peaking global emissions is merely the start of an extraordinarily difficult path.²⁹

Anderson and Bows take the latest science and rates of emissions growth and look at scenarios which examine the rates of emissions reductions necessary to meet various targets for atmospheric CO₂e concentrations. They conclude that in the absence of the widespread deployment and successful application of geo-engineering technologies that remove and store atmospheric CO₂:

- if emissions peak in 2015, stabilisation at **450 ppm** CO₂e requires subsequent annual global reductions of 4% in CO₂e, and 6.5% in energy and process emissions, between 2020 and 2040
- if emissions peak in 2020, stabilisation at **550 ppm** CO₂e requires subsequent annual global reductions of 6% in CO₂e, and 9% in energy and process emissions, and
- if emissions peak in 2020, stabilisation at **650 ppm** CO₂e requires subsequent annual global reductions of 3% in CO₂e, and 3.5% in energy and process emissions.

They comment: 'It is increasingly unlikely that an early and explicit global climate change agreement or collective ad hoc national mitigation policies will deliver the urgent and dramatic reversal in emission trends necessary for stabilisation at 450 ppm CO₂e. Similarly, the mainstream climate change agenda is far removed from the rates of mitigation necessary to stabilise at 550 ppmv CO₂e. Given the reluctance, at virtually all levels, to openly engage with the unprecedented scale of both current emissions and their associated growth rates, even an optimistic interpretation of the current framing of climate change implies that stabilisation much below 650 ppmv CO₂e is improbable.

'The analysis presented within this paper suggests that the rhetoric of 2 degrees C is subverting a meaningful, open and empirically informed dialogue on climate change. While it may be argued that 2 degrees C provides a reasonable guide to the appropriate scale of mitigation, it is a dangerously misleading basis for informing the adaptation agenda. In the absence of an almost immediate step change in mitigation (away from the current trend of 3% annual emission growth), adaptation would be much better guided by stabilisation at 650 ppmv CO₂e (ie, approximately 4 degrees C). However, even this level of stabilisation assumes rapid success in curtailing deforestation, an early reversal of current trends in non-CO₂ greenhouse gas emissions and urgent decarbonisation of the global energy system.

'[In addition, in the context of the need to allow transition economies to grow, economically, during the next two decades,] [e]ven atmospheric stabilisation at 650 ppmv CO₂e demands the majority of OECD nations begin to make draconian emission reductions within a decade. Such a situation is

²⁸ Meinshausen 2006b, op. cit., note 17

²⁹ Anderson and Bows, op. cit., note 26

unprecedented for economically prosperous nations. Unless economic growth can be reconciled with unprecedented rates of decarbonisation (in excess of 6% per year) it is difficult to envisage anything other than a planned economic recession being compatible with stabilisation at or below 650 ppmv CO₂e.³⁰

‘Ultimately, the latest scientific understanding of climate change allied with current emission trends and a commitment to ‘limiting average global temperature increases to below 4 degrees C above pre-industrial levels’, demands a radical reframing of both the climate change agenda, and the economic characterisation of contemporary society.’³¹

Issues for consideration: Shrinking time-frames

In general, the world’s framing of the climate change agenda is that urgent action is necessary, but that we can achieve the results necessary without significant economic pain (except in certain sectors), by around 2050.

Recent analysis indicates that:

- Climate change impacts - including a range of impacts which are likely to have disastrous implications globally - are occurring with increasing speed and severity, at a rate that was not predicted by the IPCC just several years ago
- Key climate indicators, such as the enormous growth in global emissions since 2000, are providing great cause for concern
- The annual global emissions reductions likely to be required to avoid dangerous levels of climate change are alarming. (For example, in order to meet 450 ppm CO₂e, and even assuming that global emissions peak by 2015, developed nations are likely to need to reduce their emissions by more than 6% *per annum* for several decades from 2020 - when according to Stern, annual rates of reduction in excess of 1% have only been associated with economic recession or upheaval.)

Issues:

Given the shrinking time-frames indicated by the latest scientific analysis in this area, is the world’s current framing of the climate change agenda still appropriate? Should we re-frame our approach to give a clearer indication of the immediate need for a sustained, radical restructuring of the economy, and the likelihood that an extraordinary level of effort and sacrifice worldwide will be necessary over the next two to three decades?

Given this convergence of themes, can the current climate situation be characterised as anything other than a climate emergency? If it is not, why not, and when *would* it be reasonable to characterise the climate situation as an emergency?

If it is a climate emergency, what should we do differently to address it?

³⁰ They point elsewhere to Stern’s finding that annual reductions of greater than 1 % have ‘been associated only with economic recession or upheaval’.

³¹ Anderson and Bows, *op. cit.*, note 26

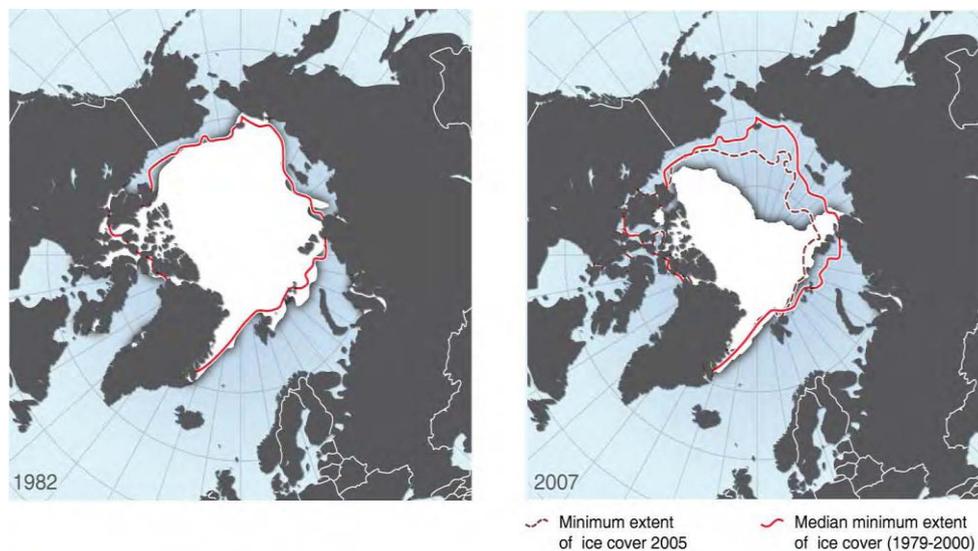
Appendix One: Recent Climate Change Science

Key examples of the findings of recent climate change science are set out below. This list is not intended to be exhaustive.

The Arctic

AR4 stated that ‘... late summer sea-ice is projected to disappear almost completely towards the end of the twenty-first century’.³² However, since 2005, the extent and thickness of the Arctic summer sea-ice has declined far more rapidly than estimated in the models referred to in AR4. In the summer of 2007 in particular, Arctic sea ice declined rapidly to unprecedented low extents, raising concern that the Arctic may be on the verge of a fundamental transition towards a seasonal ice cover.³³

Figure 1: Arctic Sea Ice Extent



Map source: UNEP/GRID-Arendal Maps and Graphics Library, accessed April 2008, © July, 2008, M. Meinshausen

As a consequence, scientists are now predicting that the Arctic will lose all its summer sea-ice well before 2100, perhaps as early as 2040, or 2030.³⁴

This loss of summer sea ice, and the subsequent warming of the Arctic region due to the loss of its reflective ice cover, is likely to be of the highest significance. This is because in addition to local ecosystem impacts, it may have other regional impacts, including speeding up the melting and disintegration of the Greenland Ice Sheet, and speeding up the release of methane from the

³²PCC, op. cit., note 20

³³Stroeve, J., et al., 2008, ‘Arctic Sea Ice Extent Plummets in 2007’, *Eos Transactions AGU*, Vol 89(2), 13-14; Stroeve, J., et al, 2007, ‘Arctic Sea Ice Decline: Faster than Forecast?’, *Geophysical Research Letters*, Vol 34, L09501

³⁴Serreze, M. C., Holland, M. M., et al, 2007, ‘Perspectives on the Arctic’s Shrinking Sea Ice Cover’, *Science*, Vol 315, 1533-1536; Stroeve (2008), *ibid*; Maslowski, W., Clement, J., et al, 2006, ‘On Oceanic Forcing of Arctic Climate Change’, *Geophysical Research Abstracts*, Vol 8, 05892. Some even predict that the Arctic will lose all its summer sea-ice as early as 2013 or earlier; personal communications with and news reports concerning comments made by a range of these and other scientists, recorded in Spratt, D., and Sutton, P., 2008, *Climate Code Red: The Case for Emergency Action*, Scribe Publications, Melbourne, Chap. 1

northern tundra.³⁵ Both of these events would have global implications, the first because of the very large sea-level rise it would bring with it, and the second because of the extremely significant impact of that methane on the global carbon cycle.³⁶

The Greenland and Antarctic ice sheets

The Greenland ice sheet is melting and losing mass far more rapidly than predicted by the IPCC.³⁷ The Antarctic ice sheet is also melting more quickly than predicted, particularly the West Antarctic ice sheet.³⁸

Significant uncertainties remain about the timing of future contribution of these ice sheets to sea level rise. However, given their potential to contribute some 7 metres and 5 metres, respectively, the increased rate of ice melt is clearly a matter for global concern.

Sea level rise

AR4 set out projections for sea level rise associated with the thermal expansion of the oceans and mountain glacier melt. Its highest estimate for the year 2100 was a sea level rise of 0.59 m. However, its projections did not take into account the full potential for sea level rise associated with ice sheet dynamics (ie, the melting of the Greenland and West Antarctic ice sheets), due to the lack of scientific knowledge in this area at the time.³⁹

Since then, work by various scientists has concluded that sea-level rise by 2100 is likely to be substantially higher than predicted in AR4; somewhere between 0.8 and 1.4 metres.^{40 41} Clearly, such an increase would have disastrous impacts on vulnerable coastlines and settlements around the world.

³⁵ Hansen, op. cit., note 9; Gregory, J. M. et al, 2004, 'Climatology: Threatened Loss of the Greenland Ice Sheet', *Nature*, Vol 426, 616; Lawrence D. M. et al., 2008, 'Accelerated Arctic Land Warming and Permafrost Degradation during Rapid Sea Ice Loss', *Geophysical Research Letters*, Vol 35, L11506; Schuur, E. A. G. et al, 2008, 'Vulnerability of Permafrost Carbon to Climate Change: Implications for the Global Carbon Cycle', *Bioscience*, Vol. 58(8), 701-714

³⁶ Gregory, *ibid*; Schuur, *ibid*

³⁷ Mote, T. L., 2007, 'Greenland Surface Melt Trends 1973 – 2007: Evidence of a Large Increase in 2007', *Geophysical Research Letters*, Vol 34, L22507; Tedesco, M., 2007, 'Snowmelt Detection over the Greenland Ice Sheet from SSM/I Brightness Temperature Daily Variations', *Geophysical Research Letters*, Vol 34, L02504; Chen, J. L., Wilson, C. R. et al, 2006, 'Satellite Gravity Measurements Confirm Accelerated Melting of Greenland Ice', *Science*, Vol 313, 1958-1960; Steffen, K., Huff, R. et al, 2007, 'Arctic Warming, Greenland Melt and Moulins', *Eos Trans. AGU*, 88(52) Fall Meet., Abstract G33B-1242

³⁸ Rignot, E., Bamber, J. L. et al, 2008, 'Recent Antarctic Ice Mass Loss from Radar Interferometry and Regional Climate Modelling', *Nature Geoscience*, Vol 1, 106-110

³⁹ IPCC, op. cit., note 16

⁴⁰ Pfeffer, W. T. et al., 2008, 'Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise', *Science*, Vol 321, 1340-1343; Rahmstorf, S., 2007, 'A Semi-Empirical Approach to Projecting Future Sea-Level Rise', *Science*, Vol 315, 368–370; Horton R. et al., 2008, 'Sea Level Rise Projections for Current Generation CGCMs based on the Semi-empirical Method', *Geophysical Research Letters*, Vol 35, L02715

⁴¹ Other recent opinion concludes that ice sheet disintegration will occur in a non-linear fashion, and that although it is impossible to predict the timing of such non-linearities with any certainty, a far higher rise, in the order of several metres or more, may occur this century. Hansen, J., 2007, 'Scientific Reticence and Sea-level Rise', *Environmental Research Letters*, Vol 2, 024002

Natural carbon sinks

The world's great natural carbon sinks are becoming less efficient, more quickly than predicted. During the period 2000 – 2007, natural land and ocean CO₂ sinks removed 54% of all CO₂ emitted from human activities. However, the efficiency of these sinks in removing CO₂ has decreased by 5% over the last 50 years, and will continue to do so in the future.⁴² As this directly impacts on the anthropogenic carbon budget (the amount of carbon which humans can contribute to the global carbon cycle), it is a matter of significant concern.

⁴² (That is, 50 years ago, for every ton of CO₂ emitted to the atmosphere, natural sinks removed 600 kg. Currently, the sinks are removing only 550 kg for every ton of CO₂ emitted, and this amount is falling.) Global Carbon Project (2008), *op cit*, note 4; Canadell and Le Quéré, *op. cit.*, note 4

Appendix Two: Projected Impacts on Australian Ecosystems

ΔT ($^{\circ}C$)	Projected Impact
<1	10–40% shrinkage of snow-covered area in the Australian Alps ⁵⁸
	18–60% decline in 60-day snow cover in the Australian Alps ⁵⁸
	Bleaching and damage to the Great Barrier Reef equivalent to 1998 and 2002 in up to 50% of years ^{59,60}
	60% of the Great Barrier Reef is regularly bleached ⁶¹
	Habitat is lost for 14% of Victoria's marine invertebrates ⁶²
	50% decrease in habitat for vertebrates in northern Australia tropics ^{63,64}
	<5% loss of core habitat for Victorian and montane tropical vertebrate species ⁶⁵
	28% of Dryandra species' core habitat is significantly reduced in SW Australia ⁶⁶
	4% of Acacia species' core habitat is significantly reduced in SW Australia ⁶⁶
	63% decrease in Golden Bowerbird habitat in N Australia ⁶⁷
	Habitat for 3 frog and 15 threatened/endangered mammals in W Australia is lost or restricted ⁶⁶
50% decrease in montane tropical rainforest area in N Australia ⁶⁸	
1–2	Up to 58–81% of the Great Barrier Reef is bleached every year ⁶¹
	Hard coral reef communities are widely replaced by algal communities ⁶⁹
	90% decrease in core habitat for vertebrates in northern Australia tropics ^{63,64}
	5–10% loss of core habitat for Victorian and montane tropical vertebrate species ⁶⁵
	88% of butterfly species' core habitat decreases ⁷⁰
	66% of core habitat for Dryandra species is significantly reduced in SW Australia ⁶⁶
100% of Acacia species are eliminated in SW Australia ⁶⁶	
2–3	97% of the Great Barrier Reef is bleached every year ⁶¹
	10–40% loss of core habitat for Victoria and montane tropical vertebrate species ⁶⁵
	92% of butterfly species' core habitat decreases ⁷⁰
	98% decrease in Bowerbird habitat in N Australia ⁶⁷
80% loss of freshwater wetlands in Kakadu (30 cm sea level rise) ⁷¹	
3–4	Catastrophic mortality of coral species annually ⁶¹
	95% decrease in distribution of Great Barrier Reef species ⁶¹
	65% loss of Great Barrier Reef species in the Cairns region ⁵⁹
	20–85% shrinkage of total snow-covered area in the Australian Alps ⁵⁸
	38–96% decline in 60-day snow cover in the Australian Alps ⁵⁸
30–70% loss of core habitat for Victoria and montane tropical vertebrate species ⁶⁵	
4–5	60–90% loss of core habitat for Victoria and montane tropical vertebrate species ⁶⁵
>5	90–100% of core habitat lost for most Australian vertebrates ^{63,64}

Source: Preston, B. and Jones, R., 2005, 'Climate Change Impacts on Australia and Benefits of Early Action to Reduce Global Greenhouse Gas Emissions', CSIRO, Australia