



climate code red

**the case for a
sustainability
emergency**

**David Spratt
Philip Sutton**



**Friends of
the Earth**

Climate 'code red'

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sustainability emergency**

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Climate Code Red
is published by
Friends of the Earth
PO Box 222
Fitzroy 3065
Australia
www.foe.org.au

in conjunction with
Carbon Equity
PO Box 96
Yarraville 3013
Australia
www.carbonequity.info

and
Greenleap Strategic Institute
PO Box 27
Farfield 3078
Australia
www.green-innovations.asn.au

ISBN 978-1-920767-08-2

First published February 2008

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Available online at
www.climatecodered.net
www.foe.org.au

Comments are welcome at
www.climatecodered.blogspot.com

Earlier versions of the following sections were published
online at www.carbonequity.info:

Part 1 as “The big melt” October 2007

Part 2 as “Target practice” November 2007

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Cover photo: The rising Earth above the lunar
horizon, taken from the Apollo 8 spacecraft, 12
December 1968. On the earth, the sunset terminator
crosses Africa. The south pole is in the white area
near the left end of the terminator. North and South
America are under the clouds.
Courtesy NASA/NSSDC

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Foreword

In November 2007 in the leadup to UN climate change negotiations in Bali, 150 corporations from around the world issued a remarkable statement. The “Bali communiqué”, as it became known, was starkly brief and contained just four action points. But its intent and significance should not be underestimated. It called for science — rather than what is considered politically palatable or “reasonable” — to be the defining factor in deciding what reductions in greenhouse gas emissions are required to avoid dangerous climate change.

Despite the unequivocal evidence on the need for urgent reductions, the nations gathered in Bali did not respond with the vision or action necessary to overcome the dire problems humanity now faces. We have, according to the USA’s leading climate scientist, James Hansen, already passed some climate “tipping points” and now face dangerous climate change in coming decades. While the evidence has grown to a now overwhelming case, governments have wasted a decade in endless negotiations and quibbling over who should go first, while ignoring the large carbon debt accrued by the rich and owed to the majority world.

It is clear that forms of “greener business as usual” are not sufficient to bring the required depth or speed of change. In Australia, the mainstream debate remains focused on emissions trading as a means of reducing emissions, yet there is no agreement on a clear target for capping emissions!

Many in industry advocate options that may ameliorate but cannot solve the climate problem — such as “clean” coal which cuts but does not fully eliminate carbon dioxide emissions and is unproven technology at the scale required — or options that add to other major problems such as “greenhouse friendly” nuclear power that maintains and spreads technical capabilities that can be used for the proliferation of nuclear weapons capability.

When do we as a community admit that the current responses are simply not enough and are wasting valuable time and getting us into worse trouble? At what point do we ask whether we need to put aside the limitations of our current models and modes of thinking and stop assuming that technological innovation and market-based mechanisms can deliver the reductions that the science is telling us we need to make in the absence of clear public policy to achieve a safe climate and the use of a full suite of measures, including lifestyle change? At what point do we acknowledge that we, as a local and global community, need to take the global warming problem seriously and consider all effective options, including those that have been treated as off-limits because they go beyond business-as-usual. This report asks exactly these questions. It argues forcefully that we must look for something new, something equal to the profound and immense task that confronts us as we stand at the start of the global-warming century.

The good news is that the authors of this report have found that humanity has been able to rise to the challenge in earlier times of crisis, where strong and visionary government intervention was required and when the whole population contributed because they understood the urgency of the task and saw that their neighbours were prepared to do the same.

We do not need a “war” against global warming, as some suggest. But we do need to acknowledge that the “solutions” currently on the table are no match for the magnitude of the crisis we collectively face. This will require a profound transformation in how we meet all our needs, not just here in Australia but globally, allowing all nations to provide for the needs of their poorest communities without burning us all off the planet. It is hard to imagine the transformation happening, in the time frame required, without putting aside “business as usual” in favour of an economic, cultural and political programme founded on urgency, purpose and united action. Perhaps this is where the declaration of the sustainability emergency comes into play.

Cam Walker
National Liaison Officer
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Preface

“The Arctic is often cited as the canary in the coal mine for climate warming. Now as a sign of climate warming, the canary has died. It is time to start getting out of the coal mines.” — NASA climate scientist Jay Zwally (who as a teenager hauled coal), December 2007 (Borenstein, 2007)

The impetus for this report was an intention to provide a brief overview of three areas of climate policy — recent science, appropriate targets, and the case for emergency action — that we wished to bring to the attention of the Garnaut Climate Change Review, which had been commissioned by the then Australian Federal Labor opposition leader Kevin Rudd and the Labor State governments.

As we started on the project, extraordinary events in the Arctic in September 2007 reinforced our view that “dangerous climate change” is not future tense, but now. The world is experiencing the dangerous impacts of rapid warming and if our purpose is to protect all people, all species and all generations, we need to conceive of climate action as returning us to a “safe-climate Earth”, rather than trading off thousands if not millions of species, and perhaps hundreds of millions of people, by opting for compromise goals such as a rise of 2°C above pre-industrial levels. Returning to a safe-climate world requires a global cooling to turn around some of the impacts so far, including the very likely complete loss of the Arctic summer sea-ice within a few years.

The massive Arctic ice melt in 2007 reinforced our supposition that global warming is a global emergency which now demands an emergency response. That is, one in which we put aside “business as usual” and “politics as usual”, and devote our collective energy and capacity for innovation, and all necessary resources, to establish a path to a safe-climate world before it is too late.

The issues of global warming, water shortages, peak oil, ecosystem destruction, resource depletion, global inequity and threat of pandemics intersect and intertwine. Together their threats and risks constitute a sustainability crisis or emergency. Effective solutions need to consider these issues together, and we are mindful of this need even though the discussion here largely focuses on how human actions have altered the heat balances in the atmosphere and on the Earth’s terrestrial surfaces and oceans, and the consequences of a heating planet.

Many people, including the UN Secretary-General, now call the situation we face a climate emergency, but they could just as easily say it is a warming, water, energy, equity and ecosystem emergency. How we translate that understanding into an emergency action plan is a huge step, but we hope the ideas sketched here are one small, tentative step down that essential path.

This report is divided into three parts.

Part 1 reviews the evidence and a range of interpretations flowing from the increasing speed of the Arctic melt, and looks at some other recent climate data and analysis, including carbon sinks, species loss and climate sensitivity.

Drawing on these experiences, Part 2 analyses current debates about climate targets and proposes a set of targets consistent with achieving a safe-climate future.

Part 3 identifies the need for a rapid transition to a post-carbon economy and looks at why the task needs to be constructed as a sustainability emergency, as opposed to going along at the pace of business and politics as usual.

Many people have helped in clarifying ideas and preparing the text. We thank Bob Thompson, Frans Timmerman, Rob Campbell, Jonathan Doig, Alan Pears, Carol Ride and Cam Walker, and the many climate scientists who patiently responded to our sometimes erratic enquiries.

We hope the ideas here will be part of a much larger conversation about how we respond to fast warming, the notion of a rapid transition and the proposal for a sustainability emergency.

Overview

The extensive melting of Arctic sea-ice in the northern summer of 2007 starkly demonstrated that serious climate-change impacts are already happening, both more rapidly and at lower global temperature increases than projected. Human activity has already pushed the planet's climate past several critical "tipping points", including the initiation of major ice sheet loss.

The loss in summer of all eight million square kilometres of Arctic sea-ice now seems inevitable, and may occur as early as 2010, a century ahead of the Intergovernmental Panel on Climate Change projections. There is already enough carbon dioxide in the Earth's atmosphere to initiate ice sheet disintegration in West Antarctica and Greenland and to ensure that sea levels will rise metres in coming decades.

The projected speed of change, with temperature increases greater than 0.3°C per decade and the consequent rapid shifting of climatic zones will, if maintained, likely result in most ecosystems failing to adapt, causing the extinction of many animal and plant species. The oceans will become more acidic, endangering much marine life.

The Earth's passage into an era of dangerous climate change accelerates as each of these tipping points is passed. If this acceleration becomes too great, humanity will no longer have the power to reverse the processes we have set in motion.

We stand at a time where we still have the power to make a choice. Only by dealing with the full scale and urgency of the problem can we create a realistic path back to a safe-climate world. Targets should be chosen and actions taken that can actually solve the problem in a timely manner. A temperature cap of 2–2.4°C, as proposed within the United Nations framework, would take the planet's climate beyond the temperature range of the last million years and into catastrophe.

The loss of the Arctic sea-ice unambiguously represents dangerous climate change. As the tipping point for this event was around two decades ago when temperatures were about 0.3°C lower than at present, we propose a long-term precautionary warming cap of 0.5°C and equilibrium atmospheric greenhouse gas level of not more than 320 parts per million (ppm) carbon dioxide.

The USA's leading climate scientist, James Hansen, stated recently that we should set an atmospheric carbon dioxide target that is low enough to avoid "the point of no return". To achieve this, he says, we must not only eliminate current greenhouse gas emissions but also remove excess carbon dioxide from the atmosphere and take urgent steps to "cool the planet".

These scientific imperatives are incompatible with the "realities" of "politics as usual" and "business as usual". Our conventional mode of politics is short-term, adversarial and incremental, fearful of deep, quick change and simply incapable of managing the transition at the necessary speed. The climate crisis will not respond to incremental modification of the business-as-usual model.

There is an urgent need to reconceive the issue we face as a *sustainability emergency*, that takes us beyond the politics of failure-inducing compromise. The feasibility of rapid transitions is well established historically. We now need to "think the unthinkable", because the sustainability emergency is now not so much a radical idea as simply an indispensable course of action if we are to return to a safe-climate planet.

Part 1: After the big melt

1.1 Introduction

“For the last 10,000 years we have been living in a remarkably stable climate that has allowed the whole of human development to take place. In all that time, through the mediaeval warming and the Little Ice Age, there was only a variation of 1°C. Now we see the potential for sudden changes of between 2°C and 6°C. We just don’t know what the world is like at those temperatures. We are climbing rapidly out of mankind’s safe zone into new territory, and we have no idea if we can live in it.” — Robert Corell, Arctic scientist and IPCC member, September 2007 (Hilton, 2007)

If the climate change world was not turned upside down in September 2007, it was certainly jolted off its axis when new data revealed the floating sea-ice in the polar north to be disintegrating at a frightening speed and, in the words of one glaciologist, “100 years ahead of schedule”. This sea-ice may disappear entirely as early as 2010, and climate scientists are shocked by what they are seeing.

This extraordinary event, in which millions of square kilometres of Arctic sea-ice is literally breaking up and melting away before the world’s eyes, demands that we look anew at the impact of global warming, the pace of change, the phenomenon of non-linear or unexpected climate events, the role of climate science, and what we must do to return to a safe-climate world.

Yet those turning to the 2007 Intergovernmental Panel on Climate Change (IPCC) reports for an up-to-date, authoritative view on global warming will find no real discussion of these dramatic events in the Arctic or their consequences. The 2007 report is the IPCC’s strongest call yet for governments and businesses, nations and communities to act now and quickly to reduce greenhouse emissions. But it is not enough. The IPCC’s four-year schedule for producing reports requires a deadline for scientific papers that is often two to three years prior to the report’s final release. What happens if there is significant new evidence or dramatic events that change our understanding of the climate system in the gap between the science reporting deadline and publication? They don’t get a mention, so the IPCC report — widely viewed as the climate change Bible — is out of date even before it is released.

We have been struck by the significance of the Arctic melt and its implications for global warming and our understanding of how close we are to the “tipping points” of dangerous climate change, of the loss of the Greenland ice sheet, of sea-level rises of metres this century, and for producing global temperature rises that take us well into the danger zone. It forces us to reconsider what “dangerous” climate change means, and how rapidly we must reduce carbon emissions.

Yet just as the Arctic demands that we be more stringent in thinking about what constitutes dangerous climate change, there is an undertone in public discussion that the widely supported (though far too high) target of 2°C is too big an ask, so in Bali it was 2–2.4°C and in many other places its “let’s go for 3°C instead”. The fact that when the maximum temperature about three million years ago was 2–3°C greater than now, sea levels were 25 metres higher and the northern hemisphere was free of continental glaciers seems not to be a matter to be considered. Our conclusions are very different from this loose talk of 2°C or 3°C caps.

And the Arctic summer of 2007 is not the only reasons for our conclusion that we now face a global climate emergency that requires extremely action and a transition to a post-carbon economy as fast as humanly possible, rather than at a leisurely “politics as usual” pace. Already there is evidence that the Earth’s major carbon sinks are becoming less efficient and are leaving more carbon in the atmosphere. Rapid heating of the Arctic opens the possibility of the release of catastrophic amounts of greenhouse gases as the permafrost melts.

The decade from 2004 to 2014 is likely to see temperatures rise by 0.3°C, a pace which if maintained would be too fast for 70% of ecosystems to adapt, especially forests. Yet the indications are that decadal temperature rises are likely to exceed 0.3°C till well past mid-century. We are on course to kill off much of the biosphere. Such a prospect demands that we “think the unthinkable” and find extraordinary ways and means to reverse this slide into oblivion for many or most species.

Because we are primarily guided by the need to advocate actions that are capable of fully solving the problem, we can only conclude from the available evidence that if we are to stop global warming becoming “dangerous”, it is not a question of how much higher will be OK, but rather by how much we need to lower the existing temperature if we are to return our planet to the safe-climate zone.

1.2 The accelerating loss of the Arctic sea-ice

“We are all used to talking about these impacts coming in the lifetimes of our children and grandchildren. Now we know that it’s us.” — Professor Martin Parry, co-chairman of the IPCC impacts working group (Adam, 2007b)

Events in the Arctic in the northern summer of 2007 have profound consequences for climate policy, the role and methods of the IPCC, the assessment of projected sea-level rises and the question as to whether we may have already passed one or more of the critical “tipping points” for dangerous anthropogenic interference with the climate system.

In its 2007 Working Group I Report, the IPCC said that “Arctic sea-ice is responding sensitively to global warming. While changes in winter sea-ice cover are moderate, late summer sea-ice is projected to disappear almost completely towards the end of the 21st century” (IPCC, 2007a).

But even before they were drafted, the 2007 IPCC projections were well behind the physical reality in the environment. In late 2005, Tore Furevik of the Geophysical Institute in Bergen had graphically demonstrated that “the recent [Arctic] sea-ice retreat is larger than in any of the 19 IPCC models” (Furevik, 2005). In December 2006, data was presented to an American Geophysical Union (AGU) conference suggesting that the Arctic may be free of all summer sea-ice as early as 2030 and likely by 2040 (Holland, Bitz et al., 2006), setting up “a positive feedback loop with dramatic implications for the entire Arctic region” (Amos, 2006).

This was affirmed by studies published in March and May 2007 (Serreze, Holland et al., 2007; Stroeve, Holland, et al., 2007) which led Penn State climatologist Richard Alley to comment that the Arctic sea-ice appears to be shrinking “100 years ahead of schedule” (Spotts, 2006).

Despite the warnings, experts were “shocked” at the extent of Arctic ice-sheet loss during the 2007 northern summer; Mark Serreze, an Arctic specialist at the US National Snow and Ice Data Center (NSIDC) at Colorado University in Denver, told the Guardian: “It’s amazing. It’s simply fallen off a cliff and we’re still losing ice” (Adam, 2007a).

A feature in the “Washington Post” painted the picture: “This summer the ice pulled back even more, by an area nearly the size of Alaska. Where explorer Robert Peary just 102 years ago saw ‘a great white disk stretching away apparently infinitely’ from Ellesmere Island, there is often nothing now but open water. Glaciers race into the sea from the island of Greenland, beginning an inevitable rise in the oceans. Animals are on the move. Polar bears, kings of the Arctic, now search for ice on which to hunt and bear young. Seals, walrus and fish adapted to the cold are retreating north. New species — salmon, crabs, even crows — are coming from the south. The Inuit, who have lived on the frozen land for millennia, are seeing their houses sink into once-frozen mud, and their hunting trails on the ice are pocked with sinkholes” (Struck, 2007).

The 2007 Arctic sea-ice minimum on 16 September was 4.13 million square kilometres, compared to the previous record low of 5.32 million square kilometres in 2005, representing a precipitous decline of 22% in two years: “The minimum for 2007 shatters the previous five-day minimum set on September 20–21, 2005, by 1.19 million square kilometres (460,000 square miles), roughly the size of Texas and California combined, or nearly five United Kingdoms” (NSIDC, 2007). This loss of ice extent of more than 20% in two years compares to the decreasing trend in ice area of 7% per decade between 1979 and 2005 (Alley, 2007). The ice retreat is likely to be even bigger next summer because this winter’s freeze is starting from such a huge ice deficit (Revkin, 2007).

NSIDC research scientist Walt Meier said 2007 was “the biggest drop from a previous record that we’ve ever had and it’s really quite astounding... Certainly we’ve been on a downward trend for the last 30 years or so, but this is really accelerating the trend” (McCarthy, 2007). As well, large areas of the Arctic sea-ice are now only one metre deep, which means the thickness of the ice has halved since 2001 (Bjornes, 2007), down from 3.5 metres in the early 1960s, and about 2.5 metres in the late 1980s and early 1990s (Blakemore and Sandell, 2006). Between 1997 and 2002, the ice thickness decreased

35% and the volume by 33% (Maslowski, 2006). The decrease in both extent and thickness suggests that the summer sea-ice has lost more than 80% of its volume in 40 years. When the sea-ice thins to around half a metre in thickness, it will be subject to even more rapid disintegration.

Serreze says we may have already reached the tipping point at which there is rapid sea-ice disintegration: "The big question is whether we are already there or whether the tipping point is still 10 or 20 years in the future... my guts are telling me we may well be there now" (Connor, 2007b) and "an educated guess right now would be 2030" for the transition to an ice-free Arctic summer (McCarthy, 2007). His colleague at Colorado, Ted Scambos, agreed "that 2030 is not unreasonable... I would not rule out 2020, given non-linearity and feedbacks" (Scambos, 2007) and says "I just don't see a happy ending for this" (Struck, 2007). These views are supported by Ron Lindsay of the University of Washington: "Our hypothesis is that we've reached the tipping point. For sea-ice, the positive feedback is that increased summer melt means decreased winter growth and then even more melting the next summer, and so on" (Connor and McCarthy, 2006). Australian-of-the-Year Tim Flannery suggests that "at the trajectory set by the new rate of melt, however, there will be no Arctic icecap in the next five to 15 years" (Flannery, 2006).

Dr Wieslaw Maslowski of the Naval Postgraduate School, whose research utilizes US military submarine mapping of the Arctic sea-ice over many decades and focuses on modelling the processes of Arctic sea-ice loss, projected a blue Arctic Ocean free of sea-ice by the summer of 2013 (Revkin, 2007), the main reason being that the modelled thickness and volume appear to be decreasing at a much faster rate than the satellite-derived ice extent (Maslowski, 2007). Maslowski's work suggests the sea-ice is significantly being thinned by the northward heat flux of warm summer Pacific and Atlantic waters, not just higher air temperatures (Maslowski, Clement et al., 2006). The polar icecap this year floated in water about 3.5°C warmer than its historical mean (Perovich, Richter-Menge et al., 2007). The reason for the northward oceanic heat fluxes may in part be explained by the US National Oceanic and Atmospheric Administration's (NOAA) Arctic report card for 2007 which found that a new wind circulation pattern is blowing more warm air towards the North Pole than in the twentieth century, and that in 2007 winter and spring temperatures were "all above average throughout the whole Arctic and all at the same time", unlike in previous years (NOAA, 2007; BBC, 2007).

When the ice becomes sufficiently thin it will be sensitive to a "kick" from natural climate variations such as stronger wind/wave surge action that will result in rapid loss of the remaining summer ice cover. And the news gets worse. Louis Fortier, scientific director of the Canadian research network ArcticNet, says the worst-case scenarios about sea-ice loss are coming true and the Arctic Ocean could be ice-free in summertime as soon as 2010 (Young, 2007). Maslowski told the December 2007 conference of the AGU that "our projection of 2013 for the removal of ice in summer is not accounting for the last two minima, in 2005 and 2007... So given that fact, you can argue that may be our projection of 2013 is already too conservative" (Amos, 2007c). NASA climate scientist Jay Zwally told the same conference that after reviewing recent data, he concluded that "the Arctic Ocean could be nearly ice-free at the end of summer by 2012" (Beck, 2007a), while NASA's Josefino Comiso said: "I think the tipping point for perennial sea-ice has already passed... It looks like [it] will continue to decline and there's no hope for it to recover" (Inman, 2007). NASA satellite data shows the remaining Arctic sea-ice is unusually thin, making it more likely to melt in future summers. Combining the shrinking sea-ice area with the new thinness of the remaining ice, it is calculated that the overall volume of ice has fallen by half since 2004 (Borenstein, 2007).

In addition, it now appears that winter sea-ice is not resetting fully. Mark Serreze told the AGU meeting that "We had always thought, that at least in the early stages of climate warming, that the Arctic sea-ice would recover in the autumn" because "after all even with the globally warmed world, winter happens in the Arctic, we'll still have refreeze of that ice," but "what we're starting to see is that winter ice is not recovering any more... We see that at the end of November we have two-million square kilometres less ice than we should have in a typical year" (ABC, 2007c).

"The reason so much [of the Arctic ice] went suddenly is that it is hitting a tipping point that we have been warning about for the past few years," says NASA's James Hansen, who has repeatedly warned that the "'Albedo-flip' trigger mechanism over large portions" of ice sheets could lead to "eventual non-linear ice sheet disintegration". Germany's Potsdam Institute for Climate Impact Research says Arctic sea-ice has "already tipped"; while Paal Prestrud of Oslo's Center for International Climate and Environmental Research says "I'd say we are reaching a tipping point or are past it for the ice. This is

a strong indication that there is an amplifying mechanism here” (Doyle, 2007; Hansen, 2007a).

Both publicly and privately, many cryosphere climate scientists are alarmed at these developments, with one correspondent acknowledging in a recent private communication “that we are in a lot more climate trouble than we thought”. Similar sentiments have been expressed by Australian climate scientists, who privately acknowledge that the whole question of dangerous climate change, caps and mitigation strategies now needs urgent review and that much of the orthodoxy is now out of date. What constitutes dangerous climate change must be and is being urgently reviewed.

The Arctic floating sea-ice is headed towards rapid summer disintegration as early as 2013, a century ahead of the IPCC projections... climate change impacts are happening at lower temperature increases and more quickly than projected.

The central point is that the Arctic is now irreversibly headed towards total summer sea-ice loss very quickly and way beyond the expectation of the IPCC (Figure 1), whose Arctic scenarios are no longer credible, and of most scientists’ views of only two to three years ago. This climate system non-linearity should reinforce the need for strict adherence to risk aversion and the precautionary principle in assessing what is likely to constitute

dangerous human interference, and how we should respond in constructing emission scenarios and policies to avoid it.

In a lecture at the Royal Society on 29 October 2007, the environmental scientist James Lovelock told his audience that “The positive feedback on heating from the melting of floating Arctic and Antarctic ice alone is causing an acceleration of system-driven heating whose total will soon or already be greater than that from all of the pollution carbon dioxide (CO₂) that we have so far added” (Lovelock, 2007); an analysis being prepared for peer-reviewed publication. While it may be tempting to dismiss his back-of-the-envelope calculation, Lovelock’s credentials as a scientist¹ suggest that this deeply disturbing observation should at least be critically considered.

NASA’s James Hansen coined the phrase “albedo flip” to describe a rapid change or “flip” in the climate which occurs when large areas of ice sheets are lost as a consequence of human-induced warming. In relation to climate, albedo is a measure of the proportion of solar radiation which is reflected (rather than absorbed) when it hits the Earth’s surface. White ice reflects most of the radiation (with an albedo of 0.8–0.9) whereas as dark surfaces such as bitumen or dark sea can have an albedo of less than 0.1. The Earth’s average albedo is 0.3. So when light-reflecting ice sheets are lost and replaced by dark sea, rock surface or green vegetation, the Earth suddenly absorbs a lot more solar radiation and the region can heat rapidly. And the heating causes more regional ice sheet disintegration in a classic “positive feedback”. This is what is now occurring in the Arctic. And the eventual consequence is higher global temperatures as well, which may be estimated at around 0.3°C.²

Thus 2007 summer Arctic Ocean surface temperatures were much warmer than in previous years by up to by 5°C, largely the result of solar heating of the upper ocean as less cloud cover increased the albedo feedback. “That feedback is the key to why the models predict that the Arctic warming is

¹ He developed the scientific design of worked for space exploration instruments for NASA , invented the kitchen microwave, designed the electron capture detector, discovered the ozone hole, and developed the Gaia theory of earth system science.

² As the ice is lost and regional temperatures increase, the atmosphere holds more water vapour, cloud cover increases and this “negative feedback” reduces the ice albedo effect because less sun hits the surface. Thus general climate models show that the cloud feedback can “damp or delay the climate system’s response” but that “that surface [ice loss] albedo changes far outweigh the influence of cloud changes” (Tremblay, Holland et al., 2007; Holland and Bitz, 2003). There are no general climate model studies which specifically address the question of the likely global temperature increase as a consequence of the total loss of the Arctic sea ice and its albedo effect. Based on Parkinson, Rind et al. (2000) who find a 0.0107C warming for every 1% of ice sheet loss, and taking the Arctic sea-ice extent to be ~30% of total ice cover, we use 0.3°C as being the global temperature increase from total Arctic sea-ice loss. A higher figure may be more consistent with recent evidence including typical temperature flips in glacial–interglacial cycles. On the other hand, there is a small chance that later this century an abrupt change in the North Atlantic thermohaline circulation (the “Gulf Stream”) caused by global warming could generate a strong cooling effect along the Norwegian coast leading to the re-establishment of year-round Arctic sea-ice cover.

Figure 1: Arctic sea ice summer extent loss compared to IPCC projections

Arctic ice extent loss to September 2007 compared to IPCC modelled changes using the SRES A2 scenario. September loss data from satellite observations. Data smoothed with a 4th order polynomial to smooth out the year-to-year variability. Chart courtesy Dr Asgeir Sorteberg, Bjerknes Centre for Climate Research and University Center at Svalbard, Norway. Date: 23 September 2007
www.carbonequity.info/images/seai07.jpg

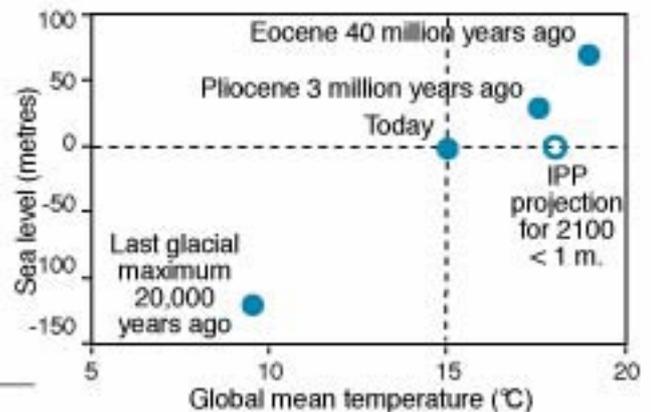
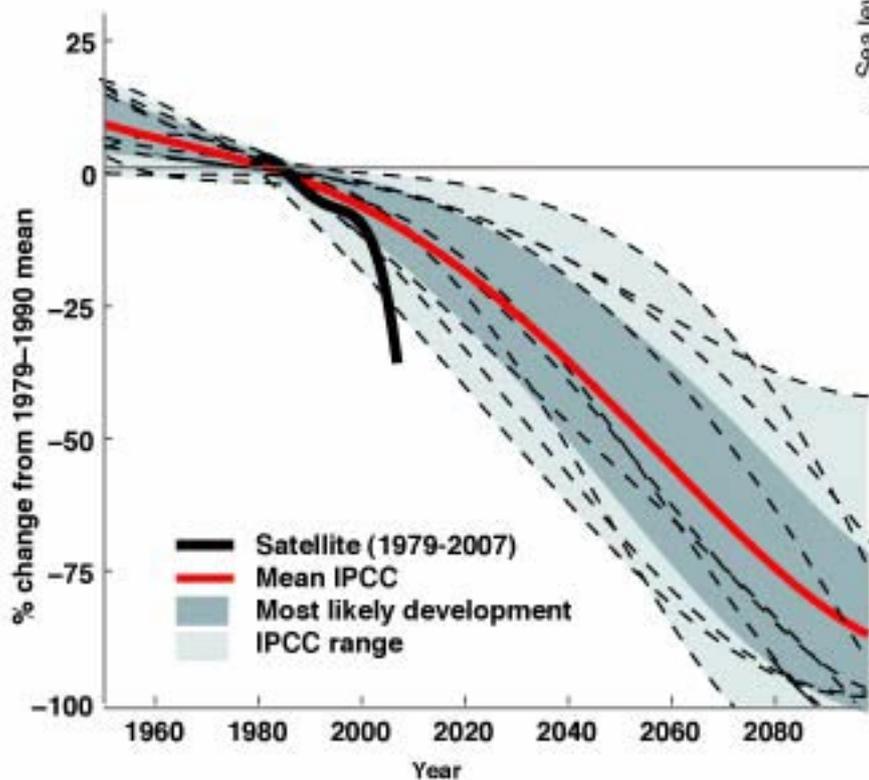
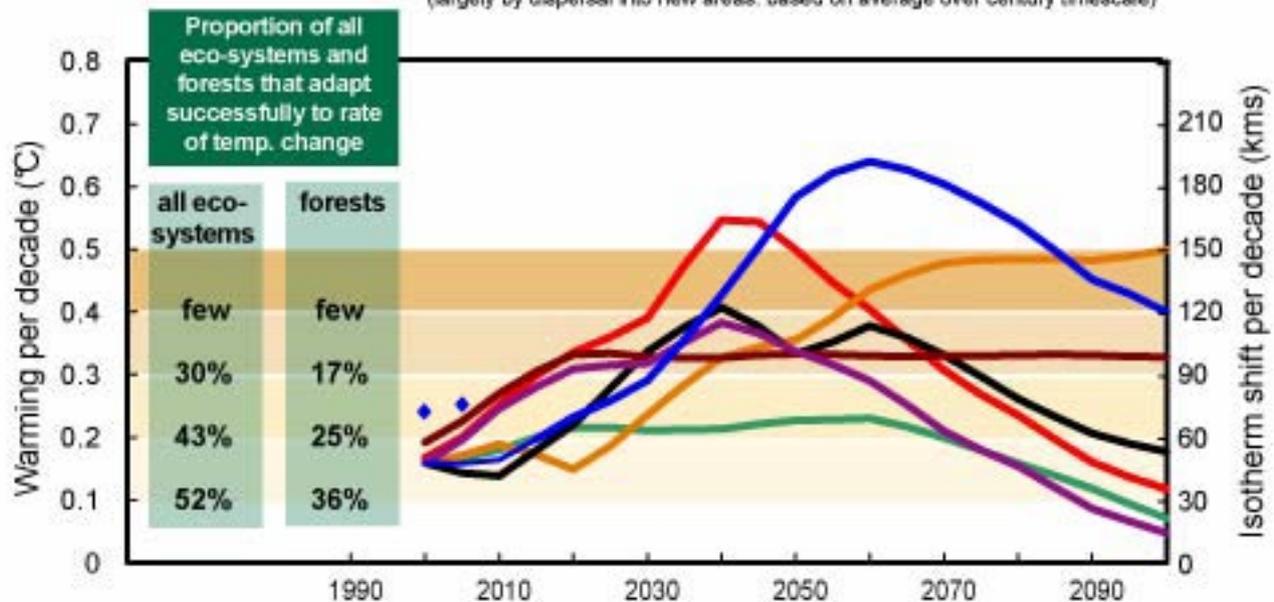


Figure 2: Mean global temperature and sea level

Mean global temperature and sea level (relative to today's) at different times in Earth's history, with the projection for the year 2100 (1m. above today's sea level). For the long term a much higher sea-level rise must be expected than that predicted for 2100 by the IPCC. Source: Rahmsdorf 2007, after Archer 2006.

Figure 3: Speed of temperature change and capacity of ecosystems to adapt

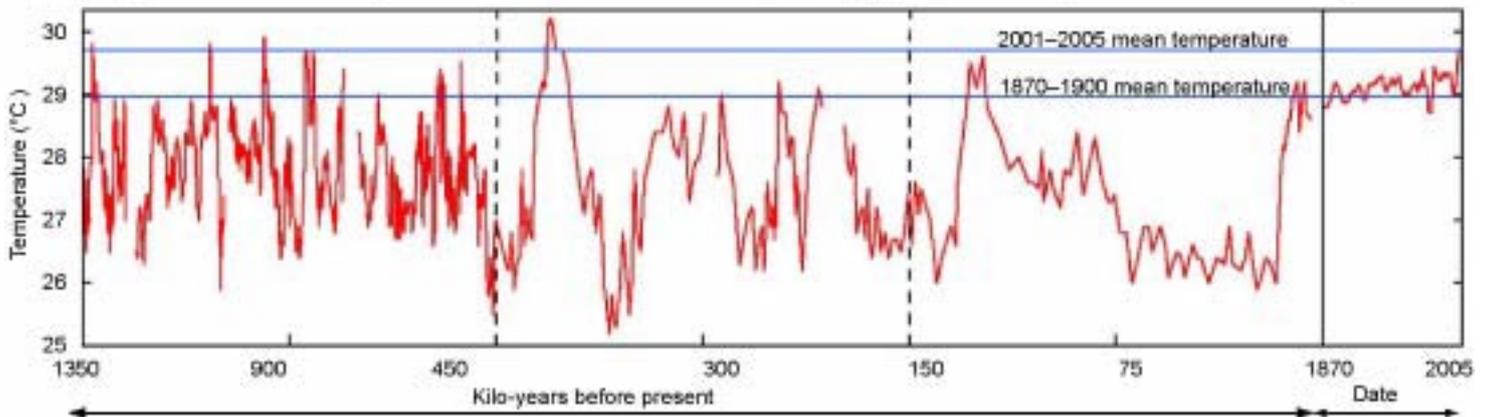
(largely by dispersal into new areas; based on average over century timescale)



- A1 is rapid growth, population peaks mid-century, global economic development:
- A1F1 - fossil-fuel intensive
- A1B - balanced energy across sources
- A1T - non-fossil energy sources
- A2 - self-reliance, population continues to increase, regional economic development
- B1 - as per A but service/info. economy, clean technologies, sustainability and equity
- B2 - intermediate levels of development and technological change
- VUT mid-range - adjusting for underestimation of Asian economic growth
- ◆ Observations

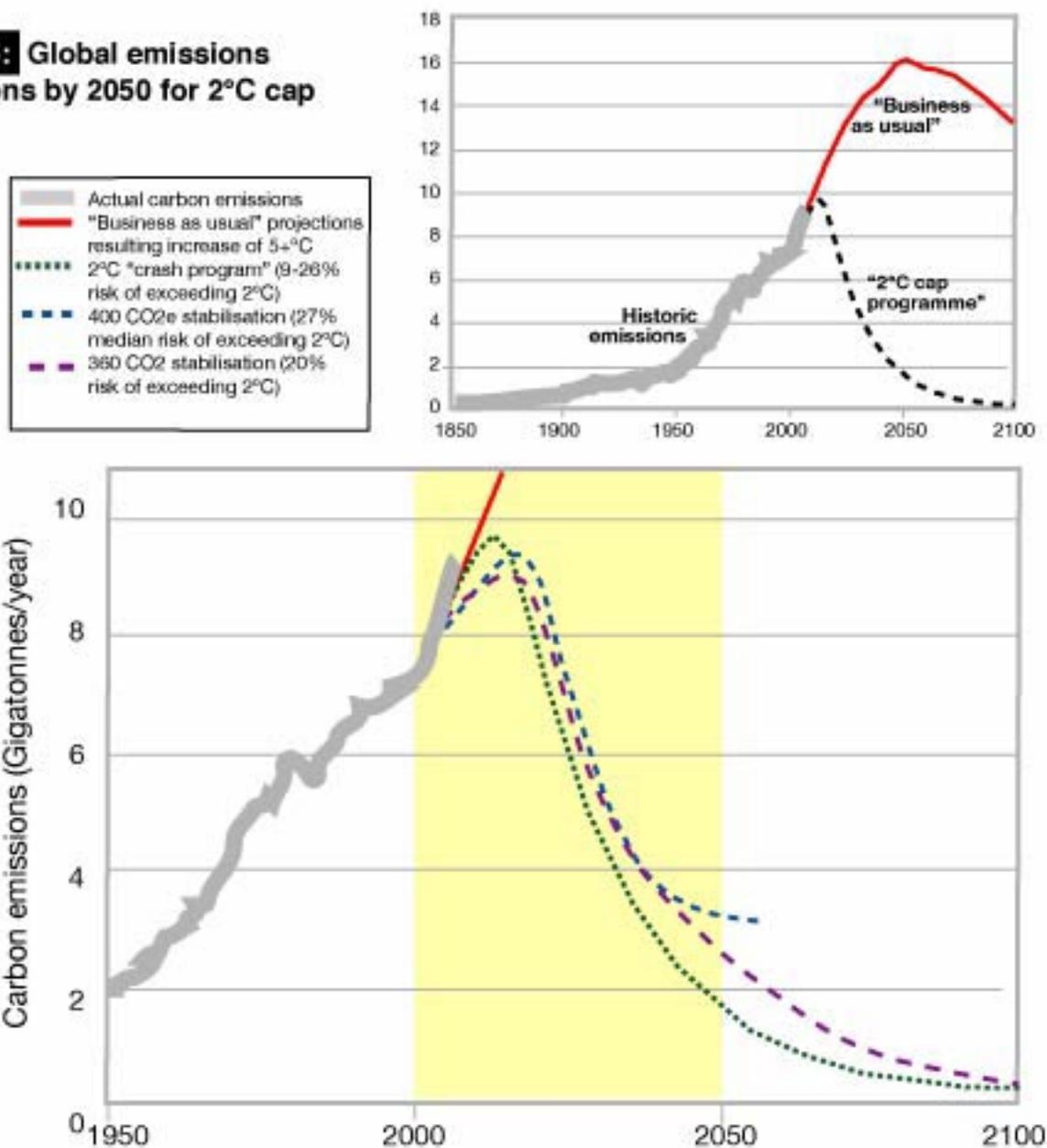
Sources: Adaption rates - Leemans & Eickhout "Another reason for concern: regional and global impacts on ecosystems for different levels of climate change", Global Environment Change 14 (2004) 219-228; Rates of change - Sheehan & Jones "Emissions scenarios - how are they tracking globally", paper to Gamaut Review forum, 13 November 2007, www.gamautreview.org.au

Figure 4: West Equatorial Pacific sea surface temp. (0.3°N, 159.4°E) over the last 1.35 million years



SST in Pacific Ocean Warm Pool in past millenium, recent time scale expanded. Data after 1880 is 5-year mean. Source: Medina-Elizade and Lea, Science Express, 13 October 2005; data for 1880-1981 based on Rayner et al., JGR, 108, 2003, after 1981 on Reynolds & Smith, J. Climate, 7, 1994.

Figure 5: Global emissions reductions by 2050 for 2°C cap



Sources: Historic emissions/BAU path: GCP Report No 5/2006 www.globalcarbonproject.org. BAU based on 2001 IPCC report scenario. 2°C "crash program" path: Athanasiou, T., S. Kartha, P. Baer, 2006, "Greenhouse Development Rights", EcoEquity/Christian Aid (www.ecoequity.org) 400ppm CO₂e stabilisation: Meinshausen, M. (2006), "On the Risk of Overshooting 2°C" (www.stabilisation2005.com/14_Malte_Meinshausen.pdf) 360ppm CO₂ stabilisation: Retzlack, S. (2005) "Setting a long-term climate objective: A paper for the International Climate Change Taskforce", Institute for Public Policy Research, www.ippr.org Note: Meinshausen's long-term stabilisation at 400ppm CO₂e has a peak of approx 480ppm CO₂e, which is very similar to James Hansen's peak of 450pp CO₂ with declining non-CO₂ forcings.

going to be faster,” NASA’s Jay Zwally told the 2007 AGU meeting. “It’s getting even worse than the models predicted” (Borenstein, 2007).

And then there are the questions as to quantity of methane and CO₂ that will be released as areas of permafrost in the polar north defrost as a consequence of rapid regional warming.

One initial estimate is that CO₂ released from permafrost may contribute an extra 0.7°C over the next 100 years, relative to IPCC A2 scenario warming of 3–4°C, but there is uncertainty depending on how much extra positive feedback is included, for example from water vapour, how much permafrost is thawed and how much carbon is released. This figure is a conservative estimate because it does not include the warming effect of methane release (Raupach and Canadell, 2008).

It is time to take a deep breath:

- Human emissions have so far produced a global average temperature increase of 0.8°C.
- There is another 0.6°C to come due to “thermal inertia”, or lags in the system³, taking the total long-term global warming induced by human emissions *so far* to 1.4°C.
- If human total emissions continue as they are to 2030 (and don’t increase 60% as projected) this would likely add more than 0.4°C to the system in the next two decades, taking the long-term effect by 2030 to at least 1.7°C. (A 0.3°C increase is predicted for the period 2004–2014 alone by Smith, Cusack et al., 2007.)
- Then add the 0.3°C albedo flip effect from the now imminent loss of the Arctic sea-ice, and the rise *in the system* by 2030 is at least 2°C, assuming very optimistically that emissions don’t increase at all above their present annual rate! When we consider the potential permafrost releases and the effect of carbon sinks losing capacity (section 1.5 below), we are on the road to a hellish future, not for what we will do, but for *what we have already done*.

We have *already* created the conditions for extremely dangerous climate change, change that will induce further, and possibly uncontrollable, feedback.

If Lovelock is even half correct, the Arctic summer of 2007 really does demand that we look in anxious detail at its consequences. The impacts of sea-ice loss and Arctic warming are affecting the permafrost in Siberia, Alaska and other regions, triggering caribou decline in Canada, and “shrubifying” the tundra. “What happens in the Arctic actually does not stay in the Arctic,” says Richard Spinrad of the NOAA (AP, 2007). And that includes the Greenland ice sheet.

1.3 The fate of the Greenland ice sheet

“Climate change is... happening faster than the models predicted it would.” — Barrie Pittock, senior CSIRO climate scientist, 13 August 2007 (Peddie, 2007).

Global warming so far has been greatest in the high latitudes of the northern hemisphere, particularly in the sub-Arctic boreal forests of Siberia and North America (ACIA, 2005). Arctic temperatures will rise much more quickly than the global average; for a global warming of 2°C⁴, the area-mean annual temperature increase over the Arctic (60–90°N) is likely to be between 3.2°C and 6.6°C (0.45°C to 0.75°C per decade, and possibly even as large as 1.55°C per decade) (New, 2006).

The view that a 2°C global temperature increase will be hard to avoid is widespread: from Nicholas Stern (Stern, 2006a) to the co-chair of the IPCC’s impacts working group, Martin Parry (Adam, 2007b). If the likely Arctic sea-ice “albedo flip” is taken into account, we are already just about there without adding one more tonne of human emissions to the atmosphere. But well before 2°C average global warming, a high momentum melting of much of the Greenland ice sheet will be underway (Hansen,

³ Of the temperature effects produced by rising CO₂ levels, only about half are manifested as rising temperatures within 25 years, another quarter takes 150 years, and the last quarter many centuries to manifest. This is because much of the heat (or thermal) imbalance is being used to warm the deep oceans. Once that process is complete, more of the heat will be applied to warming the atmosphere. Currently the earth has a thermal imbalance of approx 0.85 W/m² (watts per sq. metre) ± .15 w/m² (Hansen 2005a). The forcing is approx 0.75°C per W/m² ± 0.25°C (Hansen 2005b), so the imbalance is 0.85 X 0.75 ≈ 0.6°C

⁴ Unless otherwise specified, temperature increases are from the 1750 pre-industrial level. The increase was 0.7°C to 2000 and 0.8°C to 2006. CO_{2e} refers to CO_{2e} (total) not CO_{2e} (Kyoto) unless specified.

2005a). Greenland's critical melt threshold is a regional temperature rise of 2.7°C (Gregory, Huybrechts et al., 2004), but with Arctic regional temperature increases at least 2.2 times the global average (Chylek and Lohmann, 2005), that point will have been triggered at just over a 1°C global rise. Yet, alarmingly, a global rise of 1.7–2°C is already in the system.

Nevertheless, the 2001 IPCC reports suggested that neither the Greenland nor Antarctic ice sheets would lose significant mass by 2100. The final IPCC report for 2007 said that “uncertainties... in the full effects of changes in ice sheet flow” contributed to an unwillingness to put an upper bound on sea-level rises this century, then noted that “partial loss of ice sheets on polar land could imply metres of sea-level rise... such changes are projected to occur over millennial time scales, but more rapid sea level rise on century time scales cannot be excluded” and then suggested that the Greenland ice sheet would be virtually eliminated and result in a sea level rise of seven metres if “global average warming were sustained for millennia in excess of 1.9 to 4.6°C” (IPCC, 2007c).

The loss of the Arctic “100 years ahead of schedule” raises two questions of significance about the Greenland ice sheet: what will be the effect on the timing of the Greenland tipping point; and what will be the effect on the rate of ice volume loss from Greenland which, if fully achieved, would raise the global sea level by five to seven metres?

Before the full extent of the dramatic Arctic sea-ice loss for 2007 was known, Tim Lenton of the University of East Anglia told a Cambridge conference that “we are close to being committed to a collapse of the Greenland ice sheet”. And in recognition of the limits of climate science models, statistician Lenny Smith told the same conference that “we need to drop the pretence that [the models] are nearly perfect”, that there were “too many unknown unknowns” and “we need to be more open about our uncertainties” (Pearce 2007b). Tipping points may be looming, and we may not even be aware that they are at hand. Is Greenland such a case?

Rising Arctic regional temperatures resulting from sea-ice loss and the albedo effect are already at “the threshold beyond which glaciologists think the (Greenland) ice sheet may be doomed”; this accelerated melting “is caused by meltwater penetrating crevasses and lubricating the glaciers’ flow... The ice is in effect sliding into the ocean on rivers of water,” a process not included in models of Arctic global warming (New Scientist, 2006). Some Greenland glacier velocities have increased more than twofold. The Jacobshavn Glacier, a major Greenland outlet glacier draining roughly 8% of the ice sheet, has sped up nearly twofold in the last decade.

A recent study found that the Greenland ice cap “may be melting three times faster than indicated by previous measurements” and that “the mass loss is increasing with time” (Young, 2006). Greenland experienced more days of melting snow in 2006 than the island had averaged over recent decades (Saupe, 2007); the area experiencing at least one day of melting has been increasing since 1992 at a rate of 35,000 square kilometres per year (Tedesco, 2007); and melt extent for 2007 was the largest recorded since satellite measurements began in 1979, beating the old record set in 2005 by 10%. The edges of the ice-sheet are melting up to ten times more rapidly than earlier research had indicated, and the ice sheet height is falling by up to ten metres a year (Shukman, 2007). Air temperatures on the Greenland ice sheet have increased by 4°C since 1991, and the increasing trend in the total area of bare ice subject to at least one day’s melting per year is unmistakable at 13% per year (Steffen, Huff et al., 2007). Steffen said the ice loss trend in Greenland is somewhat similar to the trend of Arctic sea-ice in recent decades, suggesting the rate of loss may be increasing exponentially.

As well, the Greenland ice cap is melting so quickly that it is triggering earthquake-like tremors as the ice sheet itself cracks into huge pieces several cubic kilometres in size as it scrapes across the bedrock, and there is “a massive acceleration of the speed with which these glaciers are moving into the sea” (Brown, 2007). Another indication of Greenland’s shrinking ice cap is evidence that its landmass is rising up to 4 cm per year, a buoyancy produced by carrying less weight of ice (Brahic, 2007d).

James Hansen notes that “ice sheet disintegration starts slowly but multiple positive feedbacks can lead to rapid non-linear collapse” and that “equilibrium sea level rise for ~3°C warming (25±10 m = 80 feet) implies the potential for us to lose control” because “we cannot tie a rope around a collapsing ice sheet” (Hansen 2006a, Hansen 2006b).

At this point there is a methodological problem; climate scientists have had difficulty modelling ice-sheet streams and dynamics (Oppenheimer and Alley, 2004). Robert Corell, a US-based Arctic scientist and member of the IPCC, says of Greenland: “Nobody knows now how quickly it will melt... This is

all unprecedented in the science... Until recently we didn't believe it possible, for instance, for water to permeate a glacier all the way to the bottom. But that's what's happening. As the water pools, it opens more areas of ice to melting" (Hilton, 2007). With the uncertainty and lack of verifiable projections, at an official level little is said, or what is said is dangerously conservative. This is what the 2007 IPCC report did in regard to sea-level rises, where its projection of a 18–59 cm rise by 2100 was based on models which do not "include the potential for increasing contributions from rapid dynamic processes in the Greenland and West Antarctic ice sheets, which have already had a significant effect on sea level over the past 15 years and could eventually raise sea level by many meters. Lacking such processes, models cannot fully explain observations of recent sea level rise, and accordingly, projections based on such models may seriously understate potential future increases" (Oppenheimer, O'Neill et al., 2007).

But the lack of tested projections is not to say that large parts of Greenland may not have already passed their "tipping point", just because there are not strict, verifiable models to support the assertion. The same was true of the Arctic sea-ice, which was why the limitations of the current science meant that there was a failure to predict the events until they were all but upon us, at which point most scientists who had speculated as to what was about to happen were "shocked" at the sea-ice loss in the northern summer of 2007.

Thus James Hansen identifies a "scientific reticence" that "in at least some cases, hinders communication with the public about dangers of global warming... Scientific reticence may be a consequence of the scientific method. Success in science depends on objective scepticism. Caution, if not reticence, has its merits. However, in a case such as ice sheet instability and sea level rise, there is a danger in excessive caution. We may rue reticence, if it serves to lock in future disasters" (Hansen, 2007a).

But there are useful sources other than models for thinking about the likely future rate of loss of the Greenland ice sheet, including expert elicitations and paleoclimatology. In response to the deep concerns about the 2007 IPCC Working Group I Summary for Policymakers, it has been proposed that the base of inputs be broadened "to give observational, paleoclimatic, or theoretical evidence of poorly understood phenomena comparable weight with evidence from numerical modelling. In areas in which modelling evidence is sparse or lacking, IPCC sometimes provides no uncertainty estimate at all. In other areas, models are used that have quantitatively similar structures, leading to artificially high confidence in projections (e.g., in the sea-level, ocean circulation, and carbon-cycle examples above). One possible improvement would be for the IPCC to fully include judgments from expert elicitations" (Oppenheimer, O'Neill et al., 2007).

One expert opinion suggests: "Could the Greenland ice sheet survive if the Arctic were ice-free in summer and fall? It has been argued that not only is ice-sheet survival unlikely, but its disintegration would be a wet process that can proceed rapidly. Thus an ice-free Arctic Ocean, because it may hasten melting of Greenland, may have implications for global sea level, as well as the regional environment, making Arctic climate change centrally relevant to definition of dangerous human interference" (Hansen, Sato et al., 2007a). Off the record, Arctic climate researchers will say this is not an unreasonable view; on the record they will say there are no verifiable models which produce this result. These statements are not in contradiction.

The rapid loss of Arctic sea-ice will speed up the disintegration of the Greenland ice sheet, and a rise in sea levels by even as much as 5 metres this century is possible.

So, for example, Eric Rignot, a lead author of a paper (Rignot and Kanagaratnam, 2006) showing a doubling of loss from the Greenland ice sheet over a decade, was moved to comment that "These results absolutely floored us... The glaciers are sending us a signal. Greenland is probably going to contribute more and faster to sea-level rise than predicted by current models" (New Scientist, 2006). Another informed opinion comes from Robert

Correll who reports, as mentioned above, that the Greenland ice cap is melting so quickly that it is triggering earthquakes as large pieces of ice break off, such that "scientists monitoring events this summer say the acceleration could be catastrophic in terms of sea-level rise and make predictions this February by the IPCC far too low" (Brown, 2007).

As for the paleoclimate record, global average temperatures have now surpassed those that thawed much of Greenland's ice cap some 130,000 years ago (Figure 4), when the planet last enjoyed a balmy

respite from continent-covering glaciers, and seas were five to six metres higher than today. Global warming appears to be pushing vast reservoirs of ice on Greenland and Antarctica toward a significant long-term meltdown, and the world may have as little as a decade to take the steps to avoid this scenario (Spotts, 2006; Hansen, 2005a; Hansen, Sato et al., 2006).

Following the extraordinary Arctic summer of 2007 and new data, a number of leading climate scientists have spoken out, most notably at the December 2007 AGU meeting, where amongst others James Hansen said that the Earth has hit one of its “tipping points”, based on Greenland melt data, and that *today’s level of CO₂* in the atmosphere is enough to cause Arctic sea-ice cover and massive ice sheets such as on Greenland to eventually melt away (Borenstein, 2007).

To recap, it is reasonable to expect very rapid loss of the Arctic sea-ice, with a significant impact on regional temperatures due to the albedo effect. It is also reasonable to expect, as a consequence, an acceleration of the rate of loss of the Greenland ice sheet, which may already be at or near its disintegration tipping point for a large part of the ice sheet, a situation that was previously not expected for a long time. Whatever generation it befalls, the impact will be catastrophic, and our only hope to avoid it is through an emergency response, right now. The precautionary principle suggests that we fully take into account the likelihood of these outcomes, especially for their wider impact on the climate system and global temperatures (NASA, 2007), and on the sea-level rise the loss of the Greenland ice sheet will produce, perhaps in as little as a century or so.

1.4 A 5-metre sea-level rise by 2100?

“Often, scientists do not like to release their results until they are confident of the outcome. Important decisions need to be made now and cannot wait another five to seven years. Scientists will have to leave their comfort zone and communicate their findings on emerging risks, even when scientific confidence in those findings may be low... Sometimes, it is worth taking some risks in the short term to avoid worse risks down the track. We have spent too long being risk-averse about short-term costs and ignored the benefits of avoiding long-term damages.” — Roger Jones, CSIRO Principal Research Scientist, December 2007 (Jones, 2007b)

The 2007 IPCC report’s suggestion of a sea-level rise by 2100 of 0.18–0.59 m (IPCC, 2007a) was greeted with dismay by many climate scientists. Before the report was released, satellite data showed that sea levels had risen by an average of 3.3 mm per year between 1993 and 2006, whereas the 2001 IPCC report, in contrast, projected a best-estimate rise of less than 2 mm per year (Brahic, 2007a). In late 2006, research concluded that previous estimates of how much the world’s sea level will rise as a result of global warming may have seriously underestimated the problem (Ramsdorf, Cazenave et. al, 2007) (Figure 2). Lead researcher Steve Rahmstorf said the data now available “raises concerns that the climate system, in particular sea level, may be responding more quickly than climate models indicate” (Chandler, 2006). Chairman of the Arctic Climate Change Impact Assessment, Robert Corell, said before the IPCC’s first report for 2007 was released in February that any prediction of a sea-level rise of less than a metre would “not be a fair reflection of what we know” (Pearce, 2007c).

In the IPCC synthesis report released on 16 November 2007, a qualification appeared that “because understanding of some important effects driving sea level rise is too limited, this report does not assess the likelihood, nor provide a best estimate or an upper bound for sea level rise” and the official projected rise of sea level rises of 0.18–0.59 m this century does “not include uncertainties in climate-carbon cycle feedbacks nor the full effects of changes in ice sheet flow, therefore the upper values of the ranges are not to be considered upper bounds for sea level rise” (IPCC, 2007c). Which begs the question as to why the official projections were included at all if, in this innovative turn of phrase, “the upper values of the ranges are not to be considered upper bounds”.

So how much will sea levels rise this century, and in particular, at what rate will the Greenland and West Antarctic ice sheets disintegrate, and what influence will the “premature” loss of the Arctic sea-ice have on Greenland’s rate of loss? This question has caused turmoil in scientific circles, because there is a general acknowledgement that it will be a good deal higher than the early-2007 IPCC report suggests, but there are no reliable ice-sheet disintegration models. However, this topic is now the subject of urgent collaborative work between a number of US agencies and research centres.

The lead in this discussion has been taken by James Hansen and his collaborators in a number of

recent, peer-reviewed papers (Hansen, 2005a; Hansen & Sato, 2007; Hansen, 2007a; Hansen, Sato, et al., 2007a), in which their essential argument, based on the paleoclimate record, is that the sea-level rise is likely to be about five metres this century if emissions continue down the “business as usual” trajectory. Here is the core of Hansen’s expert opinion [all warmings in this quoted material are relative to the temperature in 2000]:

I find it almost inconceivable that “business as usual” climate change will not result in a rise in sea level measured in meters within a century... Because while the growth of great ice sheets takes millennia, the disintegration of ice sheets is a wet process that can proceed rapidly.

... the primary issue is whether global warming will reach a level such that ice sheets begin to disintegrate in a rapid, non-linear fashion on West Antarctica, Greenland or both. Once well under way, such a collapse might be impossible to stop, because there are multiple positive feedbacks. In that event, a sea level rise of several meters at least would be expected.

As an example, let us say that ice sheet melting adds 1 centimeter to sea level for the decade 2005 to 2015⁵, and that this doubles each decade until the West Antarctic ice sheet is largely depleted. This would yield a rise in sea level of more than 5 meters by 2095.

Of course, I cannot prove that my choice of a 10-year doubling time is accurate but I’d bet \$1000 to a doughnut that it provides a far better estimate of the ice sheet’s contribution to sea level rise than a linear response. In my opinion, if the world warms by 2°C to 3°C, such massive sea level rise is inevitable, and a substantial fraction of the rise would occur within a century. “Business as usual” global warming would almost surely send the planet beyond a tipping point, guaranteeing a disastrous degree of sea level rise.

Although some ice sheet experts believe that the ice sheets are more stable, I believe that their view is partly based on the faulty assumption that the Earth has been as much as 2 °C warmer in previous interglacial periods, when the sea level was at most a few meters higher than at present. There is strong evidence that the Earth now is within 1 °C of its highest temperature in the past million years. Oxygen isotopes in the deep-ocean fossil plankton known as foraminifera reveal that the Earth was last 2°C to 3°C warmer around 3 million years ago, with carbon dioxide levels of perhaps 350 to 450 parts per million. It was a dramatically different planet then, with no Arctic sea-ice in the warm seasons and sea level about 25 meters higher, give or take 10 meters.

There is not a sufficiently widespread appreciation of the implications of putting back into the air a large fraction of the carbon stored in the ground over epochs of geologic time. The climate forcing caused by these greenhouse gases would dwarf the climate forcing for any time in the past several hundred thousand years — the period for which accurate records of atmospheric composition are available from ice cores.

Models based on the “business as usual” scenarios of the Intergovernmental Panel on Climate Change (IPCC) predict a global warming of at least 3 °C by the end of this century. What many people do not realise is that these models generally include only fast feedback processes: changes in clouds, water vapour and aerosols. Actual global warming would be greater as slow feedbacks come into play: increased vegetation at high latitudes, ice sheet shrinkage and further greenhouse gas emissions from the land and sea in response to global warming.

The IPCC’s latest projection for sea level rise this century is 18 to 59 centimeters. Though it explicitly notes that it was unable to include possible dynamical responses of the ice sheets in its calculations, the provision of such specific numbers encourages a predictable public belief that the projected sea level change is moderate, and indeed smaller than in the previous IPCC report. There have been numerous media reports of “reduced” predictions of sea level rise, and commentators have denigrated suggestions that “business as usual” emissions may cause a sea level rise measured in meters. However, if these IPCC numbers are taken as predictions of actual sea level rise, as they have been by the public, they imply that the ice sheets can miraculously survive a “business as usual” climate forcing assault for a millennium or longer.

There are glaciologists who anticipate such long response times, because their ice sheet models have been designed to match past climate changes. However, work by my group shows that the typical 6000-year timescale for ice sheet disintegration in the past reflects the gradual changes in Earth’s orbit that

⁵ This is a conservative starting point and one-third of the observed current rate.

drove climate changes at the time, rather than any inherent limit for how long it takes ice sheets to disintegrate. Indeed, the paleoclimate record contains numerous examples of ice sheets yielding sea level rises of several meters per century when forcings were smaller than that of the “business as usual” scenario. For example, about 14,000 years ago, sea level rose approximately 20 meters in 400 years, or about 1 meter every 20 years.

There is growing evidence that the global warming already under way could bring a comparably rapid rise in sea level. The process begins with human-made greenhouse gases, which cause the atmosphere to be more opaque to infrared radiation, thus decreasing radiation of heat to space. As a result, the Earth is gaining more heat than it is losing: currently 0.5 to 1 watts per square meter. This planetary energy imbalance is sufficient to melt ice corresponding to 1 meter of sea level rise per decade, if the extra energy were used entirely for that purpose — and the energy imbalance could double if emissions keep growing.

So where is the extra energy going? A small part of it is warming the atmosphere and thus contributing to one key feedback on the ice sheets: the “albedo flip” that occurs when snow and ice begin to melt. Snow-covered ice reflects back to space most of the sunlight striking it, but as warming air causes melting on the surface, the darker ice absorbs much more solar energy. This increases the planetary energy imbalance and can lead to more melting. Most of the resulting meltwater burrows through the ice sheet, lubricating its base and speeding up the discharge of icebergs to the ocean.

The area with summer melt on Greenland has increased from around 450,000 square kilometers when satellite observations began in 1979 to more than 600,000 square kilometers in 2002. Seismometers around the world have detected an increasing number of earthquakes on Greenland near the outlets of major ice streams. The earthquakes are an indication that large pieces of the ice sheet lurch forward and then grind to a halt because of friction with the ground. The number of these “ice quakes” doubled between 1993 and the late 1990s, and it has since doubled again. It is not yet clear whether the quake number is proportional to ice loss, but the rapid increase is cause for concern about the long-term stability of the ice sheet.

Additional global warming of 2 °C to 3 °C is expected to cause local warming of about 5 °C over Greenland. This would spread summer melt over practically the entire ice sheet and considerably lengthen the melt season. In my opinion it is inconceivable that the ice sheet could withstand such increased meltwater for long before starting to disintegrate rapidly, but it is very difficult to predict when such a period of large, rapid change would begin.

Summer melt on West Antarctica has received less attention than on Greenland, but it is more important. The West Antarctic ice sheet, which rests on bedrock far below sea level, is more vulnerable as it is being attacked from below by warming ocean water, as well as from above by a warming atmosphere. Satellite observations reveal increasing areas of summer melt on the West Antarctic ice sheet, and also a longer melt season. (Hansen, 2007c)

Hansen’s argument has been put at length here because he is one of the world’s most eminent climate scientists; he has provided a compelling critique of the limitations of the IPCC models; he has helped open a new understanding of the mechanics of rapid, wet ice-sheet disintegration; his views are based on paleoclimate evidence; his views are currently forcing a major rethink about sea-level rises amongst his fellow climate scientists; and there has been little rebuttal of this work. Perhaps most significantly, Hansen, a humble man who has twice testified before Congress on climate change (and endured the Bush administration slashing funding for the NASA Goddard Institute of Space Science because he refused to stop his public advocacy), has staked his formidable professional reputation on this issue. His preparedness to bet “\$1000 to a doughnut” that his view is closer to the mark than the IPCC should not be underestimated as a signifier of his scientific confidence.

The incongruity of the IPCC’s sea-level projection for 2100 can be seen in Figure 2 which illustrates mean global temperature and sea level (relative to today) at different times in Earth’s history, and the IPCC projection for 2100 (outline circle). For the longer-term, the paleoclimatology data suggests a much higher sea-level rise (Archer, 2006) than that projected by the IPCC.

And now with new Arctic data, Hansen has firmed his outlook. He told the December 2007 AGU meeting that there is *already enough carbon in Earth’s atmosphere to ensure that sea levels will rise several feet (metres) in coming decades* because the world decades ago passed the tipping point for major ice sheet loss, including Greenland (Beck, 2007a; Inman, 2007).

1.5 Trouble in the Antarctic

The majority of Antarctic ice is contained in the East Antarctic ice sheet, the biggest slab of ice on Earth, which has been in place for some 20 million years (Pearce, 2007a). Considered more vulnerable is the smaller West Antarctic ice sheet, whose disintegration would raise sea levels by a similar amount to the total loss of the Greenland ice sheet. While it is anticipated that the West Antarctic sheet is more stable at a 1–2°C rise, recent research demonstrates that the southern ice shelf reacts far more sensitively to warming temperatures than scientists had previously believed, based on ice-core data showing that “massive melting” must have occurred in the Antarctic during the Miocene–Pliocene warming three million years ago, when the average global temperature in the oceans increased by only 2–3°C (Schmitt, 2007).

Warming is greatest at the poles, and the air over the West Antarctic peninsula has warmed nearly 6°C since 1950, and a warming sea is melting the ice cap edges with beech trees and grass taking root on the ice fringes (Struck, 2007). Another warning sign was the rapid collapse in March 2002 of the West Antarctic’s 200-metre-thick Larsen B ice shelf, which had been stable for a least 12,000 years. Weakened by water-filled cracks where the shelf attached to the Antarctic Peninsula, “in just three climactic three days at the start of March, the entire structure gave way. Some 500 billion tonnes of ice burst into the ocean” (Pearce, 2007a). Glaciologist Ted Scambos said: “We thought the southern hemisphere climate is inherently more stable” but “all of the time scales seem to be shortened now. These things can happen fairly quickly. A decade or two decades of warming is all you need to really change the mass balance... Things are on more of a hair trigger than we thought” (Struck, 2007).

The Antarctic ice shelf reacts far more sensitively to warming temperatures than previously believed.

Much of the West Antarctic ice sheet sits on bedrock below sea-level, buttressed on two sides by mountains but held in place on the other two sides by the Ronne and Ross ice shelves. So if the ice shelves that buttress the ice sheet disintegrate, sea water breaching the base of the ice sheet will hasten the rate of disintegration.

As early as 1978, the eccentric scientist John Mercer wrote in “Nature” that “I contend that a major disaster — a rapid deglaciation of West Antarctica — may be in progress... within about 50 years”. Mercer said that warming “above a critical level would remove all ice shelves, and consequently all ice grounded below sea level, resulting in the deglaciation of most of West Antarctica”, such disintegration once under way would “probably be rapid, perhaps catastrophically so” with most of the ice sheet lost in a century (Mercer, 1978; Pearce, 2007a). Credited with coining the phrase “the greenhouse effect” in the early 1960s, Mercer’s Antarctic prognosis was widely ignored at the time, but no longer. Another vulnerability of the West Antarctic ice sheet is Pine Island Bay, where two large glaciers — Pine Island and Thwaites — drain about 40% of the ice sheet into the sea. The glaciers are responding to rapid melting of their own ice shelves by doubling their rate of flow and thinning, and the “mass loss” of ice from their catchment has tripled. NASA glaciologist Eric Rignot’s work on the Pine Island glacier leads climate writer Fred Pearce to conclude that “the glacier is primed for runaway destruction”. Pearce also notes the work of Terry Hughes of the University of Maine who says the collapse of the Pine Island and Thwaites glaciers — already the biggest causes of global sea-level rises — could destabilise the whole of the West Antarctic ice sheet; and Richard Alley who says there is “a possibility that the West Antarctic ice sheet could collapse and raise sea levels by 6 yards (5.5 metres) in the next century” (Pearce, 2007a).

NASA scientists concur: “We foresee the gravest threat from the possibility of surface melt on West Antarctica, and interaction among positive feedbacks leading to catastrophic ice loss. Warming in West Antarctica in recent decades has been limited by effects of stratospheric ozone depletion. However, climate projections find warming of nearby ocean at depths that may attack buttressing ice shelves as well as surface warming in the region of West Antarctica. Loss of ice shelves allows more rapid discharge from ice streams, in turn a lowering and warming of the ice sheet surface, and increased surface melt. Rising sea level helps unhinge the ice from pinning points. With GHGs [greenhouse gases] continuing to increase, the planetary energy imbalance provides ample energy to melt ice corresponding to several meters of sea level per century...” (Hansen, Sato et. al, 2007a).

Even in East Antarctica — whose total loss would produce a sea-level rise of 45 metres — mass loss near the coast is greater than the mass increase inland that is being produced by extra snowfall generated by warming induced increases in air humidity.

But long before the Greenland or West Antarctic ice sheets fully disintegrate, even the loss of 20% of Greenland's ice volume would be catastrophic. Nicholas Stern reported that "currently, more than 200 million people live in coastal floodplains around the world, with two million square kilometres of land and one trillion dollars worth of assets less than one metre elevation above current sea level. One-quarter of Bangladesh's population (~35 million people) lives within the coastal floodplain. Many of the world's major cities (22 of the top 50) are at risk of flooding from coastal surges, including Tokyo, Shanghai, Hong Kong, Mumbai, Kolkata, Karachi, Buenos Aires, St Petersburg, New York, Miami and London. In almost every case, the city relies on costly flood defences for protection. Even if protected, these cities would lie below sea level with a residual risk of flooding like New Orleans today. The homes of tens of millions more people are likely to be affected by flooding from coastal storm surges with rising sea levels. People in South and East Asia will be most vulnerable, along with those living on the coast of Africa and on small islands" (Stern, 2006b).

Underground water is the largest reserve of fresh water on the planet, and more than two billion people depend on it. Long before the rising seas inundate the land, aquifers will be contaminated. The 2006 Conference of the International Association of Hydrogeologists heard that rising sea levels will also lead to the inundation by salt water of the aquifers used by cities such as Shanghai, Manila, Jakarta, Bangkok, Kolkata, Mumbai, Karachi, Lagos, Buenos Aires and Lima. "The water supplies of dozens of major cities around the world are at risk from a previously ignored aspect of global warming. Within the next few decades rising sea levels will pollute underground water reserves with salt... Long before the rising tides flood coastal cities, salt water will invade the porous rocks that hold fresh water... The problem will be compounded by sinking water tables due to low rainfall, also caused by climate change, and rising water usage by the world's growing and increasingly urbanised population" (Pearce, 2006a).

Whilst big figures about large sea-level rises may seem abstract, a rise of one metre will have a devastating impact on the densely-populated river deltas in the developing world as homes and agricultural land are lost and damaged by storm surges. In industrialised regions, there will be severe impacts on coastal infrastructure from small rises: loss of beaches, ports and shipping infrastructure, flooding of access and connecting transport links, and the inundation of underground civil services, including sewers, water, electricity transmission and communications, as well as the loss of industrial and domestic buildings.

Half an hour using Google Maps with a sea-level rise overlay (for example, <http://flood.firetree.net/>) is instructive for understanding the lessons from the Arctic summer of 2007.

1.6 The impact of "slow" climate feedbacks

"This higher climate sensitivity, 6°C for doubled CO₂, is the appropriate sensitivity for long time scales, when greenhouse gases are the specified forcing mechanism and all other slow feedbacks are allowed to fully respond to the climate change" — NASA chief climate scientist James Hansen, November 2007 (Hansen, 2007e).

Climate sensitivity refers to the expected increase in global temperature associated with a doubling in the atmospheric concentration of greenhouse gases, from the pre-industrial level of 280 parts per million carbon dioxide equivalent (ppm CO₂e) to 560 ppm CO₂e. Climate sensitivity research has produced quite divergent results, particularly earlier on, but is now widely viewed as being around 3°C, known as the "Charney 3°C" after its first proponent, thirty years ago. The IPCC report uses Equilibrium Climate Sensitivity (ECS) models to conclude that it is "likely to be in the range 2 to 4.5°C with a best estimate of about 3°C, and is very unlikely to be less than 1.5°C. Values substantially higher than 4.5°C cannot be excluded, but agreement of models with observations is not as good for those values" (IPCC, 2007a).

Nevertheless, researchers have found larger possible ranges, for example of 1–10°C and 1.4–7.7°C, and it has been suggested there is a 54% likelihood that climate sensitivity lies outside the IPCC range (Andronova and Schlesinger, 2001). More recently, two researchers found they could not "assign a

significant probability to climate sensitivity exceeding 6°C" (Annan and Hargreaves, 2006), whilst another research team found climate sensitivity "inherently unpredictable" (Hopkin, 2007). A 2005 paper in "Nature" using climate models and various aerosol cooling assumptions found that "best fit" involved a climate sensitivity "in excess of" 6°C and "may be as high as" 10°C (Andreae, Jones et al., 2005; Pearce, 2007a).

A doubling of climate sensitivity would mean we passed the widely accepted 2°C threshold four decades ago, and would require us to find the means to engineer a rapid drawdown of current atmospheric greenhouse gas.

A climate sensitivity of 6°C, if established, would turn climate change policy upside down. The higher the sensitivity, the lower the permissible total emissions to meet a temperature target. At ~3°C sensitivity, atmospheric greenhouse gas levels need to stabilise around 450 ppm CO₂e to have a 50:50 chance of not exceeding 2°C; if sensitivity were established at 6°C, the stabilisation level would be around 350 ppm CO₂e to meet the same target, implying that we have long since passed the threshold of dangerous anthropogenic interference with the climate for a 2°C cap.

Recent research and data indicate that 3°C sensitivity may be too low a figure. The senior CSIRO climate scientist Barrie Pittock suggested in 2006 that the "dated IPCC view might underestimate the upper end of the range of possibilities" and there is "a much higher probability of warmings by 2100 exceeding the mid-level (climate sensitivity) estimate of 3°C". He surveyed recent data which "suggest that critical levels of global warming may occur at even lower greenhouse gas concentrations and/or anthropogenic emissions than was considered justified in the IPCC [2001] report". He elaborates on "at least eight recent developments, largely based on observed changes, [that] point to a higher probability of more serious impacts", including the lessening of global dimming, permafrost melting, biomass feedbacks, Arctic sea-ice retreat, circulation change in mid to high latitudes, rapid changes in Greenland and Antarctica, increasing intensity of tropical cyclones, and a slowing of the Gulf Stream (Pittock, 2006).

And our present situation seems to bear out this view. Doubling greenhouse gases would take the pre-industrial level of 280 ppm CO₂e to 560 ppm CO₂e; with the atmosphere now at 370 ppm CO₂e, we are only one-third of the way to that doubling. Yet with a rise of 1.7°C already in the pipeline (when thermal inertia and the Arctic albedo flip are included), it seems very likely that the heating at 560 ppm CO₂e will be a lot more than 3°C, especially if Greenland is lost and weakening of some carbon sinks proceeds along the current trends.

The problem with the established climate sensitivity range is that it only takes into account "fast" feedbacks: "Climate sensitivity is the response to a specified forcing, after climate has had time to reach a new equilibrium, including effects of fast feedbacks" which "come into play quickly as temperature changes. For example, the air holds more water vapour as temperature rises, which is a positive feedback magnifying the climate response, because water vapour is a greenhouse gas. Other fast feedbacks include changes of clouds, snow cover, and sea-ice" (Hansen, 2003).

The problem is that the ECS models omit "slow" feedbacks, such as ice sheet growth and decay, permafrost melting and methane release, and carbon cycle feedbacks that amplify climate changes on time scales of decades to centuries. Paleoclimate data identifies the impact of these missing slow feedbacks in pushing temperatures higher than expected: in the Arctic 55 million years ago temperatures were 11°C warmer than the ECS models would predict, suggesting "other feedback mechanisms" at work (Sluijs, Schouten et al., 2006); a 2006 study of Middle Ages climate found that the effect of amplifying feedbacks in the climate system "will promote warming by an extra 15 percent to 78 percent on a century-scale" compared to typical estimates by the IPCC models (Scheffer, Brovkin, et al., 2006).

The failure of the IPCC models to include slow feedbacks in climate sensitivity is explained by Hansen and Sato (2007), who argue that the "Charney 3°C" is reasonable in the short run, but that there is also a "long-term" climate sensitivity "if these slow feedbacks are allowed to operate" which Hansen and Sato estimate from the paleoclimate data to be "about 6°C for doubled CO₂". They then pose the question: "Which climate sensitivity is more relevant to humanity — the Charney 3°C for doubled CO₂ or the 'long-term' 6°C for doubled CO₂?" and they answer "both." On the time scale of the last three decades, "the Charney sensitivity is a good approximation, as little contribution from slow feedbacks would be expected. Thus climate models with 3°C sensitivity for doubled CO₂,

incorporating only the fast feedbacks, are able to achieve good agreement with observed warming of the past century. We suggest, however, that these models provide only a lower limit on the expected warming on century time scales due to the assumed forcings. The real world will be aiming in the longer run at a warming corresponding to the higher climate sensitivity [of 6°C]". And they conclude that "Elsewhere we have described evidence that slower feedbacks, such as poleward expansion of forests, darkening and shrinking of ice sheets, and release of methane from melting tundra, are likely to be significant on decade-century time scales. This realization increases the urgency of estimating the level of climate change that would have dangerous consequences for humanity and other creatures on the planet, and the urgency of defining a realistic path that could avoid these dangerous consequences" (Hansen and Sato, 2007).

This finding has enormous implications. As noted above, a long-term climate sensitivity of 6°C means we have passed the widely-advocated 2°C threshold of dangerous anthropogenic interference with the climate (around 350 ppm CO₂e for 6°C sensitivity) about four decades ago, and it therefore requires us to find the means to engineer a rapid drawdown of current atmospheric greenhouse gas for even a 2°C cap.

A key question is whether the slow feedbacks have started to operate. In the case of the Greenland and Antarctic ice-sheets, the data is already disturbing. Other slow feedbacks to be considered include the reversal of the carbon cycle as the oceans and soils take up less CO₂, and significant permafrost methane and CO₂ release.

Carbon cycle feedback: It is expected that the capacity of the Earth's carbon-drawdown mechanisms (ability to take carbon out of the air) will decrease due to both human activity and as a consequence of higher temperatures (Jones 2003), but observed changes suggest this is happening earlier than anticipated. The fraction of total anthropogenic CO₂ emissions remaining in the atmosphere has increased slowly with time, implying a slight weakening of sinks relative to emissions (Raupach, Marland et al., 2007). New research released in October 2007 confirmed that significant contributions to the growth of atmospheric CO₂ arise from the slow-down of natural sinks, or "a decrease in the planet's ability to absorb carbon emissions due to human activity," according to its lead author and Executive Director of the Global Carbon Project, CSIRO's Dr Pep Canadell. "Fifty years ago, for every tonne of CO₂ emitted, 600kg were removed by land and ocean sinks. However, in 2006, only 550kg were removed per tonne and that amount is falling" (Canadel, LeQuere et al., 2007; British Antarctic Survey, 2007). The data suggests from 1959 to 2006 an implied decline in the efficiency of natural sinks of 10%. Of the recent acceleration in the rise of atmospheric CO₂ levels, 18% is attributed to the decreased efficiency of natural sinks.

Another key factor is identified by Peter Cox at the Centre for Ecology and Hydrology in Dorset, UK, who says that plants are absorbing more CO₂ because photosynthesis speeds up with warming, but that warming also encourages plant material to break down and release CO₂. But there is a delay between commencement of the two events which for the last two decades has been lowering CO₂ levels. Thus "the entire land biosphere — the forests and soils and pastures and bogs — has been slowing the pace of global warming for some decades" but "soon the biosphere will start to speed it up" (Pearce, 2007a). Cox says it is possible that a surge of CO₂ into the atmosphere in 2003 is the first evidence of this process. Cox spent years researching carbon cycles while at the Hadley Centre in Exeter, which has one of the world's most highly regarded climate modelling systems. A summary of some of the Centre's modelling work published in 2005 (Jenkins, Betts et al., 2005) included two startling graphs. In one, the amount of total carbon stored in the Amazonian vegetation and soils (using the Hadley Centre climate model coupled to a dynamic vegetation-and-carbon-cycle model) shows a drop from around 70 billion tonnes of carbon in 2000 to just 20 billion tonnes of carbon by 2100. The second, using the same technique, compares vegetation and soil carbon levels in 2100 to 1850: whilst vegetation carbon had increased by about 60 billion tonnes of carbon by 2100, the amount of soil carbon had decreased by 130 billion tonnes of carbon.

Ocean carbon cycle feedback: Part of the decline in sink capacity comes from a decrease of up to 30% in the efficiency (capacity to absorb CO₂) of the Southern Ocean sink over the last 20 years, attributed to the strengthening of the winds around Antarctica which enhances ventilation of natural carbon-rich deep waters. Lead author Corinne Le Quéré says: "This is the first time that we've been able to say that climate change itself is responsible for the saturation of the Southern Ocean sink. This is serious. All climate models predict that this kind of 'feedback' will continue and intensify during this

century. The Earth's carbon sinks — of which the Southern Ocean accounts for 15% — absorb about half of all human carbon emissions. With the Southern Ocean reaching its saturation point more CO₂ will stay in our atmosphere" (Le Quéré, Rodenbeck et al., 2007; NIWA, 2007).

Consistent with this were the results of measurements of the North Atlantic taken from the mid-1990s to 2005 which found that the amount of CO₂ in the water had reduced by half over the decade. It is suggested that warmer surface water was reducing the amount of CO₂ being carried down into the deep ocean. Lead researcher Andrew Watson said: "We suspect that it is climatically driven, that the sink is much more sensitive to changes in climate than we expected... if you have a series of relatively warm winters, the ocean surface doesn't cool quite so much, you don't get so much sub-surface water formed and so the CO₂ is not being taken down into the deep water" and warned that the process may fuel climate change: "It will be a positive feedback, because if the oceans take up less CO₂ then CO₂ will go up faster in the atmosphere and that will increase the global warming" (Woodcock 2007).

A landmark study in 2000 found that about half of the current emissions are being absorbed by the ocean and by land ecosystems, but this absorption is sensitive to climate, as well as to atmospheric CO₂ concentrations, which are creating a feedback loop such that under a "business as usual" scenario the terrestrial biosphere acts as an overall carbon sink until about 2050, then turns into a source thereafter as the sinks fail. This is a "slow" feedback that will increase temperatures by another 1.5°C by 2100 (Cox, Betts et al., 2000).

In addition to this, satellite data gathered over the past ten years shows that the growth of marine phytoplankton, the basis of the entire ocean food chain, is being adversely affected by rising sea temperatures (Behrenfeld, Worthington, et al., 2007). Phytoplankton, the microscopic plants that permeate the oceans remove up to 50 billion tonnes of CO₂ per year from the Earth's atmosphere, as much as all plant life on the planet's terrestrial surface.

Marine life will also be further weakened by ocean acidification. The oceans are already 30% more acidic than they were at the beginning of the Industrial Revolution. If emissions continue as "business as usual", CO₂ levels in the oceans will rise to a point where, by 2050, ocean acidification will reach a level considered to be equivalent to industrial waste by the US's own water quality standards (Caldeira, Archer et al., 2007). If unabated it will have "the potential to cause extinction of many marine species... What we're doing in the next decade will affect our oceans for millions of years... CO₂ levels are going up extremely rapidly, and it's overwhelming our marine systems" (Eilperin, 2006; NASA, 2006b). Waters around the Great Barrier Reef are acidifying at a higher-than-expected rate, leading Professor Malcolm McCulloch of the Australian National University to observe that it appears "this acidification is now taking place over decades rather than centuries as originally predicted" (Kleinman, 2007). Ecosystem collapse caused by acidification will likely reduce marine biomass and therefore the capacity of the oceans to absorb CO₂.

Soil carbon cycle feedback: Soils and the oceans have historically contributed equally to absorbing atmospheric CO₂. The soil also releases carbon as plant and organic matter decompose. Guy Kirk of the National Soil Resources Institute at Cranfield University has calculated that the carbon lost by UK soil has increased by 13 million tonnes of CO₂ a year since 1978, more than the 12.7 million tonnes a year Britain saved by cleaning up its industrial emissions as part of its commitment to Kyoto. The loss is likely to be due to plant matter and organic material decomposing at a faster rate as temperatures rise, and this effect is expected to compound as temperatures increase: "It's a feedback loop," says Kirk, "the warmer it gets, the faster it is happening" (Pickrell, 2005; Connor and McCarthy, 2006). It is thought that at 2–3°C, the terrestrial carbon sink will begin to convert to a carbon source due to temperature-enhanced soil and plant respiration overcoming CO₂-enhanced photosynthesis, resulting in widespread desertification and enhanced feedback (Sarmiento and Gruber, 2003).

Bristol University researchers argue that a previously unexplained surge of CO₂ levels in the atmosphere in recent years is due to more greenhouse gas escaping from trees, plants and soils. Global warming is making vegetation less able to absorb the carbon pollution pumped out by human activity (Knorr, Gobro et al., 2007). Knorr believes "We could be seeing the carbon cycle feedback kicking in, which is good news for scientists because it shows our models are correct. But it's bad news for everybody else." Another bad sign comes from Canada's Manitoba region, where a study of a million-square-kilometre area of boreal forest found that it is now releasing more greenhouse gases than it absorbs, because of an increased incidence of forest fires. This is consistent with predictions that climate change, by producing hotter and drier conditions, would lead to more fires. "Those

wildfires have caused this transition in the boreal forest from a carbon sink to a carbon source... Climate change is what's causing the fires, if it was left unchecked, it could become a feedback", says Tom Gower of the University of Wisconsin (Weber, 2007). The fires also mean that more sunlight reaches the ground, increasing the rate of decomposition of organic matter and releasing more CO₂, and perhaps contributing to the melting of the underlying permafrost.

Burning rainforest is also emitting hundreds of millions of tonnes of CO₂ each year. For example, during the 2005-06 Amazon drought, thousands of square kilometres of land burned for months, releasing more than 100 million tonnes of carbon. Philip Fearnside of the National Institute for Research in the Amazon says that "the threat of a 'permanent El Niño' is to be taken very seriously... Disintegration of the Amazon forest, with release of the carbon stocks in the biomass and soil, would be a significant factor in pushing us into a runaway greenhouse". Daniel Nepstad, head of the Woods Hole Research Center's Amazon program, says it is "not out of the question to think that half of the basin will be either cleared or severely impoverished just 20 years from now... The nightmare scenario is one where we have a 2005-like year that extended for a couple of years, coupled with a high deforestation where we get huge areas of burning, which would produce smoke that would further reduce rainfall, worsening the cycle. A situation like this is very possible. While some climate modellers point to the end of the century for such a scenario, our own field evidence coupled with aggregated modelling suggests there could be such a dieback within two decades" (Butler, 2007).

By October 2007, there were more than 10,000 points of fire across the Amazon, most originally set by ranchers to clear land. "These fires are the suicide note of mankind," said Hylton Murray-Philipson of the London-based charity Rainforest Concern (Howden and Steven, 2007).

Total carbon emissions from tropical deforestation is estimated at 1.5 billion tonnes of carbon a year (Canadell, LeQuere et al., 2007), including illegal fires in Indonesia's vast peatlands whose haze regularly blankets Sumatra and Malaysia. Indonesia's peat swamps contain 21% of the Earth's land-based carbon and are now subject to increasing clearing, drying and burning. During the 1997 El Niño event, an estimated 0.81 to 2.57 billion tonnes of carbon were released to the atmosphere as a result of burning peat and vegetation in Indonesia. This is equivalent to 13–40% of the mean annual global carbon emissions from fossil fuels, and contributed greatly to the largest annual increase in atmospheric CO₂ concentration detected since records began in 1957 (Page, Siegert, et al., 2002).

Permafrost: As the Arctic warms, permafrost in the boreal forests and further north in the Arctic tundra is now starting to melt, triggering the release of methane, a greenhouse gas twenty-one times more powerful than CO₂, from thick layers of thawing peat. With less than one degree of warming, Arctic ground frozen by permafrost for 3000 years is melting, producing thermokarst (land surface that forms as ice-rich permafrost melts). This could affect 10–30% of Arctic lowland landscapes and severely alter tundra ecosystems even under scenarios of modest climate warming (Jorgenson, Shur et al., 2006). As the permafrost thaws and lakes form, microbes convert the soil's organic matter into methane, which bubbles through the surface water into the atmosphere; where permafrost decay is a dry process, CO₂ is released.

A recent study found that Siberia's thawing wetlands are a significant, underestimated source of atmospheric methane. With lakes in the region growing in number and size and emission rates appearing to be five times higher than previously estimated, permafrost melting is now another positive, "slow" feedback to climate warming (Walter, Zimov et al., 2006). The National Center for Atmospheric Research in Boulder predicts half of the permafrost will thaw to a depth of three metres by 2050, and glaciologist Ted Scambos says "that's a serious runaway" and that "a catastrophe lies buried under the permafrost" (Struck, 2007). Unusually warm winds in the 2007 northern summer sent temperatures soaring at Melville Island, high in the Arctic, to 22°C in July, 15°C above average. As a consequence permafrost thaw penetrated to a depth of one metre, double the usual depth, and reached the ground ice (Hall, 2007).

The western Siberian peak bog is amongst the fastest warming places on the planet, and Sergei Kirpotin of Tomsk State University calls the melting of frozen bog an "ecological landslide that is probably irreversible". One estimate puts methane releases from the melting bog at 100,000 tonnes a day, a warming effect greater than all human-caused emissions in the USA (Pearce, 2007a).

"Permafrost areas hold 500 billion tonnes of carbon, which can fast turn into greenhouse gases... The deposits of organic matter in these soils are so gigantic that they dwarf global oil reserves... If you

don't stop emissions of greenhouse gases into the atmosphere ... the Kyoto Protocol will seem like childish prattle", says Russian Arctic climate researcher Sergei Zimov (Solovyov and Doyle, 2007).

As well, new analysis of two decades of data from more than 30 sites indicates that the ability of forests in the frozen north to soak up man-made carbon dioxide is weakening (Miller, 2008; Randerson, 2008).

This accumulation of evidence suggests that "slow" feedbacks from oceans, soils and permafrost are already affecting the climate system.

1.7 Can ecosystems adapt to fast change?

"Governments don't like numbers, so some numbers were brushed out of it" — Professor Martin Parry on the IPCC Working Group II Summary for Policymakers, 18 September 2007 (Adam, 2007b)

The data discussed so far suggests that climate change impacts are happening at lower temperature increases and more quickly than previously thought. "Slow feedbacks" such as large ice-sheet loss and permafrost CO₂ and methane release are happening now.

Speaking at the launch of the full 2007 IPCC report on the impacts of global warming, the co-chair of Working Group II, Professor Martin Parry, told his audience that: "We are all used to talking about these impacts coming in the lifetimes of our children and grandchildren. Now we know that it's us." He said destructive changes in temperature, rainfall and agriculture were now forecast to occur several decades earlier than thought (Adam, 2007b). And that means a huge loss in biodiversity.

As global temperatures rise, isotherms (map lines linking areas of the same temperature) move poleward, and many species have to migrate with the isotherms to stay in the habitable zone. If they can't migrate at sufficient speed, ecosystems degrade as many species are lost. During rapid change, such as during the deglaciation and warming after the last ice age about 15,000 years ago, some widespread and dominant species became extinct when temperatures rose ~5°C over a time span of 5000 years (Jackson and Weng, 1999; Rahmsdorf, 2007). That is a rate of increase of 0.01°C per decade, twenty times slower than today's rate of change.

Thus as well as many ecosystems and species being sensitive to even small temperature changes, the rate of change in temperature is also very important in determining the impact. One study says that if a 2°C impact builds up slowly over 1000 years, most affected ecosystems are likely to adapt (most often by moving), but if the same rise happens in 50 years (0.4°C per decade) many ecosystems will "deteriorate rapidly" (Leemans and Eickhout, 2004). At 0.4°C per decade, the isotherms will be moving towards the poles at about 120km per decade, and at this rate of temperature change most ecosystems will be simply torn apart. Very fast-moving species will migrate with the temperature changes if they can survive in the ecosystems into which they move. Slow-moving species will not be able to keep up with the movement of their preferred isotherms and unless they are very tolerant of high temperatures and are not dependent on species that have moved on, they will die out. At 0.4°C change per decade, the isotherms are moving so fast that virtually all ecosystems will not be able to survive and very large percentages of the dependent species will die out. Yet this is the rate anticipated in some of the IPCC scenarios by mid-century, and few scenarios anticipate rates of less than 0.3°C per decade (Figure 3).

Another study of the IPCC report's low- and high-emission scenarios found 12–39% and 10–48% respectively of the Earth's terrestrial surface may experience novel and disappearing climates by 2100 (Williams, Jackson et al., 2007). And a 2005 study projected the effects on 1350 European plant species under seven climate change scenarios and found that more than half could be vulnerable or threatened by 2080, and that risks of extinction for European plants may be large, even in moderate scenarios of climate change (Thuiller, Lavorel et al., 2005).

Over the last 25 years, the area defined as climatologically tropical has expanded to the north and south by about 2.5 degrees of latitude in each direction. This is equivalent to a rate of 110km per decade, and is greater than the total predicted shift of 2 degrees of latitude by 2100 under the worst-case scenario of the IPCC (Seidel, Fu et al., 2008, Seidel and Randel, 2007). This will disrupt the tropical–temperate geographic transition of ecosystems, and suggests that if maintained over a

century time scale few of the affected ecosystems would adapt at the implied warming of greater than 0.3°C per decade.

The study also found that the expansion of the equatorial belt has “potentially important implications for subtropical societies and may lead to profound changes to the global climate system” since the “poleward movement of large-scale atmospheric circulation systems, such as jet streams and storm tracks, could result in shifts in precipitation patterns affecting natural ecosystems, agriculture and water resources,” with particular concern for subtropical dry belts that could affect water supplies, agriculture and ecosystems over vast areas of the Mediterranean, the south-western United States, northern Mexico, southern Australia, southern Africa and parts of South America (Connor, 2007c).

Whilst some ecosystems such as desert and grasses can adapt quickly to change, forests will be among the ecosystems to experience problems first because their limited ability to migrate and stay within the climate zone to which they are adapted. For wooded tundra, an average of 27% of the ecosystem remains in place for a temperature rise of 3°C in 100 years, or 0.3°C per decade over a century timescale. At a rate of 0.3°C per decade, Leemans and Eickhout, found that “only 30% of all impacted ecosystems can adapt, and only 17% of all impacted forests”. If the rate should exceed 0.4°C per decade, all ecosystems will be quickly degraded, opportunistic species will dominate, and the breakdown of biological material will lead to even greater emissions of CO₂. This will in turn increase the rate of warming (Kallbekken and Fuglestedt, 2007).

With emissions now tracking higher than the worst “business as usual” scenario of the IPCC, we can only say, in the plainest possible words that by mid-century we are likely to be locked into degrading or destroying most species and most ecosystems if we follow “business as usual”.

Most species, most ecosystems. Full stop.

1.8 IPCC deficiencies

This vulnerability of species to fast rates of change and wider uncertainties in climate science impel us to consider the worse-case outcomes, not just the “average” scenarios that are currently considered to be the most likely. Pittock (2006) argues persuasively that “Uncertainties in climate change science are inevitably large, due both to inadequate scientific understanding and to uncertainties in human agency or behaviour. Policies therefore must be based on risk management, that is, on consideration of the probability times the magnitude of any deleterious outcomes for different scenarios of human behaviour. A responsible risk-management approach demands that scientists describe and warn about seemingly extreme or alarming possibilities, for any given scenario of human behaviour (such as greenhouse gas emissions), even if they appear to have a small probability of occurring. This is recognized in military planning and is commonplace in insurance. The object of policy-relevant advice must be to avoid unacceptable outcomes, not to determine (just) the (apparently) most likely outcome.”

It is something that has not always been done, leaving the science in crucial areas looking flat-footed and behind-the-times. Hansen sets the stage: “For the last decade or longer, as it appeared that climate change may be underway in the Arctic, the question was repeatedly asked: ‘is the change in the Arctic a result of human-made climate forcings?’ The scientific response was, if we might paraphrase, ‘we are not sure, we are not sure, we are not sure...yup, there is climate change due to humans, and it is too late to prevent loss of all.’ If this is the best that we can do as a scientific community, perhaps we should be farming or doing something else” (Hansen and Sato, 2007).

We must choose targets and take actions that can actually solve the problem in a timely manner. The object of policy-relevant advice must be to avoid unacceptable outcomes and seemingly extreme or alarming possibilities, not to determine just the apparently most likely outcome.

Pittock (2007) has well-described the limitations of the IPCC process: “Vested interests harboured by countries heavily reliant on fossil fuels for industry and development, or for export, lead to pressure to remove worst case estimates; scientists... tend to focus on “best estimates”, which they consider most likely, rather than worst cases that may be serious but which have only a small probability of occurrence; many scientists prefer to focus on numerical results from models, and are uncomfortable with estimates based on known but presently unquantified mechanisms;

and due to the long (four-year) process of several rounds of drafting and peer and government review, an early cut-off date is set for cited publications” (often a year before the reports appear).

Inez Fung at the Berkeley Institute of the Environment says that for her research to be considered in the 2007 IPCC report, she had to complete it by 2004. “There is an awful lag in the IPCC process,” she says, also noting that the special report on emission scenarios was published in 2000, and the data it contains were probably collected in 1998. “The projections in the 2007 IPCC report [using the 2000 emission scenarios] are conservative, and that’s scary” (Barras, 2007).

The data surveyed suggests strongly that in many key areas the IPCC process has been so deficient as to be an unreliable and indeed a misleading basis for policy-making. We need to look to processes not dogged by politics, and to a more up-to-date and relevant scientific base that integrates recent data and findings, expert elicitations and the need in moments of uncertainty to fully account for the most unacceptable but scientifically conceivable outcomes. On that basis we can build strategies that would at least give us a real chance to avoid the great dangers manifesting in the climate system, of which we humans have become both the masters and, precariously, its likely victims.

The primary assumptions on which climate policy is based need to be re-interrogated. Take just one example: the most fundamental and widely supported tenet — that 2°C represents a reasonable maximum target if we are to avoid dangerous climate change — can no longer be defended. Today at less than a 1°C rise the Arctic sea-ice is headed for very rapid disintegration, in all likelihood triggering the irreversible loss of the Greenland ice sheet, catastrophic sea level increases and global temperatures rises from the Albedo flip. Many species and ecosystems face extinction from the speed of shifting isotherms. Our carbon sinks are losing capacity, and the seas are acidifying.

We have been lulled into a false sense of security by the stability of the climate during the Holocene, the geologic period that starts 11,500 years ago after the last glacial retreat and which includes the whole period of human civilisation. Yet the period of ice ages and rapid deglaciations when the climate whip-sawed between two states for millions of years is more likely the usual mode. “Abrupt change seems to be the norm, not the exception”, says Will Steffen of the ANU in Canberra (Pearce, 2007a). This is something we do not see or do not want to see, and that incapacity means that the inevitably abrupt changes, which our actions are now ensuring will occur, will be all that more devastating for our lack of foresight.

If we could start all over again, surely we would say we must stabilise the climate at an equilibrium temperature that would ensure the stable continuity of the Arctic? Given that this safe level has long since been passed, as soon as we knew there was a problem with the climate we should have aimed for a level of atmospheric CO₂ that would allow the restoration and then maintenance of the Arctic ice cap, with a safe margin for uncertainty and error.

Part 2: Target practice

“When starting a journey it makes sense to know where you are going” — Climate researchers Jonathan Pershing and Fernando Tudela, writing in 2003 (Aldy et al., 2003)

2.1 Framing the question

The last 20 years can be well represented as a struggle to answer the questions “are humans causing climate change?”, “what is dangerous climate change?” and “what do we need to do to stop it from occurring?”

Should the starting point in setting global warming goals — the framing of the issue — be short-term political acceptability, contemporary economic wisdom, or the well-being of humans and other species? Should policy goals be identified incrementally, step-by-step, or is it necessary to establish long-term goals and targets in order to ensure that immediate actions are consistent with fully solving the problem? Should goals be a vague aspiration or a practical target?

Globally the IPCC has decisively answered the first question, in the affirmative.

In Australia, the major political parties have not answered the second and third questions, articulating neither a view of what constitutes “dangerous climate change”, nor any specific atmospheric greenhouse gas or temperature caps. A central preoccupation with “not damaging the economy” has resulted in denial, delay and largely symbolic policies, such that emissions have increased more rapidly than in most developed economies, a trend likely to continue.

“Policies have not been constructed within a framework of fully solving the problem.”

The effect of a laudable incremental policy such as mandatory renewable energy targets, even when accompanied by improved energy intensity of production, has been overtaken by the impacts of population and productivity growth so that the net result has been rising, not falling, greenhouse gas emissions. Policies have not been constructed within a framework of fully solving the problem.

To solve the whole problem and determine a strategy to make a safe-climate world, we need to understand the trajectory of emissions and greenhouse gas levels, and then pose these four questions which demand answers:

- what is “dangerous climate change” and what level of risk are we prepared to take?
- what are the temperature caps that must not be exceeded to avoid “dangerous climate change” in the short and long term?
- what are the maximum levels below which greenhouse gases in the atmosphere must be kept in order to achieve these temperature caps; by how much must global emissions be reduced, and what principles should be applied between nations in the allocation of emissions reductions and the costs of emission reduction efforts?
- what actions will achieve these emissions scenarios?

2.2 What we have done and where we are headed

“Ken Caldeira has shown... that a molecule of CO₂ generated by burning fossil fuels will, in the course of its lifetime in the atmosphere, trap a hundred thousand times more heat than was released in producing it.” — Elizabeth Kolbert in New Yorker magazine, November 2006 (Kolbert, 2006)

Carbon dioxide contributes more to global warming than any other gas released by human activity. Together with water vapour, methane, nitrous oxide, and ozone, CO₂ in the air contributes to maintaining the Earth’s “greenhouse” effect, in which these atmospheric compounds trap much of the heat radiating from the Earth’s surface, keeping the surface temperature 33°C warmer than it would otherwise be. Human activity has increased the level of CO₂ by 36% from the 1750 pre-industrial level of about 280 ppm to its present level of 383 ppm. This human-induced increase in CO₂

level has increased the global average temperature by 0.8°C, with another 0.6°C in the pipeline due to thermal inertia, producing a long-term impact of 1.4°C. This is the highest CO₂ concentration in the last 600,000 years and probably in the last 20 million years, and the rate of increase has been at least ten, and possibly a hundred times faster than at any other time in the past 420,000 years (UNESCO/Scope, 2006). In addition, the “albedo flip” consequent to the loss of the Arctic sea-ice would add another 0.3°C, so the planet is now likely committed to a total rise of at least 1.7°C because of human activity.

Methane (CH₄) and nitrous oxide (N₂O) have increased by 150% and 16% respectively since 1750, so that the CO₂ equivalent for all the Kyoto-defined greenhouse gases — referred to as CO₂e (Kyoto) — is around 455 ppm. In other words, this cocktail of different greenhouse gases, working together, is having a warming effect equivalent to 455 ppm of CO₂ by itself.

Aerosols (small particles in the atmosphere from smoke, dust, manufacturing and other sources) have an uncertain cooling effect upon the atmosphere. When the effect of these is subtracted from the CO₂e (Kyoto) level, the current CO₂ equivalent — CO₂e (total) — is around 370 ppm, though this figure is not well established due to uncertainties in quantifying the aerosols’ cooling effect.

Human caused CO₂ emissions increased 70% between 1970 and 2004 (IPCC, 2007c) and are rising at an increasing rate; a May 2007 study found the annual growth in global CO₂ emissions caused by human activity jumped from an average 1.1% for 1990–1999 to more than 3% for 2000–2004. The growth rate since 2000 is greater than for “business as usual”, the most fossil-fuel intensive of the IPCC emissions scenarios, and “no region is decarbonizing its energy supply” (Raupach, Marland et al., 2007).

The IPCC scenarios are now effectively a decade old and out-of-date: “At the time of their release in 2000, they were state-of-the-art... Now, the world is growing faster and is richer than the scenario authors assumed” (Jones, 2007b).

While emissions of CO₂ are accelerating worldwide, we are gaining fewer economic benefits from each tonne of fossil fuel burned. Michael Raupach, co-chairman of the Global Carbon Project based at the CSIRO in Canberra, notes that “a major driver accelerating the growth rate in global emissions is that, globally, we’re burning more carbon per dollar of wealth created. In the last few years, the global use of fossil fuels has actually become less efficient. This adds to pressures from increasing population and wealth” (Innovations Report, 2007).

In assessing the same data for Australia, Raupach found Australia’s carbon emissions have grown at about twice the global average over the past 25 years, and about double the rate of emissions growth in the United States and Japan. Raupach concludes that because “emissions are increasing faster than we thought... the impacts of climate change will also happen even sooner than expected” (Minchin, 2007a). According to an October 2007 World Bank report, “Growth and CO₂ emissions: How do different countries fare?”, Australia increased its CO₂ emissions by 38% between 1994 and 2004, to be the sixth highest per capita emitter (on a base that excludes land use, land use change and forestry). Australia’s emissions increase was more than that of Britain, France and Germany combined, whose combined population is ten times that of Australia (Colebatch, 2007). Another report by the UNFCCC found Australia’s total greenhouse emissions had increased 26% between 1990 and 2005 and Australian per capita electricity use, at 5102 kilowatt hours per year, compares poorly with the European Union’s average of 2947kWh/yr (Beeby, 2007b).

The rising rate of CO₂ emissions is reflected in a larger annual increase in the level of atmospheric CO₂. The average increase of 1.5 ppm for 1970–2000 has jumped to 2.1 ppm since 2001 (Arguez, Waple et al, 2007; Adam, 2007c). James Hansen estimates that “if we go another ten years, by 2015, at the current rate of growth of CO₂ emissions, which is about 2% per year, the emissions in 2015 will be 35% larger than they were in 2000,” and this would take emissions scenarios necessary to avoid dangerous climate change beyond reach (Connor, 2007a). Hansen, the Director of NASA’s Goddard Institute for Space Science, says we must “begin to move our energy systems in a fundamentally different direction within about a decade, or we will have pushed the planet past a tipping point beyond which it will be impossible to avoid far-ranging undesirable consequences”. Global warming of 2–3°C above the present temperature, he warns, would produce a planet without Arctic sea-ice, a catastrophic sea level rise in the pipeline of around 25 metres, and a super-drought in the American west, southern Europe, the Middle East and parts of Africa. “Such a scenario threatens even greater

calamity, because it could unleash positive feedbacks such as melting of frozen methane in the Arctic, as occurred 55 million years ago, when more than 90% of species on Earth went extinct” (Hansen, 2006b).

Tony Blair and his Dutch counterpart, Jan Peter Balkenende, told European leaders in 2006 that “without further action, scientists now estimate we may be heading for temperature rises of at least 3–4°C above pre-industrial levels... We have a window of only 10 to 15 years to avoid crossing catastrophic tipping points. These would have serious consequences for our economic growth prospects, the safety of our people and the supply of resources, most notably energy” (Colebatch, 2006). This statement was made before the imminent loss of the Arctic sea-ice and its consequences were as clear as they are today; when that event is taken into account, the “10 to 15 years to avoid crossing catastrophic tipping points” have already evaporated.

Atmospheric CO₂ levels are now substantially higher than at any time in the last 800,000 years. Atmospheric CO₂ rose 30 ppm in the last 17 years, yet ice cores drilled in Antarctica show that in the last million years, prior to recent times, the fastest increase of CO₂ was 30 ppm over a 1000-year period. The speed of heat imbalances is way outside the planet’s recent climate history: “We really are in the situation where we don’t have an analogue in our records,” says Dr Eric Wolff from the British Antarctic Survey (Amos, 2007a). Wolf says that although opinions differ, it is generally accepted that at some stage a “step change” or “tipping point” is reached after which global warming accelerates exponentially and, according to the new evidence, “we could expect that tipping point to arrive in 10 years’ time” (von Radowitz, 2007). Recent observations from the Arctic, and its implications for the Greenland ice sheet and sea-level rises, suggest we may have already passed that point.

In 2004, the International Energy Agency projected that CO₂ emissions will increase by 63% over 2002 levels by 2030 (IEA, 2004). “Business as usual” will see global energy use more than double by 2050, from 10 gigatonnes oil equivalent (Gtoe) to 22 Gtoe, with 70% of the increase coming from fossil fuels, according to the European Union’s 2007 World Energy Technology Outlook. The report assumes energy efficiency will almost double to support an economy that is four times as large as today, but even so finds that the “resulting emission profile corresponds to a concentration of CO₂ in the atmosphere between 900 to 1000 ppm in 2050. This value far exceeds what is considered today as an acceptable range for stabilisation of the concentration” (European Union, 2007: 12–13). The conclusion is that carbon emissions cuts will come too late to avert “runaway” climate change if current policy trends continue in Europe and across the world, and this would happen despite a “massive” growth in renewables after 2030, including rapid deployment of new technologies like offshore wind.

With emissions now tracking worse than “business as usual”, the IPCC’s projections may well be too conservative. The temperature rise from 1990 to 2005 — 0.33°C — was near the top end of the range of IPCC climate model predictions, and overall “the data available for the period since 1990 raise concerns that the climate system, in particular sea level, may be responding more quickly to climate change than our current generation of models indicates” (Rahmstorf, Cazenave et al., 2007).

The 10 warmest years on record have all occurred since 1995 (Arguez, Waple et al., 2007), and it is predicted the year 2014 will “be 0.30°C ± 0.02°C warmer than the observed value for 2004,” which means there is a 50% chance that the warming for the 10 years from 2004 will be three-eighths of that for the whole of the previous century (Smith, Cusack et al., 2007).

The IPCC’s most pessimistic “business as usual” scenario has a median predicted temperature increase of 4.7°C by 2100 but, for example, average summer temperatures in the eastern US could soar by 5.5°C (10°F) by 2080, if human emissions continue to grow at their current rate of 2% a year, according to a new NASA model (Brahic, 2007b).

“Carbon dioxide (CO₂) emissions are now growing more rapidly than “business as usual”, the most pessimistic of the IPCC scenarios ... Temperatures are now within ≈1°C of the maximum temperature of the past million years.”

We have already noted that so far temperatures have risen 0.8°C above pre-industrial levels, and the warming trend is accelerating, with a further 0.6°C of warming as a result of the pollution we have already put in the air still to come, plus an Arctic sea-ice “albedo flip” also in the pipeline.

Yet Hansen and his colleagues suggest that “comparison of measured sea surface

temperatures in the Western Pacific with paleoclimate data suggests that this critical ocean region, and probably the planet as a whole, is approximately as warm now as at the Holocene maximum and within $\approx 1^\circ\text{C}$ of the maximum temperature of the past million years. We conclude that global warming of more than 1°C , relative to 2000, will constitute 'dangerous' climate change as judged from likely effects on sea level and extermination of species" (Hansen, Sato et al., 2006). Figure 4 illustrates the western Pacific paleoclimate temperature data.

With the rise over pre-industrial levels of 0.7°C up to 2000, the Hansen target is 1.7°C , yet today this is already in the system and emissions are tracking at worse than the IPCC's most pessimistic scenario. As well, rates of temperature rise from the mid-nineteenth century are higher than those of the glacial termination ten thousand years ago by more than a factor of ten, increasing to a factor of 20 from the mid-1970s. The implications for policy are far beyond the current public discourse.

2.3 What is "dangerous climate change"?

" 'Dangerous' has become something of a cliché when discussing climate change." — climate researchers, writing in 2006 (Schneider and Lane, 2006).

"Arctic climate change [is] centrally relevant to definition of dangerous human interference." — 2007 scientific paper (Hansen, Sato et al., 2007a)

What risk is acceptable in establishing "safe" global warming goals, policies and actions? In the absence of a well-informed scientific consensus that harm would not ensue, the precautionary principle suggests that if an action (or inaction) might cause severe or irreversible harm to the public or the environment, the burden of proof falls on those advocating the action (or inaction). For nuclear power stations in the USA, the regulatory standard is that there should be no more than one-in-a-million risk of serious accident. In 2004, the chance of being killed in a commercial air crash was about one in four million. If instead the risk was one in a thousand — a 0.1% chance — we would not fly.

Yet we seem to accept much higher risks as reasonable in setting global warming targets. The talk is about a 20–30% species loss for a rise of 2°C , very likely coral reef destruction, possible ice-sheet disintegration and the prospects of economic damage "on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century" (according to Nicholas Stern) as if it were a game of chance, a poker hand where with an ounce of luck the right cards will be dealt and the Earth will "get out of jail" free.

It seems that we abide by one rule when our own personal safety is at risk, but apply a much lower standard when it comes to the planet on whose good grace our own survival rests.

The precautionary principle tells us to not risk actions that could trigger an irreversible chain of climate change events or produce dangerous impacts. We cannot gamble on how far we can push the system till it breaks, and then try and unscramble the eggs. As is the case for civil aviation, climate change safety policy must allow for less than a one-in-a-million chance of catastrophic failure.

Because biodiversity, our lives, and those of succeeding generations are at stake, we must not choose to accept a level of warming that creates an unacceptable risk of unacceptable impacts. We need a model of the precautionary principle that not only guides us to avoid unsustainability, but that also guides us to get back to the safe zone if we have strayed outside that zone already.

Yet risk and uncertainty have been turned on their head: "The risk-averse nature of Article 2 of the UNFCCC (UN Framework Convention on Climate Change) requires immediate and stringent reductions in emissions of all greenhouse gases... because of scientific uncertainty, not in spite of uncertainty. Uncertainty, however, has been used as a reason for delay of emission reductions, presumably on the grounds that future knowledge may show that near-term emission reductions are unnecessary" (Harvey, 2007).

The 1992 UNFCCC urges stabilisation of greenhouse gases at a level: to "prevent dangerous anthropogenic interference with the climate system"; to be achieved within a time frame "sufficient to allow ecosystems to adapt naturally to climate change; to ensure that food production is not threatened; and to enable economic development to proceed in a sustainable manner".

While the concept of “dangerous” is generally cast into the future — for example, at a 2°C rise — other judges, such as the inhabitants of low-lying Pacific islands, know it is already dangerous.

Suggested metrics for dangerous climate change (Schneider and Lane, 2006) include:

- risks to unique and threatened geophysical or biophysical systems;
- risks associated with extreme weather events;
- total damages;
- temperature thresholds to large-scale events;
- risks to global and local ecosystems;
- loss of human cultures;
- ‘millions at risk’ — the additional number of millions of people placed at risk;
- the five key sustainability metrics: water, energy, health, agriculture, and biodiversity;
- impacts at a pace beyond the capacity to adapt;
- triggering of an irreversible chain of events;
- early warning dangers present in certain areas that are likely to spread and worsen over time with increased warming; and
- distributional metrics: inter-country equity, intergenerational equity, and inter-species equity.

Schneider and Lane (2006) also propose five measurements:

- market costs in dollars per tonne of carbon (C);
- human lives lost in persons per tonne C;
- species lost per tonne C;
- distributional effects (such as changes in income differentials between rich and poor) per tonne C; and
- quality of life changes, such as heritage sites lost per tonne C or refugees created per tonne C.

And they note their “strong belief that such broad-based, multi-metric approaches to impacts categorization and assessment are vastly preferable to focusing solely on market categories of damages, as is often done by traditional cost–benefit analyses. ‘One metric’ aggregations probably underestimate the seriousness of climate impacts.”

Pragmatically, there will be no easy agreement between nations as to what the definition of dangerous will be, nor will quantities or caps be established. But the effort must be made to get a genuinely ‘good enough’ consensus because the stakes are so high.

Of particular significance as a metric is the triggering of irreversible chains of events, or “tipping points”. The climate system “is highly non-linear and is prone to abrupt changes, threshold effects and irreversible changes (in a human time frame)... very small changes in a forcing factor can trigger surprisingly large and sometimes catastrophic changes in a system... [and] propel the Earth into a different climatic and environmental state. Examples include the rapid disintegration of the large ice sheets on Greenland and Antarctica or large-scale and uncontrollable feedbacks in the carbon cycle: activation of methane clathrates buried under the coastal seas, the rapid loss of methane from warmer and drier tundra ecosystems, increasing wildfires in the boreal and tropical zones, the conversion of the Amazon rainforest to a savannah and the release of CO₂ from warming soils. Once a critical threshold was crossed and such a series of processes was triggered, no policy or management approaches could slow or reverse the process” (Steffen, 2007).

An example is the “imminent peril” we now face of “initiation of dynamical and thermodynamical processes on the West Antarctic and Greenland ice sheets that produce a situation out of humanity’s control, such that devastating sea level rise will inevitably occur” (Hansen, Sato et al., 2007b). “A tipping point occurs when the climate state is such that, because of large ‘ready’ feedbacks, small additional forcing can cause large climate change. The ready feedbacks today are provided by Arctic, the West Antarctic ice sheet, and much of the Greenland ice. Little additional forcing is needed to trigger these feedbacks because of global warming that is already in the pipeline... Casualties of passing this tipping point would include more than wildlife and indigenous ways of life in the Arctic, and the coastal environments and cities submerged by rising seas. The increased global warming

would have world-wide effects via an intensified hydrologic cycle..." (Hansen, 2008). Thus "tipping points is not only a valid concept, but it is what distinguishes the global warming problem from other problems such as the (particulate) air pollution problem... the upshot is a real danger that the system will run out of our control [and] these changes will become unavoidable. As we realized years ago, we cannot 'wait and see' in the climate problem. We have to be smart enough to understand what is happening early on" (Hansen, 2007d).

"We suggest the goal is a climate safe for all people and all species over 'all' generations..."

So what does it mean to "prevent dangerous anthropogenic interference with the climate system"? We suggest the goal is a climate safe for all people and all species over "all" generations, and we should not discount knowable impacts beyond our own lifetime.

The world has already overshoot this goal. We have already moved beyond a safe-climate planet and global warming is now causing species extinction and taking a toll in human lives. So how much damage from climate change are we prepared to tolerate? We can only answer "the least amount possible" and certainly not levels that will overwhelm human and other species' capacity to cope. One has only to read or watch day-by-day reports in the media to understand that dangerous climate change is already here. Looking at Darfur, the farmers along Australia's failing Murray-Darling river system, collapsing ecosystems, the victims of the 2007 Greek and Californian mega-fires, the coral stress, the species lost, the changing patterns of the Asian monsoons, the fate of low-lying Pacific island communities and food production decline in sub-Saharan Africa, our world is already at the point of failing to cope. The United Nation's emergency relief coordinator, Sir John Holmes, warned that 12 of the 13 major relief operations in 2007 were climate related and said this amounted to a climate change "mega disaster" (Borger, 2007).

Climate change is *already* dangerous.

2.4 What is a safe temperature target?

It has been demonstrated in Part 1 that with a rise of less than 1°C the Arctic sea-ice is fast disappearing. Its total disintegration is inevitable — even with no further warming — and it is likely to happen in a time frame more appropriately measured in years than decades. The total loss of Arctic sea-ice will rapidly warm the north polar region and very likely trigger the loss of at least a substantial part of the Greenland ice sheet in a time span of decades to a century or so, rather than millennia, resulting in sea-level rises of several, perhaps as much as five, metres this century. This will be catastrophic for many hundreds of millions of people, swamping river deltas and making some of the world's most populous cities unliveable.

"...the loss of the Arctic, in all likelihood at an increase of less than 1°C in global average temperature... unambiguously represents dangerous human interference with the climate..."

The only conclusion to be drawn is that the loss of the Arctic, in all likelihood at an increase of less than 1°C in global average temperature compared to pre-industrial levels, unambiguously represents dangerous human interference with the climate. Therefore we already have too much greenhouse gas in the air, and we need to find the means to engineer a rapid massive drawdown of current greenhouse gases to a safe level. It is now not a question of "how much more greenhouse

gas can we add to the atmosphere?" but "by what means, at what speed and to what extent must we draw down the current levels of greenhouse gases to reach a safe level in time to avoid catastrophic climate change?"

We contend that at a rise of 0.8°C over pre-industrial levels, we now stand at the point of dangerous climate change and a further temperature rises of 0.6°C (thermal inertia) already locked into the system, plus the Arctic impacts, means we will pass further into the danger zone unless society can rapidly organise a countervailing cooling of the Earth.

The history of the disintegration of the Arctic sea-ice suggests "a downward trend for the last 30 years or so" (McCarthy, 2007) in which thinning has been occurring for at least 20 years (Blakemore and Sandell, 2007). In the late 1980s and early 1990s, shifting wind patterns flushed much of the thick, older sea-ice out of the Arctic Ocean and into the North Atlantic where it eventually melted, replaced

by a thinner layer of “young” ice that melted out more readily in the succeeding summers (Serreze, Holland et al., 2007). Serreze says that “this ice-flushing event could be a small-scale analog of the sort of kick that could invoke rapid collapse, or it could have been the kick itself... at this point, I don’t think we really know”. Pulses of warmer water entering the Arctic Ocean beginning in the mid-1990s, which promote ice melt and discourage ice growth along the Atlantic ice margin, are “another one of those potential kicks to the system that could evoke rapid ice decline and send the Arctic into a new state” (University of Colorado, 2007).

“...global temperatures should not have exceeded the levels three decades ago in order to avoid dangerous climate change. ...”

In other words, there is an unacceptable risk that events two or three decades ago triggered the rapid disintegration of the sea-ice now being witnessed, and the precautionary principle leads us to conclude that global temperatures should not have exceeded the levels three decades ago in order to avoid dangerous climate change. The temperature rise to 1980 over pre-industrial levels is around 0.5°C. This would establish a

0.5°C rise in global average temperatures over the pre-industrial level as the sensible cap to long-term temperature change, which we thus propose as a cap to “prevent dangerous anthropogenic interference with the climate system”. The fact that we have long passed this point in no way detracts from its importance as a policy goal, and a state to which we should wholeheartedly endeavour to return the planet.

Any proposal for a goal higher than 0.5°C would be foolhardy and would dangerously underestimate the consequences of not being risk averse to the likely impacts of Arctic sea-ice disintegration and the flow-on effects.

A 0.5°C cap would mean atmospheric CO₂ levels of about 320 ppm, compared to the current level of 383 ppm. Whilst once this view may have seemed a little “out there”, it is now heading towards the mainstream. In a momentous political “tipping point”, NASA climate science chief James Hansen, colourfully described by one observer as “the lone-wolf researcher often called the godfather of global warming”, told scientists and others at the American Geophysical Union conference in San Francisco in December 2007 that *we as a species passed climate tipping points for major ice sheet and species loss when we exceeded 300–350 ppm CO₂ in the atmosphere, a point passed decades ago*. Climate zones such as the tropics and temperate regions will continue to shift, and the oceans will become more acidic, endangering much marine life, he added. “We either begin to roll back not only the emissions [of CO₂] but also the absolute amount in the atmosphere, or else we’re going to get big impacts... We should set a target of CO₂ that’s low enough to avoid the point of no return”, he said, estimating it to be around 300 to 350 ppm CO₂. “We have to figure out how to live without fossil fuels someday,” Hansen said, “Why not sooner?” People must not only cut current carbon emissions but *also remove some carbon that has collected in the atmosphere since the Industrial Revolution*, a number of scientists concluded (Borenstein, 2007; Beck, 2007b, Inman, 2007).

Following Hansen, we contend that *current* proposals to establish caps of 2°C or 3°C as “reasonable” for “avoiding dangerous climate change” are not being informed by the likely impacts and expert elicitations, but have been shaped by the world of diplomacy, political tradeoffs and compromises driven by narrow, short-term and national aspirations.

In addition to the impacts in the polar north already surveyed earlier, at 1°C of warming above pre-industrial the Amazon will be drying and increasingly drought and fire affected. During the 2005 drought, some tributaries ran dry and in 1998 El Nino-generated forest fires in a drying Amazon poured almost half a billion tonnes of carbon into the air, more than 5% of global greenhouse gas emissions for the year. The Amazon, responsible for more than 10% of the world’s terrestrial photosynthesis, “is currently near its critical resiliency threshold” (Cowling, Betts et al., 2004). Further north, at 1°C of warming, California and the US Great Plains states will be subject to mega-droughts and desertification, a new and permanent “dust bowl”, similar to those during the 1000–1300 AD Medieval Warm Period when devastating epic droughts hit the plains and whole native American populations collapsed.

At 1°C of warming, the north Queensland rainforest, very sensitive to temperature rises, will be an “environmental catastrophe” waiting to happen (Williams, Bolitho et al., 2003). Just 1°C will likely reduce Queensland highland rainforest by half. The Barrier Reef is already subject to regular bleaching — 60–95% of reefs surveyed were bleached in 2002 — and the reef is now “facing

extinction" (Minchin, 2007c). Also at 1°C of warming, world cyclones will likely be more severe and small island states will be abandoned as seas rise. Ice sheets around the world will be suffering severe losses; landslides in the European Alps are already serious as permafrost melts and retreats upwards; the Kilimanjaro ice sheet, which has been intact for at least 11,000 years, is on the way to disappearing, with 80% loss in the last 100 years and the rest gone by 2015–2020, bringing forest loss to the surrounding area. Britain's Hadley Centre calculates that an increase of just 1°C of warming would eliminate fresh water from a third of the world's land surface by 2100.

"A rise of 2°C will initiate climate feedbacks on Earth and in the oceans, on ice-sheets and on the tundra, taking the Earth past significant tipping points.

A rise of 2°C will initiate climate feedbacks on earth and in the oceans, on ice-sheets and on the tundra, taking the Earth past significant tipping points. Likely impacts include large-scale polar ice-sheet disintegration and the extinction of an estimated 15 to 40% of plant and animal species, dangerous ocean acidification, significant tundra loss and increasing methane release, initiation of substantial soil and ocean carbon cycle feedbacks and widespread drought and desertification in

Africa, Australia, Mediterranean Europe and the western USA. At 2°C, Europe likely will be hit every second year by heatwaves like the one in 2003 which killed 22,000–35,000 people, caused \$12b of crop losses, reduced glacier mass and resulted in a 30% drop in plant growth, adding half a billion tonnes of carbon to the atmosphere.

At 2°C of warming, the summer monsoons in northern China will likely fail, and agricultural production will fall in India's north as forests die back and national production falls. Flooding in Bangladesh will worsen as its monsoons strengthen and sea levels rise. But in the Andes, glacial loss will reach 40–60% by 2050, reducing summer run-off and subsequent water shortages will be horrendous for nations such as Peru. At 2°C, snowpack decline in California will be one-third to three-quarters and in the Northern Rockies up to 70%, devastating agriculture as the melt run-off declines. Changing climate will have a severe impact on world food supplies. In central and south America maize losses are projected for all nations but two. In 29 African countries, including Mali, Botswana and Congo, crop failure and hunger are likely to increase.

[For a broader survey of likely impacts at 2°C and 3°C based on the peer-reviewed literature, and comprehensive references to the impacts discussed here, see: Lynas, 2007; Pearce, 2007; Romm, 2007].

Yet, what would constitute "dangerous anthropogenic interference" with the climate system is commonly answered as a temperature rise [not in excess] of 2°C, the target set by the European Union, the IPCC and the International Climate Change Taskforce, amongst many others. In 2004, two researchers neatly summarised the absurdity of the dilemma: "We'd all vote to stop climate change immediately, if we only believed that doing so would be so cheap that no country or bloc of countries could effectively object. But we do not so believe. Thus we're forced to start trading away lives and species in order to advocate a 'reasonable' definition of 'dangerous'... So it's no surprise that... the advocates of precautionary temperature targets strain to soft-pedal their messages, typically by linking 2°C of warming to carbon dioxide (CO₂) concentration targets that can be straight-forwardly shown to actually imply a larger, and sometimes much larger, probable warming... Climate activists soft-pedal the truth because they think it will help, and perhaps they are even right. Who are we to know? Nevertheless, we also believe that the waffling is becoming dangerous, that it threatens, if continued, to critically undermine the coherence of our emerging understanding. That it delays difficult, but necessary, conclusions" (Baer and Athanasiou, 2004).

2.5 Are we getting the third degree?

“The global climate-science community has indicated that changes of planetary temperature of even 1– 2°C have the potential to bring about significant global exposures to coastal erosion, sea-level rise, water supply and extreme climatic events, to name but a few. The potential number of humans impacted by a 2°C change may count in the hundreds of millions. The European Union has already set a target of maximum warming of 2°C in the belief that warming beyond this represents an unreasonable risk of “dangerous” climate change. Such a change in the average global temperature might be regarded by many as small, but it has the capacity to culminate in major consequences, something that scientists feel is still under-appreciated in both public and private policy development.” — Dr Graeme Pearman, 3 December 2007 (Pearman, 2007)

The rapid Arctic melt now under way consigns the widely advocated 2°C warming cap — always an unacceptable political compromise — to the dust bin because it is demonstrably too high and would eventually be a death sentence for billions of people and millions of species as positive feedbacks work through the climate system.

Yet there are now suggestions that we should consider a 3°C warming cap, even though “the Earth’s history suggests that with warming of 2–3°C the new equilibrium sea level will include not only most of the ice from Greenland and West Antarctica, but a portion of East Antarctica, raising sea level of the order of 25 meters. Contrary to lethargic ice sheet models, real world data suggest substantial ice sheet and sea level change in centuries, not millennia. The century time scale offers little consolation to coastal dwellers, because they will be faced with irregular incursions associated with storms and with continually rebuilding above a transient water level” (Hansen, 2006d).

The brutal question is this: do those advocating a 3°C understand in any significant way what 3°C really means? What it means in tangible, physical terms?

In the Pliocene, three million years ago, temperatures were 3°C higher than our pre-industrial levels, so it gives us an insight into the 3°C world. The northern hemisphere was free of glaciers and ice sheets, beech trees grew in the Transantarctic mountains, sea levels were 25 metres higher, and atmospheric CO₂ levels were 360–400 ppm, very similar to today. There are also strong indications that during the Pliocene, permanent El Nino conditions prevailed. Rapid warming today is already heating up the western Pacific Ocean, a basis for a coming period of “super El Ninos”.

Between 2°C and 3°C, the Amazon rainforest, whose plants produce 10% of the world’s terrestrial photosynthesis and which have no evolved resistance to fire, may turn to savannah as drought and mega-fires first destroy the rainforest, turning trees back into CO₂ as they burn or rot and decompose. The carbon released by the forests’ destruction will be joined by still more from the world’s soils, together boosting global temperatures by a further 1.5°C. It is suggested that in human terms the effect on the planet will be like cutting off oxygen during an asthma attack. A March 2007 conference at Oxford talked about “corridors of probability”, with models predicting the risk of the Amazon passing a “tipping point” at 10–40% over the next few decades.

The UK’s Hadley Centre climate change model, best known for warning of catastrophic losses of Amazon forest, predicts that under current levels of greenhouse gas emissions, the chances of such a drought would rise from 5% now (one every 20 years) to 50% by 2030, and to 90% by 2100.

The collapse of the Amazon is part of the reversal of the carbon cycle projected to happen around 3°C, a view confirmed by a range of researchers using carbon-coupled climate models. 3°C would likely see increasing and significantly large areas of the terrestrial environment being rendered essentially uninhabitable by drought and heat. Rainfall in Mexico and Central America is projected to fall by 50%. Southern Africa would be exposed to perennial drought, a huge expanse centred on Botswana could see a remobilisation of old sand dunes, much as is projected to happen earlier in the US west. The Rockies would be snowless and the Colorado river will fail half the time. Drought intensity in Australia could triple.

With extreme weather continuing to bite — hurricanes may increase in power by half a category above today’s top-level Category Five — world food supplies will be critically endangered. This could mean hundreds of millions — or even billions — of refugees moving out from areas of famine and drought in the sub-tropics towards the mid-latitudes. As the Himalayan ice sheet relentlessly

melts with rising temperatures, the long-term water flows into Asia's great rivers and breadbasket valleys — the Indus, Ganges and Brahmaputra, the Mekong, Yangtze and Yellow rivers — will fall dramatically. If global temperatures rise by 3°C (and that's becoming the unofficial target for some rich-country governments), water flow in the Indus is predicted to drop by 90% by 2100. The lives of two billion people are at stake.

For all this, 3°C is the cap effectively being advocated by the Australian Labor Party (ALP) in its policy "Labor's Greenhouse Reduction Target — 60% by 2050 Backed By the Science" released on 2 May 2007 by environment spokesperson Peter Garrett, which advocates a 60% reduction in Australian emissions from 2000 levels by 2050 (Garrett, 2007).

The fully developed 60/2050 goal was first formally articulated by a major organisation in 2000 when it was recommended by the UK Royal Commission on Environmental Pollution, to which the ALP's policy statement makes reference. However, the core idea — of making a 60% cut in CO₂ emissions compared to 1990 levels — was given prominence a decade earlier in the first science assessment of the IPCC. This was not presented as a goal as such but was provided by the scientists to help policy makers calibrate the scale of the challenge (Leggett, 2001).

The immediate source of inspiration for Labor's 60/2050 target appears to be the advocacy of Sir Nicholas Stern who, when all is said and done, advocated a 3°C target in his 2006 report to the UK government. Stern said that constraining greenhouse gas levels to 450 ppm CO₂e "means around a 50:50 chance of keeping global increases below 2°C above pre-industrial [and it] is unlikely⁶ that increases will exceed 3°C". But, he said, keeping levels to 450 ppm CO₂e is "already nearly out of reach" because "450 ppm means peaking in the next five years or so and dropping fast". In other words, it would require immediate and strong action that Stern judged to be neither politically likely nor economically desirable because he thought that the UK and other western governments would not be prepared to direct sufficient resources to solve the problem.

So instead Stern pragmatically says the data "strongly suggests that we should aim somewhere between 450 and 550 ppm CO₂e", but his policy proposals demonstrate that he has the higher figure in mind as a practical goal: "It is clear that stabilising at 550 ppm [CO₂e] or below involves strong action... but such stabilisation is feasible" even though "550 ppm is risky". So his policy framework is focused on constraining the increase to 550 ppm, at which level "there is around a 50:50 chance of keeping increases below 3°C (and it is) unlikely that increases would exceed 4°C" (Stern, 2006a, 2006b).

It is beyond reasonable doubt that Stern identifies a 2°C cap with 450 ppm CO₂e and a 3°C cap with 550 ppm CO₂e, noting that for the latter target "the power sector around the world will have to be at least 60% de-carbonised by 2050 *and with a bigger proportion de-carbonised in rich countries*" (Stern, 2006a, emphasis added). Stern's last point is often overlooked.

"The 60/2050 link to a 3°C cap was reiterated during Stern's March 2007 visit to Australia..."

The 60/2050 link to a 3°C cap was reiterated during Stern's March 2007 visit to Australia, when he told "The Age" that "It would be a very good idea if all rich countries, including Australia, set themselves a target for 2050 of at least 60% emissions reductions" because "the planet would be left with about 550 ppm of CO₂ equivalent by 2050" and this would "leave us roughly a 50/50 chance of being either side of 3°C above pre-industrial times" (Hannam, 2007).

A number of others have followed in Stern's footsteps, including ex-ABARE chief Dr Brian Fisher, Australia's lead delegate to the May 2007 IPCC meeting, who says the 2°C target, with emissions peaking by 2015, "is exceedingly unlikely to occur... global emissions are growing very strongly... On the current trajectories you would have to say plus 3°C is looking more likely" (Minchin, 2007b).

The shift in the pragmatic goal is plain in the 2007 IPCC Working Group III report. Of the 177 research scenarios assessed for future emissions profiles, only six dealt with limiting the rise to the range of 2–2.4°C. By contrast, 118 covered the range of 3.2–4°C, which suggests that the IPCC scientists, following the lead of the politicians, have also largely shifted focus from 2°C (IPCC, 2007).

⁶ 'Unlikely' does not mean that there would be a negligible chance (eg. less than one in a million). Instead it means that there is a 15% chance.

This whole dialogue about 450 ppm or 550 ppm, 2°C or 3°C needs to be considered from two other perspectives: climate sensitivity, and the threat of triggering mass loss of ocean algae.

If we accept the view that long-term climate sensitivity (including “slow” feedbacks) is around 6°C, then a doubling of CO₂ levels to 550 ppm will in the end produce a 6°C increase. To be brutal, Stern’s 550 ppm target is a 6°C increase and contemplating a 550 ppm policy target for Australia is setting an equilibrium temperature rise of 6°C as policy. And we know that “the last time the planet was 5°C warmer, just prior to the glaciation of Antarctica about 35 million years ago, there were no large ice sheets on the planet. Given today’s ocean basins, if the ice sheets melt entirely, sea level will rise about 70 meters” (Hansen, 2007e).

And what if a target of 550ppm were to result in the destruction of the ocean’s greatest CO₂ sink? In peer-reviewed research published in “Nature”, it was demonstrated that it is likely that when CO₂ exceeds 500 ppm, the global temperature suddenly rises 6°C and becomes stable again at this elevated temperature despite further increases or decreases of atmospheric CO₂ (Lovelock and Kump, 1994). This contrasts with the IPCC models that predict that temperature rises and falls smoothly with increasing or decreasing CO₂. Explaining the research, Lovelock points out that as the ocean surface temperature warms to over 12°C, “a stable layer of warm water forms on the surface that stays unmixed with the cooler, nutrient-rich waters below. This purely physical property of ocean water denies nutrients to the life in the warm layer, and soon the upper sunlit ocean water becomes a desert”, recognized by the clear azure blue, dead water of most of today’s ocean surface. In such nutrient-deprived water, ocean life cannot prosper and soon “the surface layer is empty of all but a limited and starving population of algae”. Algae, which constitute most of the ocean’s plant life, are the world’s greatest CO₂ sink, pumping down CO₂, as well as contributing to cloud cover by releasing dimethyl sulphide (DMS) into the atmosphere, a gas connected with the formation of clouds and with climate, so that warmer seas and fewer algae will likely reduce cloud formation and further enhance positive feedback. Lovelock says severe disruption of the algae/DMS relation would signal spiralling and irreversible climate change. Algae prosper in waters below 10°C, so, as the climate warms, the algae population reduces. The modelling of climate warming and regulation by Lovelock and Kump suggests that “as the CO₂ abundance approached 500 ppm, regulation began to fail and there was a sudden upward jump in temperature. The cause was the failure of the ocean ecosystem. As the world grew warmer, the algae were denied nutrients by the expanding warm surface of the oceans, until eventually they became extinct. As the area of ocean covered by algae grew smaller, their cooling effect diminished and the temperature surged upwards.” The end result was a temperature rise of 8°C above pre-industrial levels, which would result in the planet being habitable only from the latitude of Melbourne south to the south pole, and northern Europe, Asia and Canada to the north pole (Lovelock, 2006).

So, just as events on the ground compel us to conclude that the cap needs to be substantially less than 1°C, we are now getting the third degree (in reality, the sixth degree) as 2°C fades as a supposedly “unrealistic” compromise. Policy and goal-setting seem precariously wedged between scientific need and political “reality”, an ambivalence keenly expressed in Stern’s work.

The science established long ago demanded a cap well below 2°C to avoid dangerous impacts. James Hansen — before the Arctic summer of 2007, which will likely cause a further revision downward in his work — pointed to the need for a cap that was *a safe amount less than 1.7°C*: “Earth’s positive energy imbalance is now continuous, relentless and growing... global warming of more than 1°C above today’s global temperature [of 0.7°C] would likely constitute ‘dangerous anthropogenic interference’ with climate... This warming has brought us to the precipice of a great ‘tipping point’. If we go over the edge, it will be a transition to ‘a different planet’, an environment far outside the range that has been experienced by humanity. There will be no return within the lifetime of any generation that can be imagined, and the trip will exterminate a large fraction of species on the planet” (Hansen, 2005a, 2008). We have to keep reminding ourselves that Hansen is talking as a scientist; this is not just a rhetorical flourish to enliven his prose.

“This information raises the possibility that today’s CO₂ amount, ~383 ppm, may be, indeed, likely is, already in the dangerous range.”

Hansen has also suggested that an increase of “even 1°C [over the present] may be too great” (Hansen, 2007a), and more recently that: “Proxy measures of CO₂ amount and climate simulations consistent with empirical data on climate sensitivity both indicate that atmospheric CO₂ amount when an ice sheet first formed on Antarctica (34–35 million years before present) was probably only 400–600 ppm. This information raises the

possibility that today’s CO₂ amount, ~383 ppm, may be, indeed, likely is, already in the dangerous range” (Hansen and Sato, 2007b). In court testimony in Iowa, Hansen reaffirmed this view: “I am not recommending that the world should aim for additional global warming of 1°C. Indeed, because of potential sea level rise, as well as the other critical metrics that I will discuss, I infer that *it is desirable to avoid any further global warming*” (Hansen, 2007e).

But presumably because such a 1.7 °C (over pre-industrial) cap required drastic, politically challenging action, it was judged “impractical” and a pragmatic, diplomatically acceptable tradeoff of 2°C was agreed upon. Now as emissions grow even more rapidly than expected, the 2°C cap is now looking “impractical” and 3°C hangs in the air as “looking more likely”. One could imagine that in another decade, 3°C will be looking “impractical” and 4°C will be “looking more likely”. Like heating a frog slowly, with only one certain outcome.

2.6 How to avoid dangerous climate change

Caldeira [based at Carnegie Institution, Stanford University] said that he had recently gone to Washington to brief some members of Congress. “I was asked, ‘What is the appropriate stabilization target for atmospheric CO₂?’ “ he recalled. “And I said, ‘Well, I think it’s inappropriate to think in terms of stabilization targets. I think we should think in terms of emissions targets.’ And they said, ‘O.K., what’s the appropriate emissions target?’ And I said, ‘Zero.’” — Elizabeth Kolbert in *New Yorker* magazine, November 2006 (Kolbert, 2006)

What is the equilibrium atmospheric CO concentration consistent with a safe-temperature cap? What emissions scenarios are needed to return to that concentration, and by when? What principles should be applied in the allocation of emissions reductions between nations?

2.6.1 Target history

It is worth reviewing how such commonly accepted targets as the 2°C cap and the 60/2050 target came to achieve prominence in the climate debate.

The first goal set by a forum of international significance was the advocacy by the “International Conference of the Changing Atmosphere” in Toronto in 1988 of a 20% reduction in 1988 CO₂ levels by 2005.

In 1990, the first IPCC Scientific Assessment Report pointed out — for educational rather than policy purposes — that if CO₂ emissions were to be stabilised at the then current level of around 350 ppm it would require a 60%–80% cut in emissions. This guesstimate was superseded four years later when the CSIRO reported the results of 10 world climate models (Enting, Wigley et al., 1994), eight of which showed that the reductions required to stabilise the atmosphere at 350 ppm CO₂ would likely be more than 100%. That is, CO₂ emissions would need to be completely eliminated and CO₂ would need to be taken out of the air for 50–90 years. It had already been established that CO₂ levels had not exceeded 300 ppm for the last 160,000 years (Barnola, Raynaud et al., 1987), so there seemed no a priori reason why 350 ppm had been taken as a reasonable target.

By 1997 governments were not thinking of cuts on anything like this scale and the Kyoto Protocol finally settled for developed country emissions to be 5% less than the 1990 level by 2012. This would result in annual additions of CO₂ to the atmosphere of around of 6 billion tonnes, which would not stabilise greenhouse gases in the air for hundreds of years and the CO₂ level would likely climb past 1000 ppm (Weaver, Zickfield et al., 2007), this being more than three times the highest level in the last million years.

Realising that the Kyoto cuts were inadequate, the United Kingdom’s 2000 Royal Commission on Environmental Pollution recommended that if greenhouse gases were to be stabilised at 550 ppm

CO₂e, then emissions from Kyoto Annex I (developed) nations would need to be reduced by 60% below 1998 levels by 2050. It was argued that this target was needed if the world was to avoid a 2°C warming, but six years later the Stern Review published data indicating that if the atmosphere was stabilised at 550 ppm CO₂e there would be a 99% chance of exceeding 2°C. In 2003 the UK environment department found that “with an atmospheric CO₂ stabilisation concentration of 550 ppm, temperatures are expected to rise by between 2°C and 5°C” (DEFRA 2003). In March 2006 it admitted that “a limit closer to 450 ppm or even lower, might be more appropriate to meet a 2°C stabilisation limit” (HM Government, 2006; Monbiot, 2007a)

The notion of capping warming under 2°C first appeared in 1990. The Advisory Group on Greenhouse Gases of the World Meteorological Organisation, International Council for Science and the United Nations Environment Programme identified two thresholds with different levels of risk: it argued that an increase of greater than 1°C above pre-industrial levels “may elicit rapid, unpredictable and non-linear responses that could lead to *extensive ecosystem damage*” with warming rates above 0.1°C/decade likely to lead to rapidly increasing risk of significant ecosystem damage. It also indicated that a 2°C increase was determined to be “an upper limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly” (Rijsberman and Swart, 1990). Ignoring the clear dangers of even a 1°C cap, the European Union’s Environment Council adopted the more dangerous 2°C cap in 1996.

2.6.2 Emissions, temperature rises and carbon cycle

The average global temperature increase is 0.8°C over pre-industrial levels, with another 0.6°C in the pipeline, plus the Arctic “albedo flip”. The CO₂ level is now increasing by more than 2 ppm annually, which will result in a temperature increase of around 0.2°C per decade. Atmospheric CO₂ has grown 35% faster than expected since 2000 due in part to deterioration in the ability of the land and ocean to absorb carbon from the atmosphere at the required rate (Canadell, LeQuere et al., 2007), so this rate will rise. If this carbon sink efficiency continues to decline as predicted, and the world continues to produce emissions through “business as usual” (Hansen, 2005b), the suggestion that the annual rate may be 3–4 ppm by mid-century may be conservative. If realised, this would ultimately result in an ecosystem-destroying 1°C temperature increase every 25 years, or 0.4°C per decade.

Global annual human CO₂ emissions in 2006 were 9.9 gigatonnes of carbon (GtC) (Canadell, LeQuere et al., 2007) but a current imbalance in the Earth’s “natural” carbon cycle allows a net 4GtC of human emissions to be absorbed by the Earth’s carbon sinks (Jones, Cox et al., 2003), although this is climate sensitive and decreasing. So, for example, if humans tomorrow reduced their total emissions by 60% to 4GtC/year, the level of atmospheric CO₂ would not continue to increase if the carbon cycle maintains its present pattern. If the non-CO₂ gases were also appropriately reduced, the temperature would not exceed 1.4°C. A safe-climate target requires further action: for example, reducing CO₂ emissions to zero so that the sinks could slowly draw down CO₂ levels (by about 1–1.5 ppm annually); and action on non-CO₂ emissions would result in a stabilisation temperature lower than 1.4°C. If we can find the way to engineer further drawdowns of CO₂, that will also help.

The capacity of the Earth’s carbon sinks to absorb human emissions is expected to fall from 4GtC/yr to 2.7GtC/yr by 2030 (Jones, Cox et al., 2003) due to both human activity and as a consequence of higher temperatures. Recent data suggest that the carbon cycle is already moving in this direction (Knorr, Gobron et al., 2007; Canadell, LeQuere et al., 2007). Declining sink capacity means that it will take deeper emissions cuts to reach a target in 2030 than it would to reach the same target today: the longer emission cuts are delayed, the more elusive the target becomes.

2.6.3 The 2°C scenarios

If we accept that the present rise of 0.8°C is dangerous, the scale of the problem we face is qualitatively different from the widely advocated 2°C cap which allows another 40 years to reduce emissions to 60–80% below 1990 levels (by which time we would have added a further net amount of 80–100 GtC to the atmosphere). Nevertheless even the 2°C scenarios require Australian per capita emissions to be reduced from their current levels by more than 95% as we will shortly demonstrate, a proposition that falls way outside the current public discourse. And that opens the way to a new conversation about the speed and depth of action required.

Amongst others, the European Union, the IPCC and the International Climate Change Taskforce propose a temperature cap of 2°C to avoid “dangerous anthropogenic interference with the climate system”. For a 2°C cap it is suggested that in the long run CO₂e (total) needs to be below 400 ppm, and significantly less if the risk of overshoot is to be low:

- Meinshausen (2006b) calculates that “Our current knowledge about the climate systems suggests that only stabilization around or below 400 ppm CO₂ equivalence will likely [85% probability] allow us to keep global mean temperature levels below 2°C in the long term”.
- Retalack (2005) found that “To have an 80% chance of keeping global average temperature rise below 2°C... greenhouse gas concentrations would need to be prevented from exceeding 450–500 ppm CO₂-equivalent in the next 50 years and thereafter should rapidly be reduced to about 400 ppm CO₂-equivalent”.
- To have a ‘very low to low risk’ (a 9–32% chance) of exceeding the 2°C threshold, “global emissions of carbon dioxide (CO₂) ... which stand at 380 ppm today, [will need to] peak at between 410–421 ppm mid century, before falling to between 355–366 ppm (CO₂) by 2100” (Baer and Mastrandrea, 2006). This 2100 maximum is equivalent to about 400 ppm CO₂e.

It should be noted that none of these scenarios take into account the rapid loss of large ice sheets, such as the Arctic sea-ice, and in that sense are behind the times.

Apart from CO₂, a number of other greenhouse gases (including methane and nitrous oxide) contribute to global warming, whilst human-induced aerosols produce a counter cooling effect. At the moment these effects cancel out each other, though there is significant uncertainty in quantifying the cooling effects of aerosols. Emissions scenarios depend on what assumptions are made about these non-CO₂ forcings and their future emission paths. Additional uncertainty arises if climate sensitivity is greater than 3°C, in which case the emissions cap of 400 ppm CO₂e would need to be reduced or the risk of overshooting would increase. It has been suggested that “in the light of the uncertainty in our knowledge of the climate sensitivity, a long-term temperature target (such as 2°C...) can provide little guidance to near-term mitigation requirements” (Rive, Torvanger et al, 2007). So, in putting numbers to these emissions scenarios, we recognise that this is, in the end, a less than precise business.

“2°C scenarios ... are characterised by a very sharp turnaround in emissions compared to “business as usual”, falling to or below the Earth’s net carbon sink of 4GtC by 2050 and then declining towards zero.”

Based on current data, a number of 2°C scenarios are illustrated in Figure 5. They are characterised by a very sharp turnaround in emissions compared to “business as usual”, falling to or below the Earth’s net carbon sink of 4GtC/year by 2050 and then declining towards zero.

There are large uncertainties about the relationship between the level of greenhouse gases in the atmosphere and the long-term (stabilisation) temperature that will

result — for example the question of climate sensitivity — which require outcomes to be expressed in ranges, or probabilities of outcomes. The Stern report, using the Hadley Centre ensemble, shows that in the long term, greenhouse gas levels of 400 ppm CO₂e have a 33% probability of exceeding 2°C, a 3% chance of passing 3°C and a 1% chance of exceeding 4°C (Stern, 2006c: Box 8.1). Application of the precautionary principle would lead us to not accept a long-term target of 400 ppm CO₂e for a 2°C cap because of the unacceptable risk of hitting temperature rises of 2–4°C.

Because today’s figure of 380 ppm CO₂e is close to the long-term cap of 400 ppm CO₂e, and emissions are still rising, the 2°C strategies depend on a “peak and decline” strategy. Because of the time lag between the increase in greenhouse gas concentrations and the increase in temperature “the atmosphere need never reach the maximum level of temperature ‘implied’ by the greenhouse gas concentration peak... on the understanding that CO₂ concentrations can be reduced by lowering annual emissions below the level of CO₂ which is absorbed by global carbon sinks...” (Baer and Mastrandrea, 2006). This is illustrated in Figure 5, where the emission trajectories in the second half of the century drop well below the net sink capacity, which theoretically will reduce greenhouse gas levels before the full effect of earlier emissions is felt. That is, tolerating higher earlier emission levels will buy the time needed to get emissions well below the Earth’s net carbon sink, thus compensating for the carbon binge before the day of reckoning arrives.

Meinshausen describes the process: “Fortunately, the fact that we are most likely to cross 400 ppm CO₂eq level in the near-term does not mean that our goal to stay below 2°C is unachievable. If global concentration levels peak this century and are brought back to lower levels again, like 400 ppm, the climate system’s inertia would help us to stay below 2°C. It’s a bit like cranking up the control button of a kitchen’s oven to 220°C (the greenhouse gas concentrations here being the control button). Provided that we are lowering the control button fast enough again, the actual temperature in the oven will never reach 220°C” and thus for a 70–90% chance [i.e. 10–30% failure risk] of staying below 2°C Meinshausen maps an “initial peak at 475 ppm CO₂eq” for the long-term return to “400 ppm CO₂eq stabilization scenario” (Meinshausen, 2006a; Meinshausen, 2006b).

But “peak and decline” as a strategy increases the risk of “overshooting”, that is, the possibility that “on the way to an overall emission reduction target by 2050, interim targets... might be relaxed for economic reasons, leading to an overshoot in atmospheric CO₂ concentration. This could lead to a threshold concentration of CO₂ to be crossed, activating the natural feedbacks ... and therefore rendering the original target impossible. The bottom line for policy is that not only is an ultimate target CO₂ concentration based on the biophysics of the climate system critical, the pathway to that target is just as important as the ultimate target itself. This raises the most difficult question that climate policymakers will face: what is the appropriate trade-off between the costs of mitigating climate change and the risk that crossing a critical CO₂ concentration threshold could have catastrophic consequences for modern civilisation?” (Steffen, 2007).

Another looming problem is that “peak and decline” assumes emissions will eventually be cut to below the Earth’s net carbon sink capacity and this will lower the level of greenhouse gases from the “peak” before their full force is felt. If the weakening of the carbon sinks as predicted (Jones, Cox et al., 2003a; Jones, Cox et al., 2003b) and observed (Canadell, LeQuere et al., 2007; Raupach, 2007; Raupach, Marland et al., 2007) is sufficiently large, this effect will not be available and “peak and decline” will be a failed strategy and atmospheric greenhouse gases will be stranded at a far higher level than planned. Is this a prudent risk to take?

Staying a moment longer with the 2°C/400 ppm CO₂e scenario, how much would emissions have to be cut?

- Baer and Mastrandrea (2006) say that “global emissions of CO₂ would need to peak between 2010 and 2013, achieve a maximum annual rate of decline of four to five% by 2015–2020, and fall to about 70 to 80% below 1990 levels by the middle of the century. This would need to be matched by similarly stringent reductions in the other greenhouse gases.”
- “To avoid a likely global warming of more than 2°C... global emissions would need to be reduced... around 50% by 2050 [relative to 1990 levels]. Per capita greenhouse gas emissions would need to be reduced by around 70%, so that global emissions could be halved despite the globally increasing population” (Meinshausen, 2006b).
- Rive, Torvanger et al. (2007) find that, using mid-range sensitivity, to obtain a 50% chance of preventing more than 2°C of warming requires a global cut of 80% by 2050 if total emissions peak in 2025 at 14 GtCe. [For a lower risk of failure than 50%, the emission cuts would need to be substantially higher than 80%!]

Now comes the crunch for Australia. Because Australian emissions are five times the global average, and the world population will be half as large again by 2050, these scenarios require Australian per capita emissions to be cut by around 95% by 2050⁷ based on the principle of “contraction and convergence”. And all that for a 2°C cap that is nowhere near sufficiently risk-averse!

⁷Taking the lower-effort case of an overall 50% cut by 2050, this requires 1990 global emissions of 6 GtC/yr to be reduced by 2050 to 3GtC/yr. Spread over an estimated population of 9 billion people by 2050, and assuming emissions per person converging everywhere to the global average based on the principle of “contract and converge”, this is a per person target in 2050 of 0.33 tonnes of carbon per year or an average global reduction from now of 80% per person. Australian emissions in 2004 were 5.63 tonnes of carbon per person per year so that the per capita reduction for Australians from 2004 to 2050 would be 94% (Australian Government “National Greenhouse Gas Inventory 2004”: total emissions 564.7 MtCO₂e, of which 73.5% were CO₂; total population 20.2 million; 1 tonne carbon = 3.65 tonnes CO₂. So $(564.7 \times 10^6) \times (73.5/100) / (20.2 \times 10^6) / 3.65 = 5.63$ tonnes of carbon emissions per head).

If the scenarios suggesting a global 70 to 80% cut are considered, the required per capita reduction is more than

A 2007 report for the UNFCCC leads, by inference, to similar conclusions: it shows that for a stabilisation scenario of 445–490 CO₂e (which is too high!) leading to an equilibrium temperature increase (using best estimate climate sensitivity) of 2–2.4°C (which is too high!), emissions for Annex I parties need to decrease 25–40% on 1990 levels by 2020 and 80–95% on 1990 levels by 2050 (UNFCCC, 2007). Here we are obliged to note that this UNFCCC paper and the IPCC 2007 synthesis report (from which it draws the data) both fail to set out stabilisation scenarios of less than 445 ppm CO₂e despite the basis in the literature to do so for stabilisation levels of 2°C, again suggesting that for these institutions the 2°C target is off the agenda, though stabilisation levels of up to 6.1°C are considered worthy of inclusion!

“Because Australian emissions are five times the global average, the 2°C scenarios require Australian per capita emissions to be cut by around 95% by 2050.”

If the carbon sinks continue to weaken or long-term climate sensitivity is higher or less certain than generally accepted (Roe and Baker, 2007), or we want to take a lower level of risk, a cut in Australian per capita emissions of 95% by 2050 is not enough for the 2°C cap. Canadell, LeQuere et al. (2007) find that recent changes in carbon levels “characterize a carbon cycle that is generating stronger-than-expected and sooner-than-

expected climate forcing.” In lay terms, that means many climate models may be off the mark since only the most gloomy have forecast less-efficient carbon sinks than in the present.

From this vantage point, Labor’s advocacy of a 60% cut in total Australian emissions between 2000 and 2050 is not within coo-ee of a 2°C target, and not a 3°C target either.

As to the proposal floated in Labor’s May 2007 policy statement that it may be reasonable to limit emissions to 550 ppm CO₂e (total), we note that the Hadley Centre data ensemble finds that at this level there is a 99% probability of exceeding 2°C, a 69% chance of exceeding 3°C, a 24% probability of exceeding 4°C and a 7% risk of going beyond 5°C (Stern, 2006c: Box 8.1). No further discussion is required.

Other shortcomings in Labor’s May 2007 “60/2050” policy statement are reviewed in Appendix 1.

2.7 Global equity and climate action

For the sake of exposition, the above discussion used the “contraction and convergence” model as advocated by the Global Commons Institute⁸ to put figures to Australian emissions reductions for a 2°C world. It is well recognised that “contract and converge”, where every global citizen regardless of their level of economic development or capacity to construct a low-carbon life is allocated the same emissions quota or ration, is not a practical possibility on equity grounds, or politically, as a number of the more diplomatically-significant developing nations have pointed out. The developed economies are responsible for most historic atmospheric carbon emissions (and indeed most emissions since 1990), and they have both a greater responsibility and capacity to mitigate and provide resources to the world’s poor to allow a safe-climate path to development.

In a September 2007 report, the global investment bank Lehman Brothers called for a “global warming superfund” and strongly implied that nations should pay into it on the basis of their historical emissions, a sentiment we strongly support:

“The United States, the European Union, Japan, and Russia are estimated to have accounted jointly for nearly 70% of the build-up of fossil-fuel CO₂ between 1850 and 2004. Developed countries are also, directly or indirectly, responsible for much of the destruction of the world’s carbon sinks, most notably its forests. By contrast, India and China are estimated as having contributed less than 10% of the total... Developing countries are already making the point that the ‘social’ cost of carbon — and therefore the total abatement cost — is as high as it is because of past emissions. Hence, they argue, the developed countries should be paying for the amount by which the ‘social’ cost of carbon is higher than it would

96% on Australia’s 2004 emissions.

Or from another angle, Australian emissions are about five times the world’s average, so an average cut around the world of 50% demands 90% from Australia on the “contract and converge” principle, and an average cut around the world of 80% demands 96% from Australia as a nation. Then add in rising population.

⁸ www.gci.org.uk

have been but for their actions ... Those nations responsible for the bulk of the release of CO₂ into the atmosphere in the past could agree to pay for these responsibilities by paying into a global warming 'superfund'. That fund could in turn be used to reduce the amount that would otherwise be paid by the emerging countries in respect of their future emissions — or, of course, to pay for example for research and development, or adaptation" (Llewellyn and Chaix, 2007).

More systematically, a "Greenhouse Development Rights" (GDRs) framework has been designed by the US-based climate think-tank EcoEquity to support an emergency climate stabilisation programme while, at the same time, preserving the right of all people to reach a dignified level of sustainable human development free of the privations of poverty. The framework quantifies national responsibility and capacity, with the goal of providing a coherent, principle based way to think about national obligations to pay for both mitigation and adaptation. Its authors put a persuasive case that:

"...an emergency climate program is needed, that such a program is only possible if the international climate policy impasse is broken, and that this impasse arises from the inherent — but surmountable — conflict between the climate crisis and the development crisis. It argues that the best way to break this impasse is, perhaps counter-intuitively, by expanding the climate protection agenda to include the protection of developmental equity. To that end, the Greenhouse Development Rights framework is designed to hold global warming below 2°C while, with equal deliberateness, safeguarding the right of all people everywhere to reach a dignified level of sustainable human development. This standard of living, which we might say is that of a 'global middle class,' is higher than the global poverty line, but lower than the northern middle-class standard. To be explicit, we see this right to development, and the corresponding right to be exempt from global climate obligations, as belonging to poor people, not poor countries. And, indeed, the GDRs framework proceeds transparently from this premise, first defining an emergency stabilization pathway, then quantifying national responsibility and capacity to act, and finally calculating national obligations to pay the costs of both an emergency mitigation program and strenuous adaptation efforts. Moreover, it does this for all countries, and in a manner that takes income disparities within nations into explicit account. By so doing, it seeks to secure for the world's poor the environmental space and resources needed for low-carbon development. Given this goal, the GDRs framework inevitably allocates to the wealthy and high-emitting, in both the North and the South, the costs of the necessary mitigation and adaptation, and does so no matter how large (or small) these costs turn out to be. Such an approach may appear improbably ambitious, but we nevertheless see GDRs as being 'realist,' albeit in a new way. Rather than treating short-term political constraints as immutable, we've sought to construct a transparent framework capable of catalysing and then supporting an emergency climate program that could actually meet the long-term challenge before us" (Baer, Athanasiou and Kartha, 2007).

Under this framework, the GDR Responsibility and Capacity Index allocates Australia's share of the total global cost of meeting the 2°C cap at 1.7%, not an outrageous proposition. For the developed economies, the GDRs framework requires CO₂ emissions to reach zero between 2020 and 2025.

2.8 Goals for a safe-climate world

In summary, we propose the following framework and goals for a safe-climate world.

Creating a framework

All policy positions have a values framework. If the goals of climate policy are to be well formed, it is desirable to make the underlying values explicit. For example, who or what are the goals intended to benefit? And what level of risk of adverse outcomes are the goal-makers proposing on behalf of the beneficiaries?

In setting goals for limiting damage from climate change, it is useful to apply a homeostatic management model, in which it is assumed there is a range of conditions that are safe, and a series of goals and actions are developed to keep environmental conditions within that safe zone or to return them to the safe zone if they have, or are likely to, stray beyond it.

“Action based on goals should be doubly-practical: they should deliver tangible results in the real world ... and crucially they must also fully solve the problem.”

The homeostatic system’s goals need also to take account of the speed, momentum and anticipated continuity of change — both of movement away from the safe zone and of action needed to move the system conditions back to the safe zone.

Action based on these goals should be doubly practical: they should deliver tangible results in the real world (and not be just discussion or hand wringing), and crucially they must

also fully solve the problem in a timely and equitable way.

Generating a desirable set of goals

Values: In public discussion about climate change it is clear that motivations for action include concerns for people in various parts of the world and for other species, and for current and future generations. These concerns can be amalgamated into a concern to “protect the welfare of all people, all species, and all generations”. Actions in any locality would need to be cast in terms of this overall commitment.

Risk preference: When designing aircraft, bridges, large buildings or approving new pharmaceuticals, strict risk standards are applied, with a widely used rule-of-thumb being to keep risk of mortality to less than one in a million. The Apollo moon programme aimed to keep the risk of the Saturn rockets plunging into population centres to less than one in a million, to have a less than one in a thousand risk of the astronauts losing their lives, and to have less than a one in one hundred chance of mission objectives not being achieved. When it comes to climate change and the viability of the whole planet, it doesn’t make sense to apply a lesser standard of risk aversion. So we should aim, for example, to have less than one in a million chance of losing the Greenland and West Antarctic ice sheets or failing to recover the Arctic summer.

Defining dangerous climate change: The most commonly used definition of dangerous climate change is linked to the 2°C warming threshold, which seems to have been established on the basis that:

- many climate impacts have been assessed to be so bad beyond 2°C that the arguments for preventative action seem overwhelming;
- models suggest that many self-reinforcing positive feedbacks are well entrenched past 2°C; and
- the Earth has not been warmer than 2°C for the last million years and we suspect that species and earth systems might have difficulty adapting to such a new state.

This focus on future potentially catastrophic change has tended to blind us to the possibility that comparatively much milder impacts in the near term may be so severe that societies will have great difficulty coping. Since the end of the last ice age and the rise of human civilisation over the last 8000 years, the climate has been comparatively stable and benign, but there have nevertheless been times when civilisations have collapsed due to climate change. Near-term temperature increases of a lot less than 2°C may bring some human societies undone, so careful attention should be paid to at least three useful indicators of dangerous climate change. These are changes that:

- exceed the capacity of human societies and other species to cope with climate or other atmosphere-mediated challenges (such as ocean acidification) and to recover from the impacts;
- trigger positive feedbacks (such as the loss of the Arctic triggering Greenland ice-sheet disintegration) which by themselves would be enough to take the temperature and other environmental conditions to a dangerous environmental state; or
- reduce the capacity of natural carbon sinks.

The safe zone

The first step would be to use precautionary rules-of-thumb to provide a crude sense of the possible outer boundaries. We know that over the last million years the global average temperature has not been more than 1°C above the present temperature (that is, more than 1.8 °C over the pre-industrial level), that CO₂ levels take many decades to produce their full (equilibrium) warming effect, and that we have at least another 0.6°C of warming still to come from the greenhouse gases in the air now. We

also know that over the last million years the CO₂ level in the atmosphere has not been more than 300 ppm, and that while temperatures have been somewhat higher before, CO₂ levels are now nearly 30% higher than at any time in the last million years. Using these very rough indicators of a possible safe zone boundary, and with the current atmospheric CO₂ level at 383 ppm, we are clearly already well outside the CO₂ paleohistory precautionary boundary of 300 ppm. With a warming of 1.4°C already largely locked in (0.8°C current + 0.6°C in the pipeline) we are very close to the temperature-related paleohistory precautionary boundary of 1.8 °C over the pre-industrial level, without taking into account the rapid regional warming of the polar north and its global effects.

But we can also consider more specific data and emerging conditions which strongly suggest that we are much closer to a well-calibrated boundary of the safe zone than we might have thought; indeed we may have already passed over the well-calibrated boundary.

We know from the current state of the environment that carbon sinks are becoming less effective, conditions for food production are deteriorating, and conditions for other species are worsening due especially to spreading desertification and increased intensity, frequency and geographical spread of fire. The increasing incidence of major natural disasters associated with climate change — described as a “climate mega-disaster” by the United Nation’s emergency relief coordinator — is leading to donor fatigue and stretching the normal capacity of societies to cope.

One aspect worth examining in detail is the implications of the collapse of the Arctic sea-ice that became so clearly apparent this northern summer when the minimum ice extent plunged a further 22% below the previous record low in 2005.

It seems the Arctic is now routinely warm enough to eliminate all the remaining in summer without any need for the stimulus of further additions of greenhouse gases. It is already known that it will be very damaging to lose the Arctic sea-ice in summer, as this will mean that the Arctic Ocean will no longer reflect most of the incoming solar radiation, but instead will become an effective absorber of most of that energy. This physically very large “albedo flip” will lead to further warming in the Arctic of several degrees and possibly up to 10°C, and global warming of about 0.3°C, and will in turn contribute to the destabilisation of the Greenland ice sheet, adding to positive feedbacks already operating (such as the release of methane and CO₂ as a result of the melting of permafrost). Over the next century very large volumes of water are expected to be lost from Greenland, leading to metres of sea level rise. There can be no doubt that such sea level rises will constitute dangerous climate change for, at a minimum, hundreds of millions of humans and many coastal species.

It is now clear that the process of ice-mass loss from the Arctic began at least two decades ago. The temperature at this time was about 0.5°C above the pre-industrial level. So it seems reasonable, based on concern to maintain the solar reflectance value of the Arctic sea-ice, that we must keep temperatures to no more than 0.5°C warming above the pre-industrial level. Furthermore, taking this as the maximum warming cap, we can determine, using the 3°C climate sensitivity standard, that the long-run maximum level of CO₂e must not exceed 320 ppm.

“The world is already 0.3 °C warmer than our recommended temperature cap and we are 50 ppm CO₂e over the maximum greenhouse gas cap... to return to the safe zone we need to bring the temperature and the greenhouse gas levels down.”

The world is already 0.3 °C warmer than our recommended maximum temperature cap and we are 50 ppm CO₂e above the maximum greenhouse gas cap. So it is clear that:

- we have already commenced the process of causing dangerous climate change now;
- to return to the safe zone we need to bring the global temperature and the atmospheric greenhouse gases down from their present levels;
- no further greenhouse gases should be added to the atmosphere, and there needs to be a major drawing down of CO₂ using natural carbon sinks and deliberate human capture and sequestration of this gas; and

Taking into account the further 0.6°C warming in the pipeline from the current greenhouse gases in the air, the huge inertia in the economic system (driven by economic and population growth and the depletion of high quality physical resources), the increasing carbon intensity of global production, and the declining efficiency of the natural carbon sinks such that the natural system in a few decades could become a *net source* instead of a net sink for CO₂, it is now clearly an extremely urgent priority to make the needed structural changes to the economy and our lifestyles.

If one could wave a magic wand, the structural changes would be made right now, instantly, because any further addition of greenhouse gas and any further delay allows the elevated temperature to continue its damaging effects. Society's task must be to work creatively and with enormous commitment to shrink the response time down to the smallest time-period possible. Given past experiences across the world in dealing with very fast structural change, it is conceivable that the transformation could be made in as little as one or two decades if the social conditions were right.

A final issue to be taken into account is the speed with which change occurs due to environmental forcings. If changes occur slowly enough, then natural buffering processes have time to work and ecosystems and species have time to adapt to some extent. For a given level of environmental forcing the impact on species and ecosystems will usually be less if the speed of change is slow.

For example, CO₂ levels are rising in the atmosphere so fast that the oceans are less able to absorb CO₂ from the air because the process of transfer of CO₂ to the deep ocean cannot keep pace. So there is both a faster growth in CO₂ in the air and also a faster rise in surface ocean acidity (due to dissolved CO₂) than would otherwise be the case.

Already, with temperatures increasing at 0.2°C per decade, ecosystems are finding it hard to adapt or migrate to keep pace with the moving isotherms. If temperatures rise by 0.4°C per decade or more, isotherms will be moving towards the poles at 100–120 km per decade. Virtually all ecosystems will not cope with this pace of change, and will break down as a result.

The final and most profound issue when determining how quickly we need to get to a safe-climate condition is how close we are to runaway warming, the circumstance in which there is sufficient momentum from natural positive feedbacks that the warming becomes too powerful for humans to stop, no matter how hard we try. Hansen and Sato have said that the threshold for runaway warming is likely to be a 1.7°C rise above pre-industrial levels (Hansen and Sato, 2007b). As discussed in section 1.2, and considering the inertia in our present fossil-fuel-dependent energy infrastructure and in our political systems, we appear committed to passing the 1.7°C level unless we cool the earth at least enough to restore the Arctic sea ice.

How long can the Earth stay outside the safe zone before we lose the ability to pull the climate system back from the brink? At the moment we have no hard figures on this. But given what is at stake policy makers need to identify a precautionary timeline for the transition to the post-carbon economy. The safest position would be to complete the transition as fast as we can. Experience in the Second World War of the rapid change from producing consumer commodities to military equipment suggests that the transition to a post-carbon economy might be completed in as little as 10 years once a society has made a firm commitment to emergency action.

Setting specific climate action goals

In summary, the proposed action goals should be to:

- apply a risk management regime based on a 'less than one-in-a-million' chance of major breakdown in the earth system, which would damage or threaten the welfare of all people, all species, and all generations;
- reduce the current warming and keep it to less than 0.5°C above the pre-industrial level;
- reduce the current level of greenhouse gases in the atmosphere, and keep them to less than 320 ppm CO₂e (total);
- make the massive structural adjustments in as close to zero time as is humanly possible, via the application of considerable human creativity and other resources; and
- restrict the rate of climate change to less than 0.1 °C per decade.⁹

Is it feasible to pursue these goals?

Since these action goals are so much stronger than anything being advocated by mainstream organisations, there might be doubt in some people's minds about whether they are technically, logistically or politically feasible.

⁹If the other goals are achieved then the rate of upward temperature increase should be kept within this limit. But the goals should eventually result in an absolute cooling. Care would need to be taken to ensure that the cooling is not too precipitate.

The Hansen Cooling

In a draft paper released in October 2007, NASA's James Hansen argued that the impending complete loss of the Arctic sea-ice each summer (that might happen as soon as 2010) could be reversed quite quickly if the Earth could be subjected to a modest cooling because the climate system is not well buffered (Hansen and Sato, 2007b). It is subject to positive feedbacks in both directions: warming leads to feedbacks that tend to produce further warming; cooling, once established, leads to feedbacks that tend to produce further cooling.

Hansen believes that a cooling could be induced by dramatically cutting the release of global warming agents that have a short residence time in the atmosphere, curtailing the release of CO₂ as much as possible, and also trapping CO₂ already in the air by growing plants and then processing the plant material to extract carbon that can be sequestered. To get the necessary dimension of cooling for enough time to lock in a temperature trend reversal, it might also be necessary, for a few years, to use active cooling techniques too, such as injecting sulphate particles into the stratosphere.

The sustainability emergency

With the very strong action goals proposed, a legitimate concern is that this level and scale of change, in such a short time frame, is not possible in the present social and political circumstances. Huge levels of investment would be required to restructure the economy, and lifestyles would have to change to meet the proposed goals. It is hard to see the required unity of purpose during the structural change period being attained in normal political and social circumstances.

“...human societies have another mode they turn to in times of great need: the state of emergency”

Fortunately human societies have another mode they turn to in times of great need: the state of emergency. The form of emergency required to tackle this climate crisis will be different in important ways to other emergencies. It will require coordinated global actions. It will be a long emergency and the world will be very different in many ways when the emergency is over.

It is possible that governments will grasp the gravity of our situation and declare a formal state of emergency to create the right psychological, administrative and legal circumstances required to deal with the climate crisis. But most likely, a deliberate advocacy programme in support of the emergency and rapid restructuring will be needed to create the political will. Failure to declare a state of emergency is likely to result in profoundly ineffective responses to the climate crisis.

Institutionalising a scientifically-based apolitical set of goals

Once there is deep political realisation that very strong goals, such as those outlined above, are needed and cannot be held hostage to the vagaries of the political process, an effort should be made to institutionalise and depoliticise the goal-setting and goal-achievement process.

An example of this sort of mechanism may be the way interest rates in many countries are set in pursuit of an inflation policy. These countries have determined an acceptable range or band of inflation, and they require the nation's central bank to take autonomous and politically unencumbered action to adjust the interest rate to keep inflation within the acceptable range. In the case of climate change, the appropriate institutional arrangements do not presently exist, but it is not hard to imagine that once countries have established cap-and-trade systems for carbon rationing, an independent authority might be given the power and autonomy to set appropriate greenhouse reduction goals based on the interplay between preset ethical values and the actual or expected state of the environment. This or another authority would also have autonomous power to set the caps for the rationing system and/or the eco-tax rates at levels, determined through technical assessment, necessary to achieve the greenhouse gas reduction goals.

During the period of the climate crisis, society will be facing many other crises, often related to some degree to global warming impacts: the peaking of world production of low-cost oil; fresh water shortages; food shortages; the large-scale loss of biodiversity; and the possibility of pandemics. Any emergency system will need to facilitate effective action on all of the critical issues and the institutionalisation of the apolitical setting of goals will need to take into account multiple objectives too — without resorting to trading one critical issue off against another.

In summary, we have proposed that a safe-climate temperature increase cap would be 0.5°C, a level to which we should aim to return the planet if we value biodiversity and human life. *There is no ideal*

achievement timetable other than as fast as possible. The risk in saying that we should reach our target some years or decades hence is that we have got into the habit of treating the crisis as future tense, where the crunch is still to come. As practical difficulties arise we have re-calibrated the future to make the targets seem manageable, which they won't because they are incremental, and more practical difficulties arise and we recalibrate the future again, even more madly. Perhaps one day our descendants will look back and know that's how 2°C became 3°C and the seas just kept on rising — unless we find the will and the way to take the Earth back into the safe-climate zone.

Part 3: Facing up to the challenge

“We, the human species, are confronting a planetary emergency — a threat to the survival of our civilisation that is gathering ominous and destructive potential... the Earth has a fever. And the fever is rising. The experts have told us it is not a passing affliction that will heal by itself. We asked for a second opinion. And a third. And a fourth. And the consistent conclusion, restated with increasing alarm, is that something basic is wrong. We are what is wrong, and we must make it right.”

– Al Gore, Nobel peace prize acceptance speech, 11 December 2007

3.1 This is an emergency!

“This is an emergency and for emergency situations we need emergency action”

– UN secretary-general Ban Ki-moon, 10 November 2007 (ABC, 2007a)

On 13 April 1970 and 321,000 kilometres from Earth, the Apollo 13 mission to the moon was hit by an explosion which crippled the main craft, resulting in a loss of oxygen and most electrical power and water. The access panel covering the oxygen tanks and fuel cells, which extended the entire length of the main craft's body, had been blown off. Apollo Commander Jim Lovell's laconic message: “Houston, we have a problem” signalled a technological failure that led to the abandonment of mission objectives. The moon landing was aborted. The priority was survival at any cost. Life-support systems were at risk. Energy use had to be cut to a minimum. The crew shifted to the tiny lunar module and abandoned the main craft, to which the module remained attached. But the lunar module was equipped to sustain only two people for two days; now it needed to sustain three people for four days, confined in spacesuits to save oxygen, lacking heating and half frozen. CO₂ rose to dangerous levels and sequestration capacity had to be invented on the go. Course alterations had to be negotiated with inadequate mechanical control. There was no precedent, no manual, no set of pre-tested solutions. Intense creative team-work, physical and emotional support, and solving problems as they emerged combined with the driving imperative, reinforced by Mission Control in Houston, that “Failure is not an option!” The outcome was in doubt up to the last moment, but they made it, and survived to tell the tale.¹⁰

Today the message from spaceship Earth can only be: “People of the world, we have a problem”. Our planet's health and capacity to function for the journey through time is now deeply imperilled. We stand on the edge of climate catastrophe. Like Apollo 13, we have only one option and that is, for the duration, to abandon our life-as-normal project and hit the emergency button, to plan with all our ingenuity how to survive and with unshakeable determination build a path for a return to a safe-climate Earth and to act with great speed and efficacy. Our life support systems — food, water, stable temperatures — are at risk, and our consumption of fossil fuels is completely unsustainable. Energy use must be cut. The voyage will be perilous and require intense and innovative team-work to find and mobilise technological and social answers to problems. Putting aside the “cost-too-much” mantras, our collective actions need to be driven instead by the imperative that “Failure is not an option!”

If we do not succeed, we lose not just a small spacecraft but most of life on this planet.

Apollo 13, lacking its main motors and with uncertain technological control functions, had only one chance to position itself on the approach to the moon in exactly the right trajectory so that the moon's gravitational force would act to “sling” Apollo 13 back to Earth and safety. We too have only one chance to get global warming under control and guide the planet back to the safe-climate zone. If we set our approach incorrectly and don't do enough or do the wrong things, we will not have the time for a second chance.

We have already entered the era of dangerous climate change. We now know that the dynamics and inertia of our social and economic systems, if left unchecked or inadequately addressed, will sweep us on to ever more dangerous change and then, most likely within a decade, to the start of the era of

¹⁰ Thanks to David Wasdell of the Meridian Programme whose work suggested this metaphor.

simply catastrophic climate change where humans will lose all control over what happens and most of the globe will become unliveable for people and many other species (Hansen, 2006a).

It is very important to pause at this point. This description of what our future could be, if action is inadequate, is not hyperbole or rhetorical flourish to make the story more exciting. It is a very careful, measured and factual description of what we are letting ourselves slip into. It is the only conclusion to be drawn from the analysis in the first two parts of this report, and the thousands of other reports and scientific enquiries and elicitations that contribute to this view.

If climate public policy outcomes continue to be contained within the current parameters — bounded by 2°C on the “low” side and 3°C or more on the high side — they will only guarantee catastrophe, given the lessons from the Arctic summer of 2007 for ice-sheet disintegration and sea-level rises, the data suggesting that other positive feedbacks and weakening of the carbon sinks are happening more quickly and at lower temperature rises than expected, and the recognition that we are currently headed towards rates of temperature change that will tear apart virtually all natural ecosystems on the planet.

Planning to let the system run to even 2°C, let alone the increasingly-advocated 3°C, is reckless. Our targets for a safe climate, as we have established at length in the preceding section, must be to:

- apply a risk management regime based on a ‘less than one-in-a-million’ chance of major breakdown in the earth system, which would damage or threaten the welfare of all people, all species, and all generations;
- reduce the current warming and keep it to less than 0.5°C above the pre-industrial level;
- reduce the current level of greenhouse gases in the atmosphere, and keep them to less than 320 ppm CO₂e (total);
- make the massive structural adjustments necessary in as little time as humanly possible, with an unprecedented application of human creativity as well as all available economic and other resources; and
- restrict the rate of climate change to less than 0.1 °C per decade.

These are not a choice amongst many options, but a necessity for life. It requires a “crash programme” — as quickly as possible — to thoroughly decarbonise the economy in a time period measured in years to a decade or so, not decades to a century or more.

3.2 A systemic breakdown?

The usual approach to an emergency is to direct all available resources to resolving the immediate crisis, and to put non-essential concerns on the back burner for the duration.

Many people argue that in today’s world we should focus our attention exclusively on climate because a “single issue” approach is a good way to concentrate people’s minds on action, and cut through the competing, lower-priority issues. While this is a powerful practical argument, is it the right strategy? To test the approach, we need to ask whether there are issues that:

- will be seen, in retrospect, to have caused major problems if ignored;
- are of great moral significance from a caring/compassionate point of view and therefore should not be ignored;
- should be taken into account in the framing of solutions to issues that are tackled during the period of the emergency, because otherwise serious new problems will be created or existing crises will be worsened; or
- are so compelling (for any reason) in the short term that they threaten to take attention away from climate if a one-issue-at-a-time approach is applied?

When these questions are asked, it is clear there are several issues that simply must be resolved together with the climate crisis. There are those that cannot be ignored because their impacts on all people, including the rich and powerful, are so great: for example peak oil, severe economic recession, warfare and pandemics. And there are ethical issues that we should not ignore such as poverty — including adequacy of food supply at an affordable price — and biodiversity protection.

Some examples might be useful to see how this multiple issues approach might work.

It is increasingly recognised that the discovery of geological reserves of cheap conventional oil cannot keep pace with growing world demand. This problem is often referred to as “peak oil”. Its emergence is reflected, in part, in rising oil prices and the expectation they will go higher as the gap between supply and demand increases in coming years. A recent Queensland Government task force (2007) found “overwhelming evidence” that world oil production would reach an absolute peak in the next 10 years.

So should we postpone dealing with peak oil until we have solved the climate crisis? Given the enormity of the climate problem, we cannot resolve it before peak oil demands our attention in a very practical way. Or should we put off the resolution of the climate issue until we have sorted out the peak oil issue? It will take at least 10 to 20 years to carry out the economic structuring required to solve the peak oil crisis (Hirsch, Bezdek et al., 2005), yet the economic structural changes that need to be made to solve the climate crisis must be completed in the same time period. Clearly the two issues need to be dealt with together and the solutions integrated.

There are two sets of responses to the peak oil problem, focusing on supply and on demand. The supply-side solution is to substitute new sources of energy for the declining conventional oil resource by using:

- *non-conventional fossil fuel sources* such as shale oil, tar sands or from the conversion of coal or fossil fuel gas to petrol or diesel; or
- *renewable sources* such as biofuels (e.g. ethanol or methanol petrol extenders or diesel derived from carbohydrate-rich plants) or other renewable energy types such as wind, solar and geothermal to charge electric vehicles.

The demand-side solution is to find ways to reduce the need to use petroleum products and energy in general.

So if we are to solve the peak oil and climate issues together, in a way that takes appropriate account of other issues, how can we decide on the right mix of responses and appropriate solutions? To solve the climate crisis we need to eliminate human greenhouse gas emissions, take massive amounts of excess CO₂ out of the air and restore the reflectivity of the Earth surface (with clouds and ice being the strongest influences) while maintaining adequate supplies of affordable food and securing the survival of the world’s biodiversity.

If non-conventional fossil fuels were to be used and emissions released into the air, it would significantly worsen global warming. So if this supply solution is to be used, then CO₂ must be 100% captured and permanently stored. But since there is already a substantial excess of CO₂ in the air which needs to be removed faster than the natural carbon sinks can do it, we need environmentally safe and economical storage options for sequestering it. So the use of unconventional fossil fuels would either directly increase carbon emissions, or would block the sequestration of the excess atmospheric CO₂.

So perhaps instead we should use renewable energy feedstocks to replace conventional oil? The easiest way to produce renewable carbon-based fuel is to grow crops for biofuel, but the scale of petroleum use is so huge that enormous areas of arable land would be needed. This clearly competes in many cases with food production and habitat protection or restoration. The conflict with food production is already evident in the rising prices of corn (maize), soy beans and palm oil driven by rising consumption of fuel ethanol and biodiesel, especially in the US and Europe (Vidal, 2007; Sauser, 2007; Styles, 2008; Blanco 2007). And forest clearance to make way for new palm oil trees is accelerating in south-east Asia with serious implications for nature conservation (Butler, 2008).

The other possible class of responses to the peak oil crisis is to actively reduce the demand for energy, for example by replacing current cars with vehicles designed for ultra-efficiency or by enabling a switch from car travel to public transport or walking and bicycles. Another approach is to eliminate the need for mobility by changing land uses to bring destinations together or by making use of electronic “virtual travel” such as video-conferencing.

Another interesting example of the interplay between issues is the connection that now seems to exist between climate, rising oil and food prices, the sub-prime lending crisis and the risk of recession. Since the 1987 Wall Street crash, world monetary authorities have been able to use credit expansion as

a tool to stop the economy spiralling into fully-fledged recession. But now that there are strong inflationary pressures driven by rising oil and food prices (and expansionary war expenditure related to Iraq and Afghanistan), monetary authorities are not as free to use credit expansion to increase demand and for the first time in decades there is now a real chance that there will be a global recession (Blas, Giles et al., 2007).

Depending on how authorities respond, the reaction to a recession might either hinder or help effective action on climate change and peak oil. If the recession is allowed to run its course then there could be less money made available for investment in responses to the climate and peak oil crises. Or if governments invest in traditional public infrastructure areas to “prime the economic pump” then we might end up with more roads and freeways which will exacerbate the climate and peak oil problems. Only if pump-priming investment is framed with the climate and peak oil issues in mind will the response to a recession produce a virtuous cycle of change.

Systemic crisis can also be expressed when many problems come to bear on one key issue. Take food, for example. In the late 1960s and early 1970s there was concern about the likelihood of future large-scale food shortages as population was growing rapidly and there was fear that food production would fail to keep up. But generally populations did not continue to grow as fast as expected and food supply expanded rapidly, made possible by the “green revolution” which utilised new strains of higher-yield crops using increased inputs of water and fertiliser.

In many areas of the world, and especially in heavily-populated developing countries, extra water was made available through tube wells or bores. This often worked well for decades, but now groundwater stocks are running out, and in some places the water is naturally contaminated with arsenic, causing serious health problems (Pearce, 2007d).

A whole series of issues are coming together to drive a wedge between potential demand and actual supply for water. Water is running short in many areas not only because ground water has been over-used but because global warming is changing precipitation patterns and there is less usable water available.

Extreme weather events (floods, storms, extreme heat) are making it harder to get crops to market. Most of the available high-value land with agricultural potential has been utilised so there is less and less opportunity to expand the area of land under agriculture and less opportunity to replace land damaged by soil degraded by erosion and salinity. A recent UN report found that total arable land has just about reached a plateau at 14 million square kilometres, while the area under cereals has actually dropped from 7.2 to 6.6 million square kilometres between 1982 and 2002 (UNEP, 2007).

Continuing, if reduced, rates of global population growth, combined with growing incomes for large numbers of people in industrialising countries are increasing demand for food while there is growing diversion of food crops to the production of biofuels. The upshot is that the prices of many food types have been rising sharply. Between 1974 and 2005, world food prices fell by three-quarters in real terms, but now that trend has reversed with the price of wheat almost doubling in 2007 and maize, milk, oilseeds near record highs. “The Economist” food-price index increased 75% in 2007 (Weekes, 2007).

It seems the price of food (or the supply of affordable food) is becoming a key indicator of a new phenomenon: a multi-issue crisis of sustainability incorporating food, water, peak oil and global warming.

And generally, the natural physical infrastructure on which all living things depend is being put under more and more stress. Marine ecosystems are increasingly breaking down because of extreme over-fishing, and the remaining forests in many parts of the world are being permanently cleared on a huge scale, and where not fully cleared they are being broken up into isolated islands than offer less security for their dependent species and a greater chance for pest species to invade.

So there is an overwhelming case that we should not focus on climate change as a single issue. If we ignore the multiplicity of issues that could undermine life and wellbeing we may, if we are lucky, solve the climate crisis only to find that we have in the meantime crashed the life support systems of humans and other species in a multitude of other ways.

Since the beginning of the industrial revolution we have failed to build and maintain a system that enables modern society to ensure its own sustainability and the sustainability of other living species. Now we have a crisis of unsustainability with a multitude of symptoms. An effective sustainability

system would be designed to anticipate threats to sustainability and also have the capacity to restore the Earth and society to their safe zone as soon as possible.¹¹

Our urgent task is to tackle all the current threats to the ecological, social and economic systems that support us, recognising the especially grave threat posed by global warming, and in the process build sustainability into our future.

3.3 What happens when what we need to do is not “reasonable”?

If we need a “rapid mobilisation” to decarbonise production and consumption, why has climate politics so far moved in a painfully slow manner? When advocating climate action policies, how can the impasse be resolved between what needs doing quickly based on the science, and what currently seems a “reasonable” ask, taking account of the current political playing field? Understanding this fault line that runs between the two great tectonic plates of necessity and practicality is important if we are to map the terrain on which we must act.

In Part 2, we surveyed some of the forces that determine how targets have been set and framed over time. Some examples of the gap between what needs to be done and what is advocated include:

- The Advisory Group on Greenhouse of the World Meteorological Organisation, International Council for Science and the United Nations Environment Programme argued that an increase of greater than 1°C above pre-industrial levels “may elicit rapid, unpredictable and non-linear responses that could lead to *extensive ecosystem damage*” and indicated that a 2°C increase was determined to be “an upper limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly”, but the European Union’s Environment Council ignored the clear dangers of even a 1°C cap and adopted the more dangerous 2°C cap in 1996 (Rijsberman and Swart, 1990).
- The Stern report recognised a need, based in the science, for a 450 ppm/2°C cap but said it was too difficult and advocated a policy of a 550 ppm/3°C cap instead (Part 2.6).
- The Australian Labor Party’s May 2007 policy statement effectively supported a 3°C cap despite the data (some even quoted in the statement itself) which unequivocally demanded a much lower target (see Appendix 1).
- The IPCC’s failure to provide modelling for secure stabilisation at 2°C and below, despite the evidence that suggests that this is where the safe zone is located. Although the IPCC says that its role is to simply represent the science and not advocate policy, this seems to be a case of the IPCC allowing political norms to limit the scope of the research that it encourages or reports.
- Climate researchers on numerous occasions expressing privately to the authors of this report the view, for example, that the 2°C cap is too high for a safe-climate world, but sometimes advocating what they perceive as publicly-acceptable goals, saying they “won’t be listened to” if they said what they really think.
- Climate action advocates who talk of the need to occupy middle ground, a stance which turns risk aversion on its head, but is politically advantageous because it obviates the need to deal with necessary possibilities and preventative actions that are currently perceived to be “extreme”. It is dangerous to believe that “the middle-ish ground” of the science should set the upper limit on advocacy if the more severe scenarios turn out to be true, as indeed they are.
- It is not uncommon for green and climate peak advocacy organisations to make statements such as “it is more important that we agree and campaign on targets heading in the right direction than have discussions about what the targets should be”, that “it is always possible to go further and call for more later on” and so on. As a result, advocacy will often be for a

¹¹ The Natural Step principles offer very useful precautionary guidelines for the world to avoid becoming ecologically unsustainable: www.naturalstep.org. A sustainability system needs to be built on whole-systems thinking and Resilience Thinking is a very useful development of this approach (see Walker and Salt, 2006)

direction-setting and necessary but not sufficient position (“a cut of at least...”) rather than a sufficient minimum position (“a cut of...”), an approach which has become habitual.

Many people whose work centres on climate change have been struggling for so long to gain recognition for the issue, having to cope with a lack of awareness, conservatism and denialism, that they now have deeply ingrained habits of ‘self-censorship’.

In all of this there is a sense that the climate policy professionals (governments, researchers, NGOs, corporations, consultants) have established boundaries around their discourse guided by a primary concern for near-term or easy acceptability. Many people whose work centres on climate change have been struggling for so long to gain recognition for the issue, having to cope with a lack of awareness, conservatism and denialism, that they now have deeply ingrained habits of “self-censorship”. They are

very concerned to avoid being dismissed and marginalised as “alarmist” and “crazy”. But now that the science is showing that the situation is far worse than most scientists expected only a short while ago, this ingrained reticence is now adding to the problem.

Thus there is a process of “blocking” where everyone is waiting for everyone else to make the move towards advocating what really needs to be done, as illustrated in Table 1.

An associated phenomenon is the habituation of lower expectations. An NGO staffer, reflecting on her experiences, said that it has become increasingly clear to her “just how constrained the environment organisations are. It’s a legacy of 11 years of [the] Howard [government] — they’ve all come to expect so little environmental responsibility from government — so they don’t ask for much in the hope of a small gain. A very unfortunate situation”¹³. Timidity, constraint and incrementalism generally characterise recent national and State government approaches to environment issues, and the consequence is that low expectations become embedded in the relationship between advocacy organisations and government. When opportunity knocks, or changing facts on the ground demand urgent and new responses, imaginative and bold leadership does not always emerge with solutions that fully face up to the challenge. When evidence emerged in the latter half of 2007 of accelerated climate change (CAPSI, 2007) which had clear implications for appropriate targets, it appeared to have little impact on the advocacy positions of most of the peak green organisations, or perhaps they considered no change warranted. In contrast, it was recognised by some in the science community that the 2°C cap “might be regarded by many as small, but it has the capacity to culminate in major consequences, something that scientists feel is still under-appreciated in both public and private policy development” (Pearman, 2007) and a similar view was expressed at Bali by UN climate chief Yvo de Boer.

¹³ Private communication, 4 December 2007.

Table 1: Blocked at every turn

“When you warn people about the dangers of climate change, they call you a saint. When you explain what needs to be done to stop it, they call you a communist... everyone is watching and waiting for everyone else to move. The unspoken universal thought is this: ‘if it were really so serious, surely someone would do something?’... Who will persuade us to act?”

— author and policy analyst George Monbiot (Monbiot 2007b; 2007c)

Blocking: Being seen as crazy. Fear of being isolated. Being pragmatic. Going one step at a time. Only going as far as people can accept. Unwillingness to think the unthinkable and do the undoable.

All text based on actual conversations and correspondence.

Climate action groups

We trust in the science put forward by the CSIRO and the IPCC — we’re not about to doubt that — we have to trust in their abilities to lead us. They are the ones who know and we can’t say things that they haven’t and we can’t speculate on what a few scientists might be saying if it isn’t in the IPCC reports.

Scientists

Society needs to make the judgement of what it determines to be dangerous, and it’s not for us as scientists to tell you what’s dangerous or what the level ought to be, but try and inform the debate as to what the risks actually are at these various levels that society could consider.

Business

You might well be right that 60% by 2050 is not enough, but the people I talk to wouldn’t believe anything tougher. Our business is one of the good ones who know that this is a big problem, but if we are going to engage the wider business community we can only go so far.

Multi-issue environment groups

I agree with you about the goals, but I’m worried that if I put them up our lobbying wouldn’t be taken seriously. It is more important that we agree and campaign on targets heading in the right direction than have discussions about what the targets should be. It is always possible to go further and call for more later on.

Public sector

Although our climate science manager agrees with your targets... she has to stick to using scientists, not lobbyists, and science, not policy. She needs to be persuaded that setting targets and trajectories is fundamentally a climate-science issue not a political one. If we can find a scientist to make the case for real targets that you have made, this would help a lot.

Climate-friendly politicians

I can’t go further than the environment movement. I’d look extreme if I did. I know our party’s position will have to be strengthened because the science has changed but that can’t happen until after the next election/conference/ pre-selection. I wish we could go further but some people are worried that I will look too extreme in the electorate.

So who is going to lead?

This is paradoxical, because the world’s accelerating slide into demonstrably dangerous climate change is now creating new, more favourable dynamics for advocacy and leadership. These days if one takes a stand that is well-based on climate science but that is currently seen as “extreme”, it will be only months or a year or two at most before evidence from the real world will show it to be reasonable and necessary. So one would hope that the uncomfortable feeling of being too far “ahead of the pack” will pass before too long!

The reticence that people feel about going beyond the bounds of acceptability results in the advocacy of solutions that, *even if fully implemented*, would not actually solve the problem. Actions are proposed

consistent with scaled-down goals so that, for example, the “strong” position is for a cap on temperature increases of 2°C, even though it is now clear that even if we achieve a 2°C global warming, this will have already moved us into dangerous climate-change territory that may be beyond our control. NASA’s James Hansen, for example, says that if a rise of 1.7°C is exceeded, “all bets are off” (Hansen, 2006a), a position modified downwards in light of the Arctic summer of 2007 (Hansen and Sato, 2007b; McKibben, 2007).

In the examples surveyed here *the common thread is the view that the actions that the science demands we take to avoid dangerous global warming are simply incompatible with the prevailing political and economic imperatives and “realities”*. This is expressed by fears that what really needs to be done in terms of the speed and depth of the transformation to a de-carbonised economy:

- is simply not possible;
- is possible but not politically acceptable so in advocating it you will be seen as crazy and be ignored and irrelevant;
- is possible but not economically acceptable because it will cause too much disruption and lead to a recession.

Within a narrow frame of reference there is a kernel truth in these fears.

As we acknowledge in section 3.6 below, it is perfectly true that what needs to be done to deliver a safe climate, when taken as a whole, is not possible via politics and /or business as usual.

But that is precisely why there is such an urgent need to reconstruct the issue we face as a climate and sustainability *emergency*, that takes us beyond the politics of failure-inducing compromise.

Time and again, the emphasis in devising responses to global warming is on “practicality” and compromise. Most people pride themselves on being practical, getting things done in the real world, and the easiest way to do that has been to compromise and cut corners. This way you strike less resistance and it’s usually easier to get other people to support your actions. People expect you to act that way.

If you want to protect the lives of people and ensure the survival of species then there are simply limits to how much compromise is sensible... our traditional ways of being practical by compromising and cutting corners are leading to disastrous climate outcomes.

But in the case of sustainability issues, “pragmatic compromise” is a bad strategy. If you want to protect the lives of people and ensure the survival of species then there are simply limits to how much compromise is sensible. Any action (or inaction) that leads to a collapse in the ability of the environment to support large numbers of people and significant proportions of other species is not at all practical. With the climate issue, our traditional ways of being practical by compromising and cutting corners are leading to disastrous outcomes.

But there is another way of thinking about “practicality”. And it means being “doubly practical”, a necessary requirement in thinking about paths to a safe-climate world.

3.4 Making effective decisions for climate action

“The era of procrastination, of half-measures, of soothing and baffling expedients, of delays, is coming to a close. In its place we are entering a period of consequences” — Winston Churchill, November 1936 (Best, 2002)

In seeking to overcome the advocacy dilemma, what lessons can be learnt? Five key approaches stand out: pursuing double practicality, facing facts with brutal honesty, putting the science first, overcoming disempowerment, thinking beyond the “business as usual” mode.

Pursuing double practicality: Proposed actions must both be capable of being implemented, and when fully implemented, must *fully* solve the problem. For example, a 3°C cap may well be achievable logistically, but rather than solve the problem of climate safety it is very likely to result in global warming that is catastrophic, escalating beyond our capacity to affect it. So such a cap fails the test of “double practicality”.

If the world begins to seriously work on achieving a goal that cannot deliver a safe climate, that choice will either lock in serious environmental disasters or, alternatively, investments made in good faith in new industrial, urban and rural systems will have to be abandoned part-way through their economic life to be replaced by another set of investments made at a time when the environment will be breaking down and the economy will consequently be in decline as well. At this late stage the second round of investment could well fail to rescue the situation. Once again, the original course of action clearly fails the double-practicality test.

Let's take another example. One might advocate retrofitting coal-fired power stations with gas, because that will lower emissions; but if a necessary aim is complete decarbonisation of electricity generation, building new infrastructure that will continue to be carbon-emitting for its investment life is not solving the problem, but institutionalising its continuation. Similarly with the replacement of gas hot water with gas-boosted solar hot water (which continues to produce emissions). A doubly practical alternative would be electric-boosted solar hot water using zero emissions electricity from a renewable source.

When humans lived in relatively unchanging societies and environments, whether as hunter/gatherers or as peasants, it was often quite practical to approach problems in an adaptive trial-and-error way. Problems would appear relatively slowly, and errors could be corrected after the event without significant lasting damage. This mode of approach is still deeply embedded into our culture. But today in fast changing societies with high levels of technical innovation and high rates of economic growth, any problem that remains partly unsolved will be amplified as the economy grows. So the more committed a society is to economic growth, the more it must be committed to *fully* solving environmental problems in an anticipatory way, so that unsolved problem-residues do not accumulate.

This is the case for double-practicality; to be of any real use, the "solution" has to fully solve the problem.

Facing facts with brutal honesty: Problems cannot be solved fully if they are not understood fully. When a problem has trivial consequences, a misunderstanding will not matter. But if a problem has life and death implications, as the climate change issue does, then it is essential to understand the problem with the utmost clarity, unobscured by wishful thinking.

When a problem has trivial consequences, a misunderstanding will not matter. But if a problem has life and death implications, as the climate change issue does, then it is essential to understand the problem with the utmost clarity, unobscured by wishful thinking.

The British prime minister during the Second World War, Winston Churchill, understood this. Knowing that his strong and charismatic leadership style might inhibit people from telling him the truth about the progress of the war, Churchill set up an independent agency, the Statistical Office, to feed him the brutal truth, constantly updated and completely unfiltered. Equipped with both an unshakable goal and a stark understanding of exactly how grim the situation was from moment to moment, Churchill rejected all wishful thinking: "I ... had no need for cheering dreams," he wrote, "facts are better than dreams" (Best, 2002).

The purpose of facing the facts is not to wallow in anguish, but to inform the creative process so that solutions can be crafted to have the maximum chance of solving the real problems, as they actually exist, and no matter how bad they are. The worse a problem is the more vitally important it is to know its real nature.

Moreover, we should face the brutal facts even if we don't, at the start, have all the answers. We do not need a final plan in order to justify urgent climate action any more than we would expect a rescue team to have a detailed plan or a guarantee of success before they would consider whether to attempt a rescue. If a person was trapped on a mountainside, we would commit to rescuing them, then devise and try solutions until we found a way that worked. Only for trivial issues does it make sense to only take action if a solution is already known.

Management researcher Jim Collins found that companies which survived enormous challenges and continued to thrive were, without exception, the ones that had the knack for not only facing the brutal reality that they were in, but also, driven by an enormously strong will to survive, for creatively developing solutions that were equal to the problems (Collins, 2001).

Collins drew lessons from the experience of Admiral Jim Stockdale, the highest-ranking US military officer in the “Hanoi Hilton” prisoner-of-war camp during the height of the Vietnam War. Observing his own strategies for survival, and those of his fellow prisoners, Stockdale concluded that “you must never confuse faith that you will prevail in the end — which you can never afford to lose — with the discipline to confront the most brutal facts of your current reality, whatever they might be” (Collins, 2001).

This approach can be thought of as a combination of “strategic optimism and tactical pessimism”. There is a dogged determination to work for a positive outcome — “failure is not an option” — coupled with an assumption that any number of things can go wrong unless they are actively prevented.

Collins asks:

“How do you motivate people with brutal facts? Doesn’t motivation flow chiefly from a compelling vision?” The answer, surprisingly, is, “No.” Not because vision is unimportant, but because expending energy trying to motivate people is largely a waste of time... If you have the right people on the bus, they will be self-motivated. The real question then becomes: How do you manage in such a way as not to de-motivate people? And one of the single most de-motivating actions you can take is to hold out false hopes, soon to be swept away by events... Yes, leadership is about vision. But leadership is equally about creating a climate where the truth is heard and the brutal facts confronted (Collins, 2001).

To reiterate Collins’ finding, because it is so central to climate policy advocacy: *one of the single most de-motivating actions you can take is to hold out false hopes, soon to be swept away by events.*

Putting the science first: In the case of climate change facing the facts with brutal honesty required us to put the science first — meaning fully facing up to ecological impacts of our actions.

Currently climate policy is generally framed as solving the impasse between “the science” and what is “politically possible” by which is meant what is economically acceptable to governments around the world who are largely captured by corporate and bureaucratic interests.

The mantra of the former Australian Prime Minister John Howard was that he would do nothing on climate change that would “harm the economy” and it was “crazy and irresponsible... to commit to a target when you don’t know the (economic) impact”, whilst seemingly understanding not at all that failure to act would cook the planet. Asked about the impact of rising temperatures, Howard told an interviewer that a four-to-six-degree increase would be “less comfortable for some than it is now” (Jones, 2007a).

Given that dangerous climate change is dangerous, and catastrophic climate change is catastrophic, we cannot afford to do other than put the science first in the process of framing goals to achieve a safe climate.

An inverted problem is putting too much faith in technological fixes to solve all problems, including global warming. Post-enlightenment delight at the progress and capacity of technology has produced a cultural impediment to climate action: a technological over-optimism or determinism that clouds understanding of what is now required by changing human behaviour.

Overcoming disempowerment: Some say it is better not to talk about an impending disaster because you don’t want to depress people or disempower them or cause panic. But if people are really faced with a serious situation and there is some possibility that preventive or even adaptive action could be taken, then not informing people leaves them living in a fool’s paradise, unable to take useful action. If people are faced with a very bad situation it is reasonable and healthy that they should feel upset or despondent for a bit, but we know from human experience that people do not usually stay depressed if they can see a hopeful course of action or are able to engage constructively to change their circumstances. People are especially likely to restore their morale if leadership figures are actively engaged in confronting the problem, which is why people can keep their spirits up even in times of war and other disasters. And whether people panic will depend on whether or not they feel isolated, abandoned, unsupported and without any meaningful way forward.

Furthermore if we do not allow people in on the secret that climate change, if left uncorrected, is going to cause disastrous impacts, we get caught in a democratic trap. If political leaders keep problems quiet, they cannot put forward effective policies to solve them because people are not

informed or capable of giving them active support. And it is doubly impossible for the bigger political parties to provide effective leadership if many scientists, the main sources of “objective” information, do not tell the full story and environmental and climate change social advocacy groups put forward policies and demands that cannot fully solve the climate problem.

Thinking beyond “business as usual”: When confronted with the need to go beyond “business as usual” many people argue that it cannot be done because “you have to be realistic”. But this is a self-referencing argument. One of the things that makes “business as usual” such a powerful mode of operation is the widely-shared *assumption* that things will go on much as they have been. However, given that humans have been able to survive through a long history that has involved a great many crises it is obvious that it has been possible to break out of “business as usual” in the past when new ways of acting were needed — or we wouldn’t be here now!

Humans developed many of their characteristics because we were dependent on environments that were very vulnerable to abrupt climate change events including ice ages and rapid deglaciations, with sea levels rising and tumbling by tens of metres. William Calvin suggests this led to a premium being placed on cooperation and creative action within human social groups and to the massive expansion of the human brain to support these strategies (Calvin, 2002). It is clear that humans would have had to repeatedly move from the “business as usual” to crisis mode; those people and bands that failed to make the transition perished and those who were able to effectively harness their capabilities to adapt survived. We are the descendants of those who succeeded, which suggests we should have the capacity to switch out of “business as usual” mode to a productive crisis mode. The big question mark over our ability to respond is whether we have to wait till a crisis is fully upon us or whether we can anticipate it and act preventively.

The big question mark over our ability to respond is whether we have to wait till a crisis is fully upon us or whether we can anticipate it and act preventively.

Today many of us seem to be seeking to avoid the reality that over the next 10 to 20 years the economy will need to be rebuilt, and that given the required scale of change and urgency of the task, this *cannot* be done within the “business as usual” framework. Instead we are creating a “new business as usual”, an attempt to deal with the immediate pressures of the sustainability crisis in a way that minimises

the changes in business models and power relations at the expense of really solving the problems. It is a suite of responses designed principally to sustain for another decade or two the business models and competitiveness of the currently dominant firms and organisations and the lifestyles of all of us who enjoy the benefits of the high-carbon economy without paying its true price.

While the new “business as usual” mode is in many cases a well-intended response to the emerging climate and sustainability crisis, it is still an avoidance response in relation to the deeper nature of the crisis. The question then becomes can we, being both brutally honest and doubly-practical, get beyond “business as usual” in either its traditional or “new” form to build a truly sustainable society?

3.5 Climate solutions

In our day-to-day life, especially if we live in an affluent community, most problems are not a matter of life and death. So if we don’t know how to make a problem manageable we can often drop it, because partial success or even a failure to engage at all doesn’t carry great consequences for us personally.

But climate change is not an optional problem and compromise outcomes produce very serious consequences. So even when we have only limited ideas on how to solve the climate problem, we must persist with all our will. So in this section we include a brief survey of possible solutions to illustrate three propositions:

- effective action on climate change is not decades away because many perfectly workable solutions exist now;
- provided that we never forget that whenever we strike an apparently insurmountable problem, failure to work out a solution is not an option, and we can nevertheless take heart from the existence of readily available solutions in many areas;

- having a clearer idea of the nature of the physical solutions helps us to think more concretely about the political, cultural and administrative challenges if solutions are to be rolled out at the necessary scale and speed.

Since this section is intended to illustrate these propositions rather than being a comprehensive compendium of solutions for the complete sustainability emergency, the emphasis is on climate solutions, but they take into account the full spectrum of sustainability emergency issues.

To restore a safe climate we need to make changes, as fast as possible, that will result in the Earth cooling by at least 0.3 °C compared to the present. To make this possible, system changes are needed as described in Table 2.

Table 2 <i>Climate system changes</i>	<i>Method</i>
Stop adding to the positive forcings of the temperature.	Cut greenhouse gas emissions to as close to zero as possible.
Cut the current level of positive forcing. Unless cut, the current positive forcings will keep the temperature too high and will drive the temperature still higher because: (a) the system is still at least half a degree from reaching equilibrium (thermal inertia), (b) as currently structured the human economy will continue to create positive forcings, and (c) natural positive feedbacks are now adding further to the warming.	Allow natural CO ₂ sinks to draw down excess CO ₂ from the air. (See sections 1.5 and 2.6.2) Add large-scale human processes for capturing excess CO ₂ from the air and drawing it down into human created sinks. For example, on a massive scale grow trees and other biomass for making charcoal and dig it into the soil, year after year. Or grow biomass for use as biofuel and capture the CO ₂ when the fuel is combusted, then geosequester it.
Using environmentally safe options, consider adding negative forcing if this is needed to slow the peak rate of warming and bring the “Hansen cooling” ¹⁴ forward to the earliest possible time.	This might be done by growing forests that create water dynamics that (a) efficiently capture heat from the land surface and redistribute it to the upper boundary of the troposphere where it can more easily radiate into space, and (b) that also stimulate the creation of clouds with high reflectivity. Among other options that are still being studied to determine their environmental and technical suitability is the notion of seeding the stratosphere with sulphates to create a reflective layer.

3.5.1 Stopping additions to heating: cutting emissions to zero

After examining the available options for drastically cutting greenhouse gas emissions it has become clear that this goal is not beyond our collective capacity or imagination, given the innovation that has created a diverse suite of sustaining technologies over the last 30 years. “Zero carbon Britain: An alternative energy strategy” finds that by 2027 the UK could produce 100% of electricity without the use of fossil fuels or nuclear power, while also almost tripling its supply, and powering most heating and transport systems (Helweg-Larsen and Bull, 2007).

The failure so far to engineer energy use along sustainable paths is not principally a failure of technological or economic capacity, but of political and social will.

There are new, lightweight materials for vehicle construction, and household appliances that use a small fraction of the energy of those now in use. Carbon neutral buildings do work, electricity from renewables is the fastest-growing energy industry, hundreds of millions of people are moved by electric mass transport every day, and life prospered before gas-guzzling jet aircraft became aerial buses. With high-speed electric rail and advanced telecommunications we could manage without mass air travel. One study estimates savings resulting from using telecommunications networks to conserve energy and increase clean energy use at home, in the workplace and in ways we connect

¹⁴ A “Hansen cooling”, named after James Hansen who first proposed the idea, uses a modest human-induced cooling to turn the natural positive feedbacks in the climate system into reverse (so they cool the system rather than warm it), for example such that the Arctic summer sea-ice and the permafrost begins to grow back.

people to be 5% of total Australian emissions, with estimated energy and travel cost savings of \$6.6 billion per year (Mallon, Johnston et al., 2007).

The key strategies for cutting greenhouse gas emissions to zero are resource efficiency backed up by the substitution of renewable energy for fossil fuel sources. The integration of these strategies is illustrated in two sectors: industry and materials production and transport.

Efficiency: The greatest reduction in greenhouse emissions — and the most economically efficient — can be made by comprehensive and visionary efficiency programmes for energy and other resources. And the stronger the efficiency goals the higher the net environmental and social benefits — because generally the *system-wide* synergies (relating to the full suite of sustainability issues) increase with the strength of measures, rather than decrease as is expected under traditional diminishing marginal utility theory.

In California, energy efficiency programmes implemented over recent decades have held electricity consumption per capita roughly constant while overall US per capita consumption has almost doubled. A McKinsey Quarterly report says we could reduce energy consumption by 25% and save money doing it, and probably cut 50% using off-the-shelf technology, and if we knew that the price of energy would double, in say five years, we could almost certainly double our efficiency (McKinsey, 2006). Friedrich Schmidt-Bleek, founder of the Factor Ten Institute, says an overall energy efficiency improvement of 90% is achievable with commercially-available technology today (Brown, 2008). Australian researchers say a cut by two-thirds is feasible using ultra-efficient technologies and synergies, much of it paid for by lower energy bills. In Australia, a domestic solar hot water system has a typical pay-back period of 8–10 years (hot water is about one-quarter of residential emissions). So much of this transformation won't cost a cent in the long run: even replacing an inefficient incandescent light bulb with the humble compact fluorescent will bring a net benefit of \$50 or more from life-cycle energy savings and lamp replacement savings.

The scandal is that sometimes the most energy-efficient domestic technologies and appliances aren't even on the market, or businesses and consumers are not aware of the choice. A refrigerator in the USA on average uses double the electricity of a refrigerator in Europe, which in turn uses four times the electricity than the most efficient refrigerator on the market, which is currently not even available in Australia! Leading-edge fridge technology with evacuated panel insulation can reduce energy needs by 80-90% compared to the typical refrigerator in use today, cut typical peak load by 100 watts per unit and avoid supply-side investment (in generating capacity) of \$200 per household or \$1.5 billion in Australia.

World electricity demand can be cut 25% with the introduction of market-leading appliance and lighting efficiency standards (Brown, 2008).

Zero-emission homes and commercial buildings are a reality today. The UK Government has legislated that from 2016 all new homes are to be zero emission on heating and cooling, with large eco-towns already on the drawing board (Osborne 2007; Planning Portal, 2007). The French government has made a commitment that all new buildings will be net energy producers by 2020 (Real Climate, 2007). The German government has a 20-year programme to upgrade the nation's housing stock to meet high-energy efficiency standards.

Renewable energy: A suite of renewable energy technologies is now available for power generation, and "there is no technical reason to stop renewable energy from supplying 100 per cent of grid electricity" (Diesendorf, 2007b). Is such a technological turnaround feasible in a short period of time? Such events are not unprecedented. Between 1986 and 2001 annual mobile phone production rose from one to 995 million. Today 160 million people in China get hot water from solar water heaters. One-third of installed global photo-voltaic capacity is on German houses because of far-sighted policies.

The potential of wind power is immense, the technology uses 99.5 percent less water than coal (AWEA, 2007), and when geographically distributed can replace base-load fossil-fuel generators with minimal backup. Generating costs are rapidly falling, and will be economically competitive with fossil-fuels in Australia with only a modest carbon tax within two decades (MMA, 2006; Roy and Mawer, 2002). By 2020 wind power is expected to be competitive as a primary energy supplier, regardless of a carbon price signal (Mallon and Reardon, 2004). In Denmark, the government plans to generate 75% of national electricity need through wind power by 2025. By 2010 Germany will have

installed wind power potential sufficient to generate the equivalent of 40% of Australia's current electricity needs. Lester Brown's "Plan B" climate stabilisation plan involves the installation of 125,000 wind turbines around the world each year until 2020; a daunting technological task, though certainly achievable when compared to the 65 million cars produced each year (Brown, 2008).

As the scale of production increases and costs continue to decline, solar photovoltaic (PV) energy may become the cheapest source of energy in many locations because it can bypass ageing and fragile electricity grids and deliver power directly to the end user, fundamentally changing the underlying economics of energy (Bradford, 2006). Germany's PV revolution means more than 400,000 German homes have installed solar panels, and with the current growth rate of installations, Germany plans to be installing over one million solar electric units on house rooftops per year by 2010. As the scale of PV increases, and innovation continues to reduce panel prices by perhaps half in the near period, an energy-efficient Australian home will have the opportunity to be essentially self-sufficient in electricity for \$10,000-15,000. This is comparable with the cost today of building capacity for a typical home with fossil-fuel generators and the associated distribution infrastructure, without taking carbon pricing into account.

The solar thermal industry is already well established, is by far the lowest cost option for solar electricity and is on the cusp of some remarkable scale-up breakthroughs, such that it is predicted to be cheaper than coal within five years. An area of solar thermal collectors 35 kilometres square in a high-irradiance area would produce enough electricity to meet Australia's total power needs (Wibberley, Cottrell et al., 2005)¹⁵.

The Club of Rome and the Trans-Mediterranean Renewable Energy Cooperation have developed a proposal which suggests that fast deployment of concentrating solar thermal power (CSP) technology in desert areas and integration into European, North Africa and Middle East markets using a low-loss transmission grid can supply 90% of their electricity requirements. Such "additional strong and determined emergency measures" are now required, they argue, because "it is now too late to achieve the required U-turn with a business oriented slow transition to low / no carbon technologies" (TREC / Club of Rome, 2007).

A September 2007 study found that bioelectricity installed capacity in Australia could grow by 2020 to the equivalent of 8% of 2004 electricity generation, with most biomass coming from "wheat stubble, plantation forest waste, sugar plantation waste, and oil mallee; hence no land is transferred from food production to bioenergy production. Indeed, oil mallee can help to combat dry-land salinity and hence will make more land available to food production" (Diesendorf, 2007c).

Other renewable technologies such as wave and tidal power and geo-thermal will all play growing roles in de-carbonising the economy. Iceland, for example, now heats close to 90% of its homes with geothermal energy. With the introduction of a reasonable price on carbon emissions, economies of scale, continuing innovation and climbing oil prices, the suite of renewable energy technologies will become the most cost-effective means of producing electricity.

Materials production: In industry, efficiency programmes are reducing greenhouse gas emissions from energy use by as much as 80%, using smart technologies, new processes and materials, cogeneration and relocation of production to achieve synergies. Increasingly there are lower impact substitutes for materials such as aluminium, cement and steel which require large energy inputs during production.

Five broad strategies can be applied to the energy-intensive materials sector, especially metal production and cement. The first is to redesign the products and "platforms" that deliver services together with their associated supply chains so that their production and use *needs less material*. The second is to *recycle* materials in an energy and materials-efficient way to recover discarded materials. The third is to *substitute* materials that have lower embodied climate impact (where this improves the performance of the system as a whole). The fourth strategy is to *switch energy sources* used in the production of each particular type of material. And the fifth is to use long-lasting materials as a way of *sequestering excess carbon* from the air.

In practical settings these five strategies are usually combined to create the maximum impact.

¹⁵ The report establishing the feasibility of such a solar thermal project was apparently suppressed by the Howard government (Beeby, 2007a).

Needing less materials: Designing products, buildings and infrastructure to use less material depends on a range of strategies such as light-weighting, enabling long life, re-use and effective maintenance and repair. Light-weighting has been employed increasingly since the 1970s oil crisis. Previously weight was thought to correlate with strength, reliability and longevity and quality; now light-weight is thought to correlate with sophistication and quality.

Recycling: Natural systems have evolved to achieve extraordinarily high recycling rates. For example carbon recycling in natural systems is over 99% (Kump et al., 1999). The scale of the human economy is now so huge that the same imperatives will necessitate a shift to a closed-cycle economy. For example, the explosive growth in the production of mobile phones is leading to critical shortage of the geological reserves of some of the rare minerals used in the advanced electronics and recycling is beginning to look like the only way to keep the mobile phone sector viable (Cohen, 2007). Generally much more energy is required to create virgin resources than recycled resources. And to tackle the climate issue a great deal of physical transformation needs to occur — inefficient buildings, cars, products and infrastructure needing to be retrofitted or replaced in a relatively short period of time — which could involve a large new burst of CO₂ release unless the old materials are efficiently recovered from the scrapped assets and are recycled into new assets.

Substitution can make big cuts in CO₂ emissions, for example by substituting geopolymers, cement, very high-extender content cement and magnesium-based cements for the traditional calcium-based cement. And, especially where light-weighting is critical, such as car manufacture, steel can be replaced with carbon fibre from renewable sources. “Petroleum” products (a range of chemicals and plastics) made from compounds sourced from plants can be substituted for fossil-fuel-derived petrochemicals (Weaver, Jansen et al., 2000).

Switching energy sources: Remote-area mining and mineral processing operations are beginning to identify opportunities to use solar, wind and geothermal energy. Australia faces a strong challenge in the production of aluminium because it is one of the few places in the world where the industry is almost entirely dependent on electricity from coal-fired power stations. Elsewhere it is largely produced using hydro or geothermal power or fossil fuel gas power. As the world shifts away from fossil-fuelled energy, all materials will be made using climate-safe energy sources.

Sequestration: In some situations it is possible to sequester some of the excess carbon from the air into materials that can be recycled “endlessly” or where the products have very long lives. For example CO₂ from the air can be trapped through plant growth and the plant material can be pyrolysed to produce char and this can replace carbon from coal in steel manufacture. In this way steel becomes a storehouse for excess atmospheric carbon.

During the transition to a safe climate economy it will be important to coordinate the changes so that perverse results are not produced, for example greenhouse gas emissions accelerating during the physical structural change as inefficient or inappropriate products, buildings or infrastructure are replaced on an accelerated schedule. Typically, lots of cement and concrete are needed during an intense structural change period. The potential impact could be cut by ensuring that any increments to energy supply are from renewable energy sources and by preparing to switch as early as possible to low-impact sources or types of cement, concrete, steel, aggregate, and so on. To make sure the transition is as effective as possible, it needs to be pre-planned and modelled to identify opportunities for synergy.

Transport: Our aim must be to eliminate all fossil fuels from the transport sector. Electrifying rail networks to shift freight from roads and people from planes is today’s technology, and when powered by renewable energy is a zero-emission form of transportation. In France, new road construction is being severely curtailed in favour of expanded rail travel using state-of-the-art French TGV technology, which is replacing air travel on many routes due to shorter travel times, reduced check-in and security and formalities, and the convenient location of stations in city centres. The high-speed rail link between London and Paris now takes less than 140 minutes. You can wait in an airport that long! Five years of Australia’s major road funding would be enough to electrify a basic national rail network for freight. A high-speed passenger service would require new infrastructure.

Commercially available hybrid vehicles use about half the petrol of a similarly-sized car, while plug-in hybrids use a quarter of the petrol. New lightweight steel substitutes produce further efficiencies, allowing a total reduction of 90% in fuel use. Fully-electric vehicles are now available and their costs

will go down with increasing scales of production and with further innovation. Honda has unveiled a zero-emission fuel-cell vehicle with a top speed at 160 kph and a range of about 430 kilometres. Electrically assisted bikes achieve very impressive environmental performance. And a normal bicycle requires 99% less material and construction costs than a car. Changes in urban layout to bring frequent destinations together and increased density of buildings and clusters of buildings can allow cities to use walking as the principal means of mobility, with public transport and bicycles as the dominant support modes (Register, 2006).

3.5.2 Reducing the current heating processes

To reduce atmospheric carbon, the earth's natural carbon sinks must be protected and strengthened. Sinks that can respond rapidly to rising atmospheric levels of CO₂ are the oceans, where the water absorbs some of the additional CO₂ and some of it is absorbed by calcifying marine organisms with subsequent burial in sea-floor sediments. and forests and grasslands on land. The sinks may be enhanced by such measures as protecting and expanding forests, and cooling the earth will help restore the absorptive capacity of the ocean, soil and forest sinks which are currently exhibiting decreased capacity (section 1.5).

Black soil: Of great interest are processes, which human activity can actively expand, that can draw down, or sequester, excess atmospheric CO₂ in the ground. Black soil or *terra preta* refers to the product of taking biomass such as wood (the growth of which naturally removes CO₂ from the air) and turning it into char (agricultural charcoal) via a process known as pyrolysis. The carbon-rich char is then buried in the soil, locking it away from the atmosphere. These processes also provide many beneficial effects for the soil including increased water retention, and mineral and micro-organism enrichment, which increases fertility and the ability to moderate the effects of weather extremities, resulting in increased plant yields and nutritional content. The pyrolysis process releases by-products including methane and hydrogen that can be used for combustion or to feed fuel cells (Helweg-Larsen and Bull, 2007). This technology has an established ability to take greenhouse gases out of the atmosphere and reduce the current greenhouse gas concentration.

Biomass is currently being used in other ways for power generation, and research and modelling demonstrates the feasibility of biomass geosequestration as a means of reducing of CO₂ levels (Rhodes and Keith, 2005; Metz et al., 2005). The practicality and economic viability of biomass geosequestration at a sufficient level to produce negative emissions scenarios and as a means of reducing of CO₂ levels to 350ppm has also been explored (Oberstiener, Azar et al., 2002; Azar, Lingrem et al., 2006). Oberstiener suggests "as an illustration, a maximum removal rate of 5 billion tonnes of carbon a year would mean that it could take as long as 70 years before historical emissions, some 350 billion tonnes of carbon from 1850 to 2000, are reversed, assuming that no other emissions take place over this period". Johannes Lehmann of Cornell University estimates that "by the end of this century *terra preta* schemes, in combination with biofuel programmes, could store up to 9.5 billion tonnes of carbon a year — more than is emitted by all today's fossil-fuel use" (Marris, 2006).

Even if we fully deployed only the existing crop waste, "we could remove on the order of 1 billion tons of carbon per year from the atmosphere, while producing in the order of 1 billion kWh of electricity... Using forest die off might double that, or more, for a number of years, while the energy produced would replace fossil fuel sources" (Fournier, 2007).

Today we have most of the technology, and ideas needed, to build a new carbon-free economy. It is now a matter of whether we have the political will to drive a rapid transition.

3.6 Can “politics as usual” solve the problem?

“I am old enough to notice a marked similarity between attitudes over sixty years ago towards the threat of war and those now towards the threat of global heating. Most of us think that something unpleasant may soon happen, but we are as confused as we were in 1938 over what form it will take and what to do about it. Our response so far is just like that before the Second World War, an attempt to appease. The Kyoto agreement was uncannily like that of Munich, with politicians out to show that they do respond but in reality playing for time.”
— environmental scientist James Lovelock (Lovelock, 2006)

What would a rapid transition to a safe-climate economy look like? It would include:

- Building capacity to plan, coordinate and allocate resources for high priority infrastructure projects and to invest sufficiently in the means to make safe-climate producer and consumer goods.
- Fostering research and innovation to produce, develop and scale up the necessary technologies, products and processes.
- National building and industry energy efficiency programmes, including mandatory and enforceable minimum standards for domestic and commercial buildings, and the allocation of public resources to help householders, especially those with limited financial capacity, to reduce energy use.
- The rapid construction of capacity across a range of renewable technologies at both a national and micro level to produce sufficient electricity to allow the closure of the fossil fuel-fired generating industry, sometimes referred to in Australia as a project to “build several Snowy Mountains schemes” for the 21st century.
- The conversion and expansion of Australia’s car industry to manufacture zero-emission vehicles for public and private transport.
- The renewal and electrification of national and regional train networks to provide the capacity to shift all long-distance freight from road and air to rail;
- Providing safe-climate expertise, technologies, goods and services to less developed nations to support their transition to the post-carbon world.
- Adjustment and reskilling programmes for workers, communities and industries affected by the impacts of global warming and by the transition to the new economy.

Such a transition would be characterised by a managed but rapid speed of change. Speed is of the essence, so the emphasis is not just on a transition to a safe-climate economy, but a *rapid* transition. If it isn’t as rapid as humanly possible, it will fail to solve the problem. Global warming is already dangerous at a rise in global temperatures of 0.8°C with at least another 0.6°C locked into the system and impossible to avoid, and more to come given the inertia of the world’s energy and political systems. If it takes the world 10 or 15 years to stop increasing the rate of emissions increasing and another 40 or 50 years to stabilise atmospheric carbon levels, it is very likely that the resulting stabilisation temperature level (an increase of more than 2°C) and the rate of temperature increase (0.2–0.3°C/decade) will be too much for many ecosystems, let alone triggering positive feedbacks in the climate system that will escalate warming beyond control. There is even a 50% chance that warming will exceed 0.3°C for the decade 2004–2014 (Smith, Cusack et al., 2007).

We are in a struggle against time and our analysis suggests that the world will only get one shot at the major restructuring that is needed. We have to act with great speed and get the broad outlines of the needed change right the first time.

In order to allocate the resources to build new, environmentally-sustainable productive capacity, a greater proportion of national wealth will need to be devoted to producer goods (factories, equipment, new transport facilities and technologies, etc) and to household-level changes in energy use and transport methods and, for the duration of the restructuring, less of the national wealth will need to be devoted to discretionary personal consumption and associated investment.

As we have discussed, the planet’s resource use is unsustainable, so behavioural change is necessary in any case. The use of high-carbon products for which there is no available environmentally sound

technological substitute needs to be radically curtailed. Infrastructure and investments that depend on the high-carbon economy may have to be scrapped before their use-by date, or converted to other purposes.

As peak oil relentlessly drives the cost of petrochemicals up, a trend reinforced by climate policies that increase the price of carbon pollution, the way we produce and consume goods will change. Rising global transport costs will put a downward pressure on the global distribution of lower value goods¹⁶ and more goods will be produced locally, helping to rebuild national and regional manufacturing capacity and jobs. People will be more likely to travel and holiday locally, and less at long distances from home. "Food miles" and "product miles" will influence consumption patterns. We may personally move at a more planned and steady pace, and the mad rush of contemporary life may abate.

The question is how can we make this rapid transition. Can the present workings of our political system and the imperatives of a deregulated market economy make this happen very quickly? To be blunt, the short answer is no.

Look around for the proof. It isn't happening anywhere at the necessary scale and speed. Even in those countries that have worked hard to improve energy efficiency and build renewable energy capacity and better transport options, the capacity of human beings to invent new ways of using energy works against these advances: the fast-growing, high-polluting air travel sector, the air conditioner boom, or the plasma TV binge are just three examples. And in the West our conventional mode of politics is short-term, adversarial and incremental, a culture of compromise which is fearful of deep, quick change; which suggests it is simply incapable of managing the transition at the necessary speed.

In the West our conventional mode of politics is short-term, adversarial and incremental, a culture of compromise which is fearful of deep, quick change; which suggests it is simply incapable of managing the transition at the necessary speed.

Sharp changes means disruption, and disrupting business is a political sin. "Politics as usual" in the developed world places the free-market economy at the heart of its project, and governments as a matter of political faith are by-and-large loathe to intervene decisively. Even though Sir Nicholas Stern named global warming as the "greatest market failure in history", governments have been ideologically reluctant to act sufficiently to correct this greatest of market distortions.

Over the last three decades, as global warming has slowly become recognised as a phenomenon, modern capitalism may be seen as the growing domination of global finance capital over industrial capital, setting corporate activity free of national and democratic restraint. Around the world the dominant political agenda is for the free market, the release of capital from government regulation. We hear the mantras endlessly: public sector bad, privatisation good; lower taxes good, government spending bad. But as Robert Reich, the US Secretary for Labor 1993-97 notes: "free markets... have been accompanied by widening inequalities of income and wealth, heightened job insecurity, and environmental hazards such as global warming" (Reich, 2007). The neo-liberal market economy, shed of democratic control and with a fetish for monetary growth and "shareholder value", has failed the test of sustainability.

At a book launch in late 2007, Ian Dunlop, a former international oil, gas and coal industry executive, and CEO of the Australian Institute of Company Directors from 1997-2001, named the crucial issue of the next few decades as being how to "bring runaway capitalism into alignment with the sustainability of the planet and global society, and indeed with democracy?" He noted that "the political and corporate structures we have created render us uniquely ill-equipped to handle this emergency" and that "perverse [corporate] incentives have led to a paranoia with short-term performance... Organisations previously highly-regarded for their long-term thinking, have dispensed with that expertise, in the process losing valuable corporate memory." Henceforth, he argued "the rules must change to ensure long-run sustainability" and identified a number of implications:

¹⁶ A 25% increase in fuel prices produces a 10% increase in freight rates, reducing international trade by 5% according to Thomas Homer-Dixon (2007: 386). So a doubling of the oil price can reasonably be expected to cut international trade by one-fifth.

- genuine sustainable development must become a cornerstone because conventional growth is untenable;
- success must be re-defined based on long-term sustainability, not short-term consumption;
- markets must be re-designed to enhance the local and global “Commons” (Dunlop, 2007).

The corporate agenda runs politics, as Reich has articulated: “Democracy, at its best, enables citizens to debate collectively how the slices of the pie should be divided and to determine which rules apply to private goods and which to public goods. Today, those tasks are increasingly being left to the market... Democracy has become enfeebled largely because companies, in intensifying competition for global consumers and investors, have invested ever greater sums in lobbying, public relations, and even bribes and kickbacks, seeking laws that give them a competitive advantage over their rivals. The result is an arms race for political influence that is drowning out the voices of average citizens. In the United States, for example, the fights that preoccupy Congress, those that consume weeks or months of congressional staff time, are typically contests between competing companies or industries... While corporations are increasingly writing their own rules, they are also being entrusted with a kind of social responsibility or morality. Politicians praise companies for acting “responsibly” or condemn them for not doing so. Yet the purpose of capitalism is to get great deals for consumers and investors. Corporate executives are not authorized by anyone — least of all by their investors — to balance profits against the public good. Nor do they have any expertise in making such moral calculations. Democracy is supposed to represent the public in drawing such lines. And the message that companies are moral beings with social responsibilities diverts public attention from the task of establishing such laws and rules in the first place” (Reich, 2007).

In short, “business as usual” is no substitute for the state establishing such “laws and rules” as are necessary to protect “the public good”, in the present case embodied in the need for a healthy planet. Yet such a step seems beyond the political process in its usual mode. In short, “the imperative of large-scale [climate] responses clashes with the current fashion of seeking to minimize the role of the public sector” (Ackerman, 2007).

Carbon pollution is a product which, while privately enormously profitable, wreaks such public damage as to be capable of changing our planet beyond recognition. Orthodox economic theory would demand that the rational course of action is to place a price (tax) on that pollution where the marginal abatement curve (cost of reducing the damage) meet the marginal damage curve (the cost of doing more damage). This is likely to be very high — Stern says it may be over \$A100 per tonne of CO₂ — but in fact if the cost of the marginal damage (destroying the Earth’s ecosystems) is beyond value and of infinite cost, then the amount we should be prepared to pay to stop it — the abatement price — should also be infinite. But this logical conclusion, based on orthodox economics, is not top of mind for most people managing the orthodox economy.

To drive the transition, carbon must be squeezed out of the economic equation, either by putting such a high price (tax) on it that demand for it rapidly drops as other options becomes more attractive, or carbon is rationed in decreasing quantities — “cap and trade” is a fancy name for rationing — until the economy is decarbonised.

But there is a problem. We are addicted to the lifestyle of our high-carbon economy, which means — like cigarettes and alcohol which are highly taxed — that you can increase the price of carbon-intensive products a lot and people will still keep on buying them because they can’t/don’t want to go without it and they are unaware of the low-carbon alternatives. Technically, our addiction to the high-carbon lifestyle means carbon emissions have high price inelasticity and therefore simple price mechanisms are not an effective or fair means for rapidly reducing consumption towards zero. For example, the demand for petrol is highly inelastic, such that a doubling of the price of petrol only reduces demand for petrol by 10% in the short-term and 40% in the longer term as people switch to more fuel efficient cars, other means of transport, and so on. That is, to reduce the demand for petrol by just 40%, governments would need to double its price, and that is equivalent to a price on CO₂ emissions of around \$500 per tonne.

In the world of “politics as usual”, that isn’t going to happen.

So how can we make the needed rapid transition happen and where and when did we last act in a similarly decisive way to protect life from a critical threat?

The world wars are the obvious case. When life is threatened, even quality of life, people en masse know how to go beyond “business as usual” and do what needs to be done.

In the Second World War, after Pearl Harbour, the USA’s military imperatives demanded a rapid conversion of great swathes of economic capacity from civil to military purposes. Within weeks, car production lines became tank lines and manufacture of passenger cars ceased for the duration of the war, new methods to mass produce military aircraft were devised, and consumer spending was dampened by selling “war bonds” to fund the cost of rapidly expanding military production and control inflation. Price controls were introduced, and rationing of key goods was mandated as was necessary, the main result being “a striking egalitarianism of consumption, especially regarding food” (Wiki, 2007). Yet the economy, real wages and profits all grew, though civil rights were significantly curtailed.

Although not driven by a life and death struggle to survive, the rapid industrialisation of a number of Asian economies, for example the “tiger” economies of South Korea, Singapore, Taiwan and Hong Kong, and China’s current economic revolution all show what can be achieved in terms of transforming economic production when the government and a country’s enterprises work to a plan to drive up or change the character of output. In all cases industrialisation was rapid because domestic demand was held down by state policies in favour of investing in export capacity, savings rates were high, and skills development emphasised. This is not to glorify these development drives: in the Asian “tiger” economies there were very significant downsides, including autocratic rule in the service of the development elites, the suppression of labour and democratic rights, and damage to the environment. Nor are these example given because they exemplify a path to rapid *growth* (which they do) but because they demonstrate the capacity for rapid *transformation*.

What is salient is in all these cases — in both war and peace — is the key role of governments in planning, coordinating and overseeing the transition, the very opposite of leaving the deregulated market to its devices and doing “business as usual”. Voluntarily measures, “business as usual” and aspirational goals will not eliminate carbon emissions from production; they will have to be squeezed out by strong regulatory and investment actions by government. The particular nature of that government will depend on the capacity of people to build its democratic character, to provide national leadership when “politics as usual” fails to do so.

We find it inconceivable that Australia could play its fair part in meeting even an inadequate 2–2.4°C cap other than by a planned rapid transition and economic restructuring constituted as a climate “state of emergency” far beyond the capacity of the society operating in the “politics as usual” and “business as usual” mode.

Even “middle of the road” climate targets require extraordinary action. If we consider the (unsafe) target cap of 2–2.4°C, it is established that this requires developed (Kyoto Annex I) countries to cut emissions 25–40% below 1990 levels by 2020 (IPCC, 2007d). For Australia, whose emissions by 2010 will be about 10% higher than in 1990, this would require a cut in the decade from 2010 to 2020 of 35–50%, or 3.5–5% per year on average to 2020. Considering the current annual growth in Australian emissions of 1.5–2%, the total turnaround on current practice to achieve emissions reductions to 2020 consistent with the 2–2.4°C cap would be a 5–7% each year. By comparison, the best recent

record in decreasing the energy intensity of an economy was ~2.5% annually, set by Japan after the 1970s “oil shock”, and achieved in part by the export of some energy-intensive industries. In this context we find it inconceivable that Australia could play its fair part in meeting even a 2–2.4°C cap other than by a planned rapid transition and economic restructuring constituted as a climate “state of emergency” far beyond the capacity of the society operating in the “politics as usual” and “business as usual” mode.

3.7 What does an emergency look like?

“We went into World War II with biplanes and came out with jet fighter planes... If we took this problem seriously, a decade from now there would be no need to make cars that emit CO₂ to the atmosphere.” — Ken Caldeira, Stanford University climate scientist, December 2007 (Zarembko, 2007)

It is noticeable that the language used in talking about climate change is shifting from talk of a “crisis” to that of a “global emergency”. Al Gore’s film and book about the “Inconvenient Truth” has helped; in the lead up to the December 2007 Bali conference the UN Secretary-General spoke explicitly of a climate emergency. Why has the language shifted? Most likely because an emergency is a crisis that can only be solved by going well beyond “business as usual” and we cannot make this shift unless we unambiguously communicate the need to each other. Using the language of emergency is the start of this process. And perhaps the climax of the process is the formal declaration of a “state of emergency” by governments.

When a state of emergency is declared we know a number of things: that the authorities rate the problem as very serious, that priority will be given to resolving the crisis, that we are all in the crisis together, and that “business as usual” no longer applies — officially!

A state of emergency — formal or informal — is a recognition that a current or potential threat to life and health, property and/or the natural environment is sufficiently large that the response demands a mobilisation of resources beyond the normal functioning of the society or system. Such threats may be civil or military: they may be natural (fire, flood, tsunami, earthquake), political (war and conflict), biomedical (infectious disease) or result from a combination of factors (famine, population displacement).

To deal with an unfamiliar emergency it is often necessary to undertake “crash programmes” — programmes that crash through the barriers to success — to create new capability. Iconic examples of crash programmes are the Manhattan project (through which the US developed the nuclear bomb) and the Apollo programme to get astronauts to the moon. But sometimes the emergency is so demanding that the whole economy needs to be mobilised to new purposes. The experience of the two world wars comes to mind: after Pearl Harbour in 1941, the USA was able to redirect and switch from being the world’s largest consumer economy to become the world’s largest war economy within a year.

But in the case of climate change, we need to go one step further and change not only *what* the economy produces but also *how* it produces. Here the experience of Japan, the Asian tiger economies and more recently China is instructive. For example in two decades South Korea transformed its economy completely from a very poor agricultural economy to a middle-income, world-competitive manufacturing economy.

Transformational programs can either focus on scaling up of existing technologies or processes (to produce a result quickly) or pursuing fundamental innovation to solve a new problem (for example, the Manhattan project which set out to build a nuclear bomb and the related nuclear industry with virtually no knowledge at the start about how to do this). Some transformational programmes combine aspects of both scaling up and fundamental innovation (for example, the Apollo programme).

All of these very fast, large-scale transformations are characterised by a strong engagement by governments to plan, coordinate and allocate resources far beyond the capacity of the system’s normal functioning.

All of these very fast, large-scale transformations are characterised by a strong engagement by governments to plan, coordinate and allocate resources, backed by sufficient administrative power to achieve a rapid response or transformation beyond the capacity of the society or system’s normal functioning.

A state of emergency will likely exhibit many or most of the following characteristics in Table 3.

Table 3 <i>Normal “political paralysis” mode</i> (when crises are constrained within business-as-usual mode)	<i>Emergency mode</i> (when societies engage productively with crises — <i>not</i> in panic mode)
Spin, denial and “politics as usual”	Assess the situation with brutal honesty
No perceived urgent threat	Immediate or looming threat to life, health, property or environment
Problem not yet serious	High probability of escalation beyond control if immediate action not taken
Time of response not important	Speed of response crucial
One of many issues	Highest priority
Labour market	Emergency project teams, labour planning
Budgetary “restraint”	Devote all available/necessary resources, borrow heavily if necessary
Community and markets function as usual	Non-essential functions and consumption may be curtailed or rationed
Slow rate of change due to systemic inertia	Rapid transition, scaling up
Market needs dominate thinking and response choices	Planning, fostering innovation
Targets and goals determined by political tradeoffs	Targets and goals not compromised
Culture of compromise	Failure is not an option
Lack of political and national leadership, adversarial politics	Heroic leadership, bipartisanship

With few exceptions, the present responses to global warming may be reasonably represented as the “Normal/political paralysis” mode. We are not always brutally honest about the new climate data and its consequences, nor about the severity and proximity of the impacts that will occur if present trends continue. Necessary targets and goals are being severely compromised, and the speed of response is hopelessly inadequate and will result in global warming worsening and moving beyond our capacity to construct practical responses. There is neither effective leadership nor bipartisanship. We are not devoting the necessary resources to solving the problem, whether it be research and innovation, planning for a rapid transition, or scaling up production. Not only has failure become an option, it has become the norm. On all objective measures the world is going backwards as emissions rise at an increasing rate, events occur more quickly than expected and positive feedbacks kick in.

If the planet’s health were being cared for in the emergency ward of a hospital, at this point the priest would be on standby. In short, global warming is not being treated as an emergency, though it is the greatest threat in human history.

In short, global warming is not being treated as an emergency, though it is the greatest threat in human history. Contrast this with other emergency responses. If the planet’s health were being cared for in the emergency ward of a hospital, at this point the priest would be on standby. In a hospital emergency department when life is under threat, an immediate response is required and delay is not acceptable. Saving life is given top priority and other functions may be delayed or cancelled (e.g. scheduled elective surgery) if

necessary. Resources allocated as necessary to respond to the emergency without an arbitrary limit, with specialist labour skills on standby. Compromise in patient care is not an option. As with

runaway climate change, medical emergencies generally have only two possible outcomes: no compromise is physically possible between survival and death.

Similarly in the case of a bush fire, the normal functioning of the affected community is curtailed in so far as it necessary to save life and devote all available resources (including mobilising them from far away) to fight the fire. Speed of response is crucial, plans are made in advance, action is centrally coordinated, and specialist teams are ready and trained. No effort is spared, people are given leave from their regular jobs, whole communities support the fire-fighters and each other. Resources to fight the fire are not denied because it might “hurt the economy”.

Yet in proposing a “crash programme” to curb global warming, the response is often that drastic action is not politically possible, it will “cost too much” and “damage the economy”, waste good capital or be too disruptive. This seems a particular favourite of global warming deniers and doubters when the “science” arguments start to wither and die.

Even amongst many of those who acknowledge that global warming is an urgent problem, there is a tendency to devalue the predicted impacts. Anyone who talks about living with a 3°C rise, as some of the climate professionals do, appear not to have come to grips with what those impacts really mean in practice, in a very nitty-gritty, life-and-death way, as opposed to bouncing figures around models or negotiating tables. (We suggest that reading “Six degrees” (Lynas, 2007) and “With speed and violence: why scientists fear tipping points in climate science” (Pearce, 2007a) should be mandatory for anyone who wants to talk publicly about living in a 3°C world!) In devaluing the real impacts and therefore the economic damage, the cost of doing nothing is undervalued and the cost of action is overvalued, especially since many energy efficiency measures, for example, are cost positive rather than cost negative. The concern about “economic damage” is not that the society as a whole will be worse off by becoming more climate friendly, but that corporations who have made themselves dependent on continuing to emit large volumes of carbon pollution free of charge will be worse off and long-established personal habits and cultural norms will have to change.

That one can’t have an economy in a land not to fit to live in is a leap of imagination too big for some.

The historical evidence, for example of the emergency mobilisation in the USA for the 1939-45 war, suggests precisely the opposite to the fear-mongering of the economic damage lobby. In the period 1940–1945, unemployment in the USA fell from 14.6% to 1.9%, and GNP grew 55% in the five years from 1939. Wages grew 65% over the course of the war to far outstrip inflation, and company profits boomed, all at a time when personal consumption was dampened by the sale of war bonds, some basic goods and foods were rationed and at the height of the mobilisation 40% of the economy was directed towards the war effort.

The war economy shows that production and technologies can be switched quickly and at a huge scale when there is the need and the will. The conversion of production to war materials was extremely successful: from a small base of war production in early 1941, the United States was out-producing the combined Axis war production by the beginning of 1943. Merchant shipbuilding grew from a total of only 71 ships for the period 1930–1936, to more than 100 in 1941 alone. 127,000 military aircraft were produced in the four years from 1941, and output by 1944 was 28 times the rate in 1939.

Lester Brown sums up the case for a sustainability emergency:

The year 1942 witnessed the greatest expansion of industrial output in the nation’s history. A sparkplug factory was among the first to switch to the production of machine guns. Soon a manufacturer of stoves was producing lifeboats. A merry-go-round factory was making gun mounts... The automobile industry was converted to such an extent that from 1942-1944, there were essentially no cars [for commercial sale] produced in the United States.

This mobilization of resources within a matter of months demonstrates that a country and, indeed, the world can restructure the economy quickly if it is convinced of the need to do so. In this mobilization, the scarcest resource of all is time. With climate change, for example, we are fast approaching the point of no return. We cannot reset the clock. Nature is the timekeeper. (Brown, 2003)

Human societies are able to develop well-honed emergency methods for handling familiar crises, especially when they are frequently repeated, such as floods, fires, storms, droughts and, in some societies, wars. But we have the greatest trouble with unfamiliar crises, especially unfamiliar disasters that are anticipated but that are not yet physically fully apparent.

Unfamiliar disasters must be handled in the imagination by simulation and by learning from real life experience in analogous situations. There is no other way to handle unfamiliar anticipated disasters because the only available real-life experience is the very disaster that one is trying to avoid.

But what we have learned from past experience with repeated but highly variable disasters — such as wars and pandemics — is that effectiveness in action is improved by doing practical “exercises” based on a range of scenarios. Perhaps the reason that humans have the ability to be actors or writers of fiction is that our ancestors evolved this skill because they benefited from the sort of imagination that allowed them to create and anticipate futures and through group processes of acting them out; thus enabling “virtual” familiarity to be generated.

Now that science, enhanced by its silicon-based ability to “act out” alternative futures using computer models, has made it clear that a climate disaster is a highly realistic future, we need to take this really seriously. We need to treat this future as a preventable fact. We need to start from the assumption that we don’t want to fail in our efforts to prevent this future, and so we need to start imagining and acting out a whole series of scenarios that are developed with a common purpose — to prevent climate disaster and take the world back to the safe zone in time. And then test strategies to see which ones have the highest odds of success. This notion of “back-casting from success” is an established technique that we can apply actively to the climate and the wider suite of issues that need to be tackled under the sustainability emergency.

3.8 The climate emergency in practice

“Individual carbon rationing with penalties for those who exceeded their quotas was one of a number of radical measures that might be needed to tackle climate change, according to the former NSW premier [Bob Carr].” — Sydney Morning Herald news story, 18 April 2007

We do not pretend to have a detailed roadmap for the sustainability emergency. The ideas here are simply an outline of action that seems both necessary and workable. A huge amount of effort is required to produce detailed plans for a civil emergency, for a war, or for any nation-transforming event.

In making the sustainability emergency work, there are many issues to be resolved including getting commitment, cohesion and rapid action when there is no enemy to unite against and the most deadly threat lies in the future; and recognising that it is a sustainability problem that requires a solution to not only global warming, but such interconnecting issues as peak oil, water overuse, biodiversity loss, poverty elimination and social equity. We need to end the current “phoney war” period, we need to “get it right” the first time, not stalling halfway or diverting the needed change. There is also the need to avoid the poor decision-making that comes if panic mode prevails, avoiding timed-out or dead-end transitions, and dealing with power and self-interest.

However, there are a few ideas that can be roughly sketched out.

The sustainability emergency as a formally declared state is a signal that we are all in it together — like declaring war but without the war. Before that happens we need to work out in some detail how a state of sustainability emergency could operate in such a way that it does not eliminate, but instead enhances, democracy. Instead we need to work out how governments and communities can act at huge scale and speed on the sustainability crises and build democratic strength at the same time.

There is an approach to democracy that is now being used in a small way called deliberative democracy where large numbers of the public are engaged in sorting through important big issues to generate recommendations for government or whomever (for example, the Purple Sage and Watermark projects¹⁷). This is something like a citizens’ jury system but on a mass scale. People involved in a deliberative democracy programme would be supported with experts and facilitators in the same way that parliamentary committees have technical and logistics support. This process, if it involved most people at various points in their life, would reverse the dumbing-down that is so prevalent now and would instead create a virtuous “smarting up” process of engaging the populace in tough issues that need strong responses. This helps create the political space needed for

¹⁷ www.watermarkaustralia.org.au

governments to act and allows democracy to not only survive for the duration of the state of sustainability emergency but to become more effective and be a major driver of effective outcomes from the emergency.

But will the sustainability emergency mean lower production and fewer jobs? During the war mobilisations, this was not the case. But now we need to live by using less of many of the world's resources, which runs counter to the conventional notion that economic growth is built on using more energy, more carbon, ever more precious and finite inputs. "Go for growth" was the slogan championed by the outgoing Australian government in the November 2007 national election, which it lost.

In Holland, an alternative and sustainable vision of our economic future sees growth not as a threat, but as the driving force behind innovation. The results of a five-year programme of research and "learning-by-doing" based on setting up new innovation networks and working with new methods to search for sustainable technological solutions was published in 2000 as "Sustainable Technology Development" (Weaver, Jansen et al., 2000). It found that "delivering sustainability means finding ways to meet human needs using a fraction of the natural resources we use today. The world's richer nations would be wise to target at least ten-fold improvements by 2050 in the productivity with which conventional natural resources and environmental services are used. And they need to bring new, sustainable resources on-stream to augment the resource base and replace the use of unsustainable alternatives... In principle, technology could play a pivotal role in sustainable development. Whether it does or not depends on whether innovators can be encouraged to make this an explicit goal, adopt long-term time-horizons and search for renewable technologies. Given the long lead-times involved, there is no time to waste in beginning the search."

The further development of the renewable energy industry since the book was published seven years ago is one concrete expression of the power of innovation to "meet human needs using a fraction of the natural resources". As are the still-evolving electric car, decentralised energy networks, and new materials that can replace the need for high-carbon products. Some innovations will be rediscovering the old: making food and products locally rather than transporting them long distance by oil-intensive modes of transport such as planes and ship. Surely we can do without jet-transported Californian spring cherries at our fresh food markets in the middle of a cold Melbourne winter?

Local food production, recycling, building and making more things locally and restoring local manufacturing will be part of a more sustainable economy. In practice, the emergency means renovating most buildings for energy efficiency, building a whole new power system, reconstructing how we move, and creating an Australian electric vehicle industry, just to name a few high-employment tasks. Some industries will close and new ones will replace them, and that will cause employment problems in some sectors and regions. This requires a carefully managed policy for just transitions from the old high-carbon industries to the new, sustainable industries, but it is not a reason to oppose the transition.

The sustainability emergency will have many characteristics similar to other rapid transitions: planning with a clear end state in mind; building and preparing public support before the emergency is declared; building research capacity and parallel innovation because all critical problems must be solved in parallel not serially one after the other; constraining discretionary consumption to allow re-allocation of productive capacity to capital goods; and labour power planning and labour reskilling, to name a few.

Many other features of the sustainability emergency are unique and will pose new problems to be solved. For example, the threat in the future from a deteriorating climate system will be much worse than even the current difficult situation, so that action now needs to be much stronger than is required to cope with problems that are immediately apparent.

We also need to find a fair mechanism for rapidly driving down the *total demand* for carbon-polluting products. We could virtually eliminate carbon pollution from most aspects of our lives, but leaving just one sector out of the loop could bring it all undone.

For example, air travel is the fastest growing sector of global carbon emissions, and there are few readily-available low-carbon substitutes. The Australian federal transport department projects air travel emissions for domestic and international flights (with fuel uplifted in Australia) to increase to six million tonnes of carbon by 2020. Spread over an estimated Australian population in 2020 of 24

million, that is around 0.25 tonnes carbon per person per year. Aircraft emissions have a radiative forcing effect of 2.7¹⁸, so effective total air travel emissions by 2020 will be two-thirds of a tonne of carbon per person, compared to the Earth's net natural carbon sink capacity by 2020 of less than half a tonne of carbon per capita. Air travel alone is enough to blow the carbon budget.

Thus the total quantity of *all* carbon emissions must be controlled or, in other words, rationed. Existing "cap and trade" schemes are generally deficient in including only some emissions, giving away permits, legitimising rorts and failing to deal with cross-border issues.

The proposal currently being studied by the UK government to introduce personal carbon allowances (or rations) to guarantee that the national carbon budget is achieved seems well-suited to the demands of the sustainability emergency. The proposal is well established (FEASTA, 2003; Fleming, 2005; Monbiot, 2006; Miliband, 2006):¹⁹

- An authority independent of government, like the Reserve Bank, sets a national carbon emissions budget each year, which is decreased each year in a series of downward steps in accordance with the rapid transition plan.
- Because households (in Australia) are directly responsible for about one-quarter of emissions (generated by household energy use and personal private travel), one-quarter of the carbon budget would be made available free of charge as an equal "carbon credit" (or ration) for each citizen via an electronic swipe "carbon card" which would be used to draw on an individual carbon credit balance each time household gas and electricity, petrol and air tickets are paid for. Unused credits could be sold.
- For the energy embedded in commodities purchased such as food and personal services, the carbon ration would already have been paid by the manufacturer, and its cost built into the end price for the consumer.
- If a person lacks the carbon credits to cover a purchase or is an overseas visitor without a carbon credit, he or she could buy on the "spot" market at the point of sale.
- The balance of three-quarters of the national emissions budget would be auctioned to business and government in an "emissions trading" market where the price would rise and fall such that the business and government demand for carbon emissions would not exceed the carbon budget target.

Because both individuals and businesses can trade their carbon credit within the overall national carbon emission target, there is a financial incentive to switch rapidly to low-carbon technologies and to pursue low-carbon innovation. If a new technology needs less of one's ration, it will become more attractive, and business has an incentive to make long-term, low-carbon investment decisions.

Rationing is feasible and was used very effectively during the 1939-45 war and for years afterwards. Studies in the UK showed that war rationing was accepted because it was seen to be both necessary and egalitarian (Roodhouse, 2007). UK feasibility studies suggest issues such as administration, and people's capacity to track their carbon allowance, can be resolved (Starkey and Anderson, 2005; Roberts and Thumim, 2006). The transaction costs will not be overwhelming, being less demanding than systems such as Australia's Medicare.

While rationing could exacerbate fuel poverty for lower-income households, so do measures that put a price directly on carbon (such as taxes). Either way there is a need for government to mandate and provide resources for upgrading the energy efficiency of domestic and commercial buildings. Such programmes are well established in countries including Germany and the UK.

Personal carbon rationing appears more equitable than the alternatives. Because rationing works by imposing quantity restrictions at the outset rather than raising prices, it does not in itself increase the price of household and personal energy consumed. So it is fairer than tax increases because personal carbon allowances provide free entitlements and only impose financial penalties for those who go above their entitlement, while providing an income to those who use less than their entitlement. In

¹⁸ The total warming effect of aircraft emissions is 2.7 times as great as the effect of the same emissions at ground level.

¹⁹ See also documentation and reports at www.teqs.net/links.html

general, people on low incomes use less energy and emit less CO₂ than average (particularly if personal air travel is included), and the better off emit more than average. The rich will therefore need, on average, to buy allowances from the poor. Research in the UK shows that carbon allowances would be more progressive than a carbon tax. Even if the revenues were recycled through the tax system as effectively as possible through targeted increases in benefits to low-income households, rationing would produce a fairer outcome (Dresner and Ekins, 2004).

Rationing offers a number of other benefits. It is egalitarian in that everyone gets an equal, free carbon allowance; it allows people to make choices and offer a personal carbon budget to keep within, which is a more interesting challenge than just watching prices go up; it encourages behaviour change in the knowledge that others, including businesses and the government, are also acting within the scheme; it helps address the depletion of our energy resources; and it is more effective in reducing emissions when targets are high.

David Miliband, then British Environment Secretary (and now Foreign Secretary), told an audience in 2006 that “the challenge we face is not about the science or the economic ... it is about politics” ... and that carbon rationing can “limit the carbon emissions by end users based on the science, and then use financial incentives to drive efficiency and innovation” (Miliband, 2006).

Such a proposal is one of many that will need to be planned in detail, but if we are going to engage in a rapid transition to a safe-climate economy, personal and corporate carbon rationing seems to have all the attributes necessary to help make the sustainability emergency work in practice.

The political obstacles to having a sustainability state of emergency recognised are daunting, but they also signal our collective task. The threats, which even the experts have been underestimating, are larger and have a greater sense of immediacy than most people acknowledge, but there is not yet a strong consensus around nature of the challenge and the drivers, scale and gravity of the problem. Tomorrow’s problem has to be solved today, when it is not yet sensed as being immediately threatening.

How can the scale, gravity and urgency of the threats be effectively communicated based on solid knowledge? What are key messages? What messages are likely to encounter most resistance and how might we think about this? Who are the priority partners in these conversations? What are effective means to employ in each conversation? What are the windows of greatest opportunity?

These are some of the tasks in articulating how to implement the emergency.

3.9 Conclusion

“We have to figure out how to live without fossil fuels someday... Why not sooner?”

— James Hansen, director of the NASA Goddard Institute for Space Science, 13 December 2007 (Inman, 2007)

“Code red” is used in some hospitals to signify the status of a general surgical patient who needs advanced life support. Our planet too needs life support, for part of its diverse life has already been drained away by global warming. This understanding is widespread.

We have already gone too far. NASA’s James Hansen told the December 2007 meeting of the American Geophysical Union that the current CO₂ level of 383ppm was already dangerous, “the evidence indicates we’ve aimed too high” and that we should set a target of CO₂ that is low enough to avoid the point of no return. He said that the CO₂ tipping point for many parts of the climate is around 300 to 350 ppm CO₂, and that we must not only cut current carbon emissions but also remove some carbon that has collected in the atmosphere since the Industrial Revolution (Inman, 2007; McKibben, 2007).

The game has changed and James Hansen’s articulation of the 300–350 ppm target will be recognised as a great tipping point in the global debate about climate action.

In having helped articulate and document the increasing gravity of climate impacts, Hansen, perhaps the world’s most reputable climate scientist, is now saying *it is time to start taking carbon out of the atmosphere* because it is now too late and no longer relevant to speculate on how much *more* may be safe. The game has changed and Hansen’s articulation of the 300–350 ppm target will be recognised as

a great tipping point in the global debate about climate action. In many ways, it points the sign post down the emergency road.

So now the message is that we must cool the planet. Like the patient with very high cholesterol, the effective response is not despair but a determined programme of action to bring the level down to a safe one as quickly as possible. Because other life-threatening complications — large positive feedbacks — are already making an appearance, the key is not only the target but getting there in double-quick time. Speed-of-change is now the difference between success and failure, and like the emergency services getting to a fire or serious accident, a slow response is not acceptable.

If we don't stop emitting greenhouse gases rapidly, it will be too late.

So if we are serious, how much of the world's economic capacity should be devoted to providing a rapid transition to a zero-emissions economy and a safe-climate future? Economic modellers will bicker over tenths of a per cent, and calculate that we might avoid dangerous climate change and yet only shave some tiny amount off GDP in 40 years time. Or get to "carbon-neutral" by cutting emissions 60% by 2050 and buying credits from the rest of the world for the balance.

We can only say *we must devote as much of the world's economic capacity as is necessary*, and as quickly as possible, because the alternative of not doing enough will likely produce a world where far fewer species and a lot less people will survive. It makes no sense to give high priority to producing yet more "cream on the cake" (more luxuries for the well-off) when the very viability of the planet as a life-support system is at stake.

Environment scientist James Lovelock, co-author of the Gaia thesis, says temperature increases of up to 8°C are already locked into the system and will result in large parts of the surface becoming uninhabitable, wiping out 90% of the world's present human population (Lovelock, 2006).

Two years ago Lovelock's view was widely dismissed as fanciful. But the non-linearity of some climate events we are now witnessing and the pressure building in the system that will rapidly bring catastrophic positive feedbacks into play — large ice sheet loss, carbon-cycle reverse, larger permafrost methane releases — make such an outlook not unreasonable unless we treat the situation now as an absolute emergency. We are close to blowing the system, as many leading figures are now saying with increasing urgency. UN climate chief Yvo de Boer said in Bali in December 2007 that reducing emissions by between 25-40% by 2020 would cap the average global temperature rise to 2°C, but this could still result in "catastrophic environmental damage" (AAP, 2007); the UN Secretary-General calls it "an emergency" (ABC, 2007a); James Hansen says that "we are on the precipice of climate system tipping points beyond which there is no redemption" (Hansen, 2005c); and Mark Serreze, a senior scientist at the US government's snow and ice data centre says "the Arctic is screaming" (Borenstein, 2007).

It's "now or never" for truly radical action and heroic leadership. How much of our productive wealth we must devote to this life-saving action should not be calculated in tenths of a per cent, but in how many per cent and, if necessary, in how many tens of per cent. During the last global mobilisation, the 1939-45 war, more than 30%, and in some cases more than half, of the economy was devoted to military expenditure, as Table 4 shows.

Table 4 *Military burden 1939-1944 (military outlays as % of national income)*

	1939	1940	1941	1942	1943	1944
USA	1	2	11	31	42	42
UK	15	44	53	52	55	53
Germany	23	40	52	64	70	–
Japan	22	22	27	33	43	76

Source: Harrison, M. (2000) "The Economics of World War II: Six Great Powers in International Comparison", Cambridge University Press

Is not the cause and the need now much greater?

At a rough calculation, \$300–400 billion invested in renewable energy and energy efficiency in Australia would allow us to close every coal-fired electricity generator, transform our rail and transport system and key industries, and provide a just transition for those economically displaced by

the changes. And much of that investment in energy efficiency would be repaid in lower energy costs over time. That's just 3–4% of our total economic production for 10 years, minus the energy savings, and is miniscule compared to the war effort. Can we not identify 3–4% of total personal consumption, and government expenditure, and corporate activity that could reasonably be re-directed to this necessary task? It seems a very cheap up-front price to pay. And we reap the rewards of this investment forever more.

One objection would be that some power-generating companies may go out of business, and that would undermine one of the great institutions of modern life: "shareholder value". Some of the generating capacity is getting towards the end of its anticipated life and has already been depreciated down, others may be compensated. It's not a big problem compared to letting coal-fired power station wreck the climate. We, through superannuation funds, are many of those shareholders in the electricity generators. Contrary to a preoccupation with "shareholder value", we suspect that most citizens would think the greatest "value" would be to truly value the future of our planet and be able to see an end to the coal industry and the development of sustainable industries for those displaced in the process.

The problem is political inertia, not cost to the economy. It will cost an estimated US\$130 billion to ensure that all Indian households enjoy access to electricity by 2030 (Gibbs, 2008). Let's say the cost would be 50% higher if it came from renewable sources. That would be \$20 billion a year for 20 years, or around 3% of the total US military and intelligence budget (including Iraq and Afghanistan) of \$US700 billion in 2007. Two years of US spending in Iraq and Afghanistan would more than pay the whole bill!

Wherever one looks, the story is the same. It is estimated that it might cost an additional US\$30 billion per annum to de-carbonise power supplies in countries outside the OECD. That would amount to less than 0.1% of the total annual production of the OECD countries. Compare that to a world war, when the antagonists will devote a third of their economy or more to military spending.

Yet when every nation on earth is threatened by catastrophic global warming, most governments refuse to act with the necessary speed or financial commitment. Why are they so narrow in their vision, even within their own framework of maintaining the long-term conditions for capitalist development? Why is so little courage or foresight or capacity exhibited by those who govern us.

If they cannot lead, perhaps they should step aside and let all of us who value the planet start to solve the problems.

At a Sydney book launch in late 2007, Ian Dunlop, a former chair of the Australian Coal Association told his audience that "the Rudd government now faces the stark fact that we are in the midst of nothing less than a global sustainability emergency. The immediate pressure-points are human-induced climate change, water shortages and the imminent peaking of global oil supply... Unfortunately the political and corporate structures we have created render us uniquely ill-equipped to handle this emergency... Our ideological preoccupation with a market economy based on short-run profit maximisation is rapidly leading towards an uninhabitable planet. As inconvenient as it may be politically and corporately, conventional economic growth and rampant consumerism cannot continue..." (Dunlop, 2007).

Many of us — in business and at work, in climate action groups, in NGOs and in political parties — know in our hearts that on climate the world is going backwards very rapidly and the sorts of solutions that currently dominate national and global forums are simply too little, too late because of the continuing preoccupation with "politics as usual" and "business as usual".

But sometimes we dare to imagine that there could be a really rapid transition, a great national and international mobilisation, to a safe-climate, post-carbon sustainable way of living. We now need to "think the unthinkable", because the sustainability emergency is not so much a radical idea as now simply a necessary mode of action.

Responses to “Climate Code Red”

A diverse range of people were invited to respond to “Climate Code Red”. Here’s what they said.

Tom Athanasiou

Tom Athanasiou is the co-author (with Paul Baer) of “Dead Heat: Global Justice and Global Warming” and, more recently, “Honesty about Dangerous Climate Change”. He is the executive director of EcoEquity and a core member of the team developing the “Greenhouse Development Rights” framework (www.ecoequity.org).

The pressure to soft-pedal is very, very high. I know because I feel it. I’m tempted. I do not wish to be dismissed as an apocalyptic. So when I read, in this fine and even astonishing report that “politics as usual” must be cast aside, and quickly, there’s something in me that baulks. After all, the mainline debate at Bali was about a “25–40% cut by 2020” for the developed countries. Isn’t this enough? Doesn’t it tell us that we’re moving quickly, or at least as quickly as we can? Must we go so far as to call for emergency mobilization? Must we seek to put all “available and necessary resources” at the service of a global crash programme to stabilize the climate?

The question is an open one. The questions here are political, and have no determinate answers. But if you’re a “pragmatist,” and especially if you wish to avoid any inconvenient temptations to “face the facts with brutal honesty” — temptations that, given the state of the science, can only disturb any confident incrementalism that you may yet harbour — then you should not read this report. For even if you’re quite certain that there’s no viable alternative to politics as usual, “Climate Code Red” will bring you doubt. And it will not be doubt that you can set easily aside.

I can’t say that James Hansen — for this paper begins as a digest of the tumult and measured alarm that emanates like a shock wave from Hansen’s team — is certainly right. But I can find no flaw in his recent argument that we’ve already passed the “tipping point,” and can only agree that the “reticence” of well-socialized scientists, and indeed the IPCC itself, has become part of the problem. And though I wouldn’t go so far as to say that today’s “widely advocated 2°C warming cap” is “is demonstrably too high and would eventually be a death sentence for billions of people and millions of species as positive feedbacks work through the climate system,” I can certainly see the point. 2°C indeed appears to be too much, and it may well be far, far too much, and it’s a measure of our desperation that we do not say so at every opportunity.

The real value of this paper, though, can only be appreciated if you know that Hansen is not alone its guiding figure. True, he begins it, but it’s Churchill that looms over the ending, and it’s ultimately the later man’s blunt, pugnacious presence that seals the deal. Which isn’t to say that “code red” is an artifact from the past. Spratt and Sutton aren’t fighting the last war, but preparing for the next. As must we all.

Jonathan Doig

Jonathan Doig is convenor of Sutherland Climate Action Network

This small book should be required reading for... well, anyone who can read! Because as it clearly points out, climate change requires every one of us to take, and whole-heartedly support, sudden and sweeping personal and societal changes.

Almost no-one — not even the experts — seems to have the full picture that is presented so clearly here. Most of us still think climate change is off in the future, or is being adequately reported by the IPCC and dealt with by the UN processes.

Parts one and two of the book put paid to those quaint notions with thoroughly referenced facts and compelling logic, while part three breaks through the conventional wisdom of climate change politics and leads us to take the bold, necessary first steps towards actually facing up to this immense and urgent crisis.

This could be the “little red book” of our generation — I hope it sparks a genuine revolution towards our ultimate survival. For my own part, I plan to use it to help spur an emergency response in our local area and across Australia.

Ian Dunlop

Ian Dunlop was formerly an international oil, gas and coal industry executive. He chaired the Australian Coal Association in 1987-88, chaired the Australian Greenhouse Office Experts Group on Emissions Trading from 1998-2000 and was CEO of the Australian Institute of Company Directors from 1997-2001. He is Chairman of the Australian National Wildlife Collection Foundation (CSIRO), and Deputy Convenor of the Australian Association for the Study of Peak Oil.

The inevitable logic of exponential growth in both population and consumption is now hitting the real limits of global ecosystems and resource availability, as population rises toward 9 billion by mid-century. The immediate pressure points are human-induced climate change, water availability and the peaking of global oil supply, which are converging rapidly in a manner never previously experienced. But these are only the tip of the broader global sustainability iceberg; further constraints and limits will become increasingly evident as the major developing countries move up the growth escalator.

This situation is not unexpected; it has been forecast for decades going back before the 1972 "Limits to Growth" analysis. In the meantime we have created a political and capitalist system which has proved incapable of recognising that the most important factor for its own survival is the preservation of a global biosphere fit for human habitation. Our institutions are totally short-term focused; politically due to the electoral cycle and corporately due to perverse incentives. Thus we are uniquely ill-equipped to handle these major problems, which are all long-term.

Our ideological preoccupation with a market economy based on short-run profit maximisation is rapidly leading towards an uninhabitable planet. As inconvenient as it may be politically and corporately, conventional economic growth and rampant consumerism cannot continue. Markets are important, but they operate within rules. Henceforth, the rules must change to ensure long-run sustainability.

Nationalism and short-term vested interests have so far prevented the development of a global governance framework capable of handling this "Tragedy of the Commons". However, the issue of global sustainability is now much bigger than any nation state. Global warming, in particular, is moving far faster than the scientists had predicted, to the point where we are already in the danger zone.

The stark fact is that we face a global sustainability emergency. But it is impossible to design realistic solutions unless we first understand and accept the size of the problem. We know those solutions; what is lacking is the political will, firstly to honestly articulate the problem and secondly to implement those solutions.

"Climate Code Red" is a sober, balanced analysis of this challenge, unadorned by political spin, proposing a realistic framework to tackle the emergency. It should be essential reading for all political and corporate leaders, but particularly for the community. The extent of change we require will only occur if the political and corporate world see that the community is demanding it.

If we are to have a reasonable chance of maintaining a habitable planet, placing our efforts on an emergency footing is long overdue. We only play this game once; a trial run is not an option.

Alexandra Gartmann

Alexandra Gartmann is Chief Executive Officer of the Birchip Cropping Group.

"Climate Code Red" is a confronting and sometimes daunting wake-up call to the urgency in which we need to act about climate change.

It confirms, with support from many scientists from all over the world, that humans have played a significant role in the warming of the earth. Even the 2007 IPCC report, which gets a battering for being out-dated and not doing enough to raise the alarm bells, confirms that humans have caused climate change. The question is no longer "are humans causing climate change?" it is now "what is dangerous climate change and what do we need to do to stop it?"

The facts highlighted in this book are disturbing. Who will grow our food, are the risks beyond our control? Spratt and Sutton emphasise that although we now see climate change as a real danger to our planet, the goals and targets we set to combat climate change are shaped by politics and often compromised by narrow and short-term needs.

The alarm bells are ringing throughout this book. Spratt and Sutton recognise that we have an emergency on our hands. But they reiterate that all hope is not lost, we are not facing a hopeless situation and we already have many of the tools, knowledge and creativity that can make a difference.

The changing climate is impacting on the regions in which we live. In the Victorian Wimmera–Mallee we have experienced yet another drought year and climate change is said to be the biggest issue facing the agricultural industry in Australia. The Birchip Cropping Group (a not-for-profit community research and development organisation) are investigating how climate change will affect individual farm businesses and communities, working on tools and knowledge to apply them and communicating the affects and adaptation strategies required to survive and continue to produce food for society.

Deborah Hart

Deborah Hart is an environmental campaigner and founder of local climate change action group LIVE (Locals Into Victoria's Environment), a mother and arts development professional.

We are in trouble with a capital T.

Mid-last century, out of concern for human impacts on the planet, the global think-tank, the Club of Rome, commissioned the seminal work “Limits to growth”. Whilst it’s findings were attacked and the authors accused of not only jumping at shadows but being downright crazy people, their predictions have proven to be remarkably accurate. A large body of enlightened and important research has since advanced our understanding of the need to make a transition to a sustainable society. In revisiting the original findings recently, authors Donella and Dennis Meadows and Jorgen Randers identified one of the keys to a “transformation” as: “...relevant, compelling, select, powerful, timely, accurate information flowing in new ways to new recipients, carrying new content, suggesting new rules and goals (rules and goals that are themselves information)”.

It is in this context, as the convenor of an Australian local climate change action group, that I congratulate and sincerely thank David and Philip for their extraordinary and immensely valuable work. There is no escaping the fact that we are an integrated global society and this book is exactly the “transformational information” people all over the world need to receive now.

As Spratt and Sutton contend, we must be *brutally honest* about our situation and *doubly practical* about the solution(s). For far too long we have allowed vested interests, and the bureaucrats mastered by them, to marginalise our scientists, environmentalists, innovators and visionaries; those who have been attempting to inform us of the deadly ramifications of our impacts on the Earth’s climate and ecosystems. It is time to put our listening ears on to what the scientists and the environmental experts are telling us we urgently need to do and it’s all here in this book.

“Climate Code Red” logically, systematically and in straight-talking language demonstrates that the science is in and our time is nearly past. Fortunately we are presented with a small window of opportunity to make the necessary transition to sustainability; the only option which will give us some chance of surviving, with other species and ecosystems, on a living planet worth inhabiting.

“Climate Code Red” clearly presents the recent findings from the world’s eminent climate scientists of much faster than predicted global warming. We have a full-scale emergency; the greatest threat to life on Earth as we know it. We must act accordingly to solve global warming now. Clearly it would be madness to accept climate change policies which are compromised and likely to lead to environmental collapse. We cannot accept failure as an option.

We must approach this crisis in complete confidence that we can succeed because we do have the intellectual capacity to fully assess and understand our situation, along with the technical expertise, material wealth and creative ingenuity to solve these man made problems. But we will have to abandon fast our current narrow socio-economic systems which are failing us woefully — both practically (via a collapsing environment) and socially (via increasing inequity within and between nations, mounting alienation and violence).

We must halt global warming and in the process will achieve a transition to a new sustainable system which values and respects people and nature, above objects and things. It’s really not such an unattractive option or insurmountable hurdle is it?

Greg Hunt

The Hon. Greg Hunt MP is Federal Member for Flinders and the Opposition spokesperson on climate change, environment and urban water.

I have read “Climate Code Red” with interest and note the issues it poses to all of us who recognise that climate change is a fundamental global challenge. It is important that policy be based on a clear understanding of the current scientific understanding, which in the case of the polar regions in particular is of increasing concern.

There is both a global obligation to act and a responsibility for Australia to act to contribute itself to the solution.

Australia must lead a Global Rainforest Recovery Plan which aims to protect existing rainforests and other global forests and restore degraded areas back to forest. We must also protect against destruction or degradation of other critical ecosystems, especially peatlands and wetlands. This involves a clear commitment to establishing mechanisms for reduced emissions from degradation of natural carbon sinks and reservoirs.

Australia must seek a post-2012 international climate agreement in which both developed and developing world countries have common but differentiated responsibilities. No global solution will be effective without all major emitters having commitments. The nature of those commitments may differ by country but we must seek a consensus on the need for commitments.

I recognise that while climate change is a global task and a global responsibility Australia has a specific responsibility to act and it will be necessary for Australia to accept a long term, 2050 target for greenhouse abatement and accept a medium term target for 2020 subject to the developing world being part of the solution with their own commitments.

We need a conversation in Australia that actively includes all sections of the community in understanding the impacts of global warming and what scale of actions we need to take to ensure a safe-climate Australian future.

Kirsten Kennedy

Kirsten Kennedy is a member of Pine Rivers Climate Action Network, a mother, teacher and environmentalist.

When our children explain to their own children the history of the early 21st century, will they tell a story of deterioration, despair, and a planet out of control? Or a story of repair, renewal, and united global endeavour?

As we face the future of our planet and the survival of our kind, we are at a critical junction in time. We have the knowledge. We have the power. We have the resources. We just need the motivation. “Climate Code Red” is a wake up call that we can’t ignore.

Here is the science that shows us that we can’t keep carrying on with “business as usual”. Indeed, if we did just that, future generations would never forgive us. This book should get your alarm bells ringing! Turn off your big screen TV in your air-conditioned house and do something that will make the world a better place. Now is the time. The world is waiting for you.

Dennis Meadows

Dennis Meadows is the author of ten books, including “The Limits to Growth” which has been published in over 30 languages. He was director of three university-based public policy institutes, and received international awards for his contributions to environmental education.

I have no scientific expertise in climate science, but the situation portrayed here corresponds to my understanding of the problems and the options posed for global society by exponential growth in greenhouse gas emissions. One should read this report for the details, but it is also useful to step back and grasp the larger picture. In 1972 I directed an international team of scientists in an effort to understand the long-term causes and consequences of physical growth on the planet. Our report, “The Limits to Growth”, said that continued reliance on economic growth would call forth from the environment in the early decades of the 21st century a diverse and rapidly escalating set of forces to stop expansion in population and in the use of materials and energy.

Thirty-five years ago we had no scientific way to foresee the precise nature and timing of those forces. Humanity was still below the planet's carrying capacity and there was little evidence of the symptoms that are now signalling overshoot. Now it is apparent that climate change will bear a large proportion of the burden for stopping expansion of the global economy, and it will do so during the lifetime of most who are reading these words.

Others are beginning to share this view. In October 2007, German Chancellor Angela Merkel participated in a global warming symposium of Nobel prize winners in Potsdam, in which one report made the point that "Climate change is the thin end of the wedge of an irresolvable conflict between finite resources and unending growth... At the end of the day, the resolution of this conflict would be possible only by weaning post-industrial society from its continued reliance on growth."

Climate change is not a *problem* but a *symptom*, one member of the family of difficulties that will arise on the Earth until the pressures that support population growth and rising material standards are neutralized and then reversed.

If we could push a magic button tomorrow, reduce greenhouse gas emissions to zero and restore the climate to a benign state, that would not eliminate the crisis on the Earth. It would only mean that the other pressures — water scarcity, food shortages, air pollution, crowding, pestilence — would come more to the fore.

But we do not have a magic button, so we are going to have to work very hard and long to avoid the catastrophe of a large rise in global temperature. This book does not pretend to give a precise set of recommendations for doing that. But it makes a good start, and it justifies the heroic efforts that will be required and is a useful counterbalance to the politically subservient forecasts of government leaders who do not want to offend important constituencies and who hope that any proximate problems from climate change will only appear after they leave office.

Christine Milne

Senator Christine Milne is the Australian Greens climate change spokesperson and Vice-President of the World Conservation Union, IUCN.

David Spratt and Philip Sutton have provided a valuable and sobering contribution to the policy challenge of climate change at a pivotal moment.

Over recent months it has become ever clearer to many of us working in the field that global warming, accelerating faster than scientists had predicted, is leaving policy so far behind it is outdated as it is released. The current ambitious policies of the Australian Greens, developed on the basis of science 12–18 months ago, are now way too conservative. Where, then, does that leave our new federal government, elected on a platform of climate action far weaker than the Greens?

Spratt and Sutton persuasively call on us to put aside politics as usual. My great fear, however, is that none of the people now charged with setting Australia's emissions targets — Professor Ross Garnaut, Ministers Wong, Swan and Garrett, and Prime Minister Rudd — have grasped that this is a state of emergency and none are ready to set aside politics as usual.

Spratt and Sutton have provided a vital example for Professor Garnaut on the work that is needed to set emissions targets — not by "plucking figures out of the air because they are politically convenient or someone else said they might be OK", and not by economic analysis of what now seems achievable.

Emissions reductions have one purpose only: to avoid catastrophic climate change. That being the case, there is only one basis for setting targets: a science-based judgement of how much climate change we are willing to risk. Once that science-based target is set, we must then sensibly and coherently work out how to achieve it at least cost and as equitably as possible.

This "backcasting from success" which starts from the perspective that "failure is not an option" leads to Spratt and Sutton's key insight: that the expectation of failure has become the norm in climate policy.

When you consider the implications of failing to stop runaway climate change, it is a nightmare scenario, and most of the world's leaders, relying to a greater or lesser extent on the Stern Review, have decided that it is simply too hard to constrain warming to less than 3°C. Until we reverse this defeatist attitude, the prospects of success are extremely dim.

What is perhaps most disturbing of all is that many scientists and modellers also appear to have adopted this defeatist attitude. It is very telling that the lowest emissions trajectories described by Working Group 3 of the IPCC's 2007 Fourth Assessment Report still give us a 50% or greater risk of breaching 2–2.4°C warming, a temperature range where runaway climate change would be an unacceptably high risk. Even now, it appears that very little modelling has been done of emissions trajectories that adequately minimise the risk of sending our climate out of control.

While others have persuasively suggested that somewhat lower and slower targets than called for here can be justified by the science, "Climate Code Red" is a significant contribution which should be read by anyone seriously contemplating how to set greenhouse emission reduction targets.

Louise Morris

Louise Morris is Climate Change Campaigner for Friends of the Earth (Australia). In 2007 she was the Environment Victoria climate change campaigner and Victorian coordinator for Walk against Warming and The Big Switch.

In the past century we have split the atom, mapped the human genome and slowly come to accept that our survival is dependent on healthy, intact ecosystems and a stable climate. "Climate Code Red" cuts through the politics of climate-change debates around what levels of greenhouse gas reductions are palatable, to focus on what we need to do to ensure that life as we know it continues.

Repeatedly we are shown how we can reduce our personal emissions by changing our light bulbs and showerheads, changing travel habits and choosing clean green renewable electricity. Changing your light bulb may be the beginning, but now we now need to change our industrial practices, engage with political representatives and ultimately our democratic system. It is these systemic and attitudinal changes that will bring about the deep cuts necessary to turn us away from our current trajectory of increasingly dangerous climate change.

Climate change is the single biggest challenge we have ever faced, and it is only with collective will and action that we can both halt our soaring emission rates and reverse large portions of the damage already done.

The authors of "Climate Code Red" rightly point out that much of the science we currently base our predictions upon is dated. In the time that it takes to collect, collate, digest and disseminate the next round of data gathered from melting ice caps or measuring greenhouse gas levels and effects, years pass, the greenhouse pollution gets worse and some of the information is no longer current. We need to act with the utmost urgency, utilising the precautionary principle to shape our decisions because we have only a matter of years to halt the damage we are doing and turn ourselves around from catastrophic climate change.

History has shown that the human species is capable of making big decisions and following them with far-reaching and visionary action. Now is the time to shape our future for the better rather than repeating the mistakes of the past. We are seeing the loss of Arctic ice sheets at a speed that scientists tell us is 100 years ahead of their predictions, perhaps indicating the Arctic ice has reached its tipping point.

Documents such as "Climate Code Red" provide indicators as to the extent of the challenge we face and that we need to be at a tipping point towards strong and decisive action that will halt dangerous climate change and decarbonise our society.

Steve Phillips

Steve Phillips is a spokesperson for Rising Tide (Newcastle).

There aren't many people around with the courage to present the stark brutal truth about climate change. Anxious not to scare people into inaction, or be dismissed as alarmist, even climate activists and researchers regularly downplay the urgency and severity of climate change, and the profound emergency response that it demands. I know I've been guilty of it myself.

Those of us campaigning on the ground against the causes of climate change are continually dismayed and infuriated at the levels of bullshit, hypocrisy, and cant that surround the issue. One moment a politician will speak righteously about the need for "action" on climate change, the next he will get on approving new coal mines, new roads, overseeing surging levels of greenhouse pollution.

People care about the issue, but not many want to actually change the way they live. Even coal corporations have taken up calling for “action on climate change.” Just don’t ask them to stop selling coal.

This is partly because the scale of the problem, and the scale of the solutions, have not entered the mainstream consciousness. Climate change is still a problem that people feel can be dealt with later, or in incremental steps, with greenhouse targets set years, even decades into the future. But if life on Earth as we know it going to continue to survive, there needs to be a major shake-up in the way all of us think, talk, and act about climate change. Let’s hope this book starts the shaking.

Alison Potter

Alison Potter is a member of Climate Change Balmain-Rozelle and has worked in communications at an environment NGO.

The report “Target Practice” validated my worst fears that the world is facing a crisis far beyond that which anyone is prepared to admit. If we do manage to survive this our societies, industries and economies will need to be turned inside out. The alternative is too hard to contemplate: mass starvation, political and social chaos, ecological collapse and epidemics of unseen proportions. But this latest report gave me inspiration that the bare bones of a map to a sustainable, ecologically intact future was out there.

The message about bringing the real science and predictions to the fore of the public debate is the crux. We need to harness the resulting fear of these predicted outcomes to drive us into an emergency state of rapid change. I’m keen to discuss the report with other members of climate action groups around Australia. I expect it to help inform our next moves.

“Facing up to the Challenge” has spurred me to consider redrafting the Joint Declaration that was written for the federal election and signed by 59 climate action groups. My initial impetus for developing this declaration from ordinary, engaged Australians was to counter the notion (repeatedly spouted by politicians) that we were not prepared to accept the changes necessary for adapting to a carbon-reduced or carbon-free economy. I wanted to state clearly that we are hungry for the changes and ready to make the sacrifices to our lifestyles, that we fear the alternative. Inspired by the contents this report, I think the Joint Declaration needs to be redrafted to spell out more specifically some of the sweeping changes that we recognise are necessary and that we are ready to embrace in the battle for survival, beyond paying more for electricity. The suggestion to return to a system similar to wartime rationing seems quite reasonable under the circumstances — although I realise many would reject this at this point in time, and many may never agree.

I have always held onto the notion that climate change presents the world with a great opportunity for change for the better. It is a problem of such dire magnitude that it must be handled effectively by every nation, at every level of government and every tier of society. It could turn our common value system on its head resulting in a global society that works more collaboratively and that exists in harmony with the natural systems of our planet. That gives me hope, but I also hope we don’t lose too much along the way. I hope this work proves pivotal in changing the shape of the debate and the way in which we tackle the climate emergency.

Joseph Reser

Dr. Joseph P. Reser is a social and environmental psychologist; Associate Professor of Psychology at James Cook University, Griffith University, and University of Queensland; Emeritus Reader at University of Durham; and Member of the Environment Interest Group of the Australian Psychological Society.

This is a very frightening but seemingly clear-eyed, well-informed, and sober consideration of the weight of evidence and argument relating to the imminent and quite possibly cataclysmic impacts of climate change. It clearly has been written as a wake-up call and antidote to the arguably sanitised and politically nuanced and conservative risk communications officially reporting on the state of the planet in the context of climate change. The report provides a compelling catalogue of the reasons why we should be very worried, why we should be far more engaged, individually and collectively, nationally and internationally, in doing something about this situation, and, indeed, why there should be a formal declaration and acknowledgment of a global state of emergency. And ideally a

galvanising, strategic, focused, and bipartisan state of emergency response. As a social and environmental psychologist reader, the critical and informed overview provided is impressive, comprehensive, and convincing.

Public and government concerns and scientific interest and involvement have largely focused on the nature, dynamics, magnitude and time frame of the physical environmental impacts of climate change, with somewhat less focus on human environmental considerations and consequences and what might be done to reduce and ideally arrest and reverse contributing human activities. But these climate change processes and events in the biophysical environment are currently having and will increasingly have far-reaching impacts on the human environment, with these human impacts being both directly and indirectly mediated through increasingly visible and dramatic local and global biophysical environmental impacts and their reporting and representation.

These multiple and complex impacts of climate change on the human environment make it very important to simultaneously consider and address not only those human behaviours and activities which are exacerbating climate change, and their impacts on ecological systems and climatic processes, but also those impacts on - and responses of - the human environment which relate to individual and collective risk appraisals and perceptions, sense making, worries and concerns, motivational dynamics, and institutional and societal adaptive and proactive responses. These latter psychological and social impacts and responses, independently and interactively, dramatically influence and mediate the effectiveness of corrective behaviour change initiatives and indeed all climate change mitigation measures, and have very direct implications for adaptive responding and resilience in the face of what will be dramatic human and societal challenges.

Carol Ride

Carol Ride is Convenor of Darebin Climate Action Now.

It has been increasingly alarming to read IPCC reports and see climate advocacy groups effectively giving up on setting targets that will provide a safe climate. While a 2–2.4°C temperature increase is cited as politically realistic, what has been missing is acknowledgement that even if we managed to achieve stabilisation at this temperature cap, we risk extraordinary loss of people and species and a planet that is inhospitable to our children and grand children. The exception was UN climate chief Yvo de Boer at Bali, who said that at 2°C we still risk catastrophic environmental damage.

“Climate Code Red” recognises the short comings of previously proposed strategies and challenges politically expedient measures. It accepts nothing short of a safe climate goal. It gives direction by using an emergency model on which to structure the economy and society, offering opportunity for creativity, employment, engagement and most of all the energising motivator of hope.

The authors’ evidence is based on recent science and thoroughly and painstakingly documented, is accessible, alarming, yet compelling reading.

Thank goodness someone has been prepared to not only show us the reality of the predicament we are in but has the tenacity and wisdom to show governments, business and the community a direction. The path has yet to be defined but the authors remind us of previous times in history when human ingenuity and the will to survive have prevailed. As Al Gore said in his Nobel Prize speech: “No one should believe a solution will be found without effort, without cost, without change.”

Appendix: Labor's "60/2050" policy

Labor's May 2007 announcement in support for a 60% reduction in Australian emissions from 2000 levels by 2050 (Garrett, 2007) was a pastiche of various expert reports and opinions and canvassed: "Limiting future increases in atmospheric CO₂ to 550 ppmv" (CSIRO), a target range of 450–550 ppm CO₂ (Stern), the impacts of a 3°C increase, "the need for reductions in annual GHG emissions of 60–90% from 1990 or 2000 levels by 2050 for countries listed under Annex 1 in the Kyoto Protocol" (CSIRO) and the 2000 UK Royal Commission, which determined "that stabilisation at 550 ppmv is unlikely to be achieved unless developed nations reduce their CO₂ by at least 60% by 2050".

Significantly, no temperature cap for avoiding dangerous anthropogenic interference with the climate was articulated, though it may be implied as supporting a 2°C or 3°C stabilisation limit. As discussed above, Labor appeared to fall in line with Stern's advocacy of a 60/2050 emissions reduction strategy, which for developed economies such as Australia's is based on a 3°C stabilisation target.

For the "60/2050" target Labor's statement also relies on the 2000 UK Royal Commission on Environmental Pollution, which set a cap of 550 ppm CO₂. In the world of climate change science and politics, this is an old report, relying on an IPCC report now 12 years out of date; since 2000 there have been two more IPCC reports, the research has moved on, and the UK government has since changed its emissions target to 450 ppm CO₂. More recent and relevant European research is not referred to: for example, climatologist Malte Meinshausen (whose research contributed to the Stern report) suggests that if greenhouse gases reach 550 ppm CO₂e as the Royal Commission suggested, there is a 63–99% chance (with an average value of 82%) that global warming will exceed 2°C (Meinshausen, 2006a).

In reference to a stabilisation target, the Garrett statement seems not to recognise that: "The British government has been aware that it has set the wrong target for at least four years. In 2003 the environment department found that 'with an atmospheric CO₂ stabilisation concentration of 550 ppm, temperatures are expected to rise by between 2°C and 5°C' (DEFRA 2003). In March last year it admitted that 'a limit closer to 450 ppm or even lower, might be more appropriate to meet a 2°C stabilisation limit' (HM Government, 2006)". (Monbiot, 2007a)

There is also a nomenclature sleight of hand in the quoted UK Royal Commission material. The target is described as "550 parts per million", but this is 550 parts of CO₂ alone. If other greenhouse gases are included, this is equivalent to 666 ppm carbon dioxide equivalent (CO₂e). According to the Stern Report, at 650 ppm CO₂ there is a 60–95% chance of 3°C of warming (Stern, 2006c: 194).

Labor's May 2007 statement says: "In 2006, CSIRO's 'Climate Change Impacts on Australia and the Benefits of Early Action to Reduce Global Greenhouse Gas Emissions' concluded that: "Limiting future increases in atmospheric CO₂ to 550 ppmv, though not a panacea for global warming, would reduce 21st century global warming to an estimated 1.5–2.9°C, effectively avoiding the more extreme climate changes"."

This is misleading and deceptive. The report that is referred to actually says: "As mentioned previously, some nations view 60% reductions by 2050 as consistent with placing the world on a path to achieving a 550 ppmv CO₂ stabilisation level. According to climate model results with the WRE550 stabilisation scenario, this level of mitigation would limit 21st century global warming to 1.5–2.9°C, with an additional 0.3–0.9°C of warming in subsequent centuries" (Jones and Preston, 2006: 32). In the whole CSIRO document all temperature increases are taken from a 1990 baseline (0.6°C at 1990) as is made explicit on page 6, for example, so that the phrase "21st century global warming to 1.5–2.9°C" means a total rise over pre-industrial levels of 2.1–3.5°C by 2100. Add in the "additional 0.3–0.9°C of warming in subsequent centuries", and the full temperature rise range becomes 2.4–4.4°C for 550 ppm. This clearly would constitute dangerous anthropogenic interference and the use of the selected phrase in the statement is deceptive.

The next paragraph in the CSIRO report (page 33) reads: "However, it is becoming increasingly clear that 550 ppmv may not be a sufficient stabilisation goal for preventing DAI. Emission reductions beyond 60% by 2050 would leave the option for stabilising at 450 ppmv or lower open. This would limit 21st warming to approximately 1.2–2.3°C, with an additional warming of 0.3–0.6°C in subsequent centuries. Such a threshold is thereby more consistent with the temperature thresholds

for DAI in Table 1, although additional warming beyond 2100 would exceed the mean threshold of 1.5°C.” To reiterate, the CSIRO report says that 450 ppm is “more consistent” than 550 ppm in avoiding dangerous climate change. This key paragraph, which contradicts the sentence quoted by Labor, was omitted from the ALP policy release.

Bibliography

Note: web URL addresses have been included where the publications and sources are publicly available. Where subscriptions are required, they have not been included.

- AAP (2007) "PM flies into Bali row", *The Age*, 11 December 2007, www.theage.com.au/news/national/pm-flies-into-bali-row/2007/12/11/1197135456300.html
- ABC (2007a) "UN chief says global warming is 'an emergency'", *ABC News*, 11 November 2007, www.abc.net.au/news/stories/2007/11/11/2087480.htm
- ABC (2007b) "Now or never to save the planet: UN", *ABC News*, 26 October 2007, www.abc.net.au/news/stories/2007/10/26/2070761.htm
- ABC (2007c) "Scientists uncover new evidence of Arctic ice melt", *ABC News*, 12 December 2007, www.abc.net.au/news/stories/2006/12/12/1810155.htm
- ACIA (2005) "Arctic Climate Impact Assessment", Cambridge University Press: Cambridge, New York
- Ackerman, F. (2007) "Economics for a warming world", *Post-Autistic Economics Review* 44, December 2007, www.paecon.net/PAERReview/issue44/Ackerman44.pdf
- Adam, D. (2007a) "Loss of Arctic ice leaves experts stunned", *The Guardian*, 4 September 2007, www.guardian.co.uk/environment/2007/sep/04/climatechange
- Adam, D. (2007b) "How climate change will affect the world", *The Guardian*, 19 September 2007, www.guardian.co.uk/environment/2007/sep/19/climatechange
- Adam, D. (2007c) "Surge in carbon levels raises fears of runaway warming", *The Guardian*, 19 January 2007, environment.guardian.co.uk/climatechange/story/0,,1994071,00.html
- Aldy, J. E., et al. (2003) "Beyond Kyoto: Advancing the International Effort Against Climate Change", Pew Centre on Global Climate Change: Arlington
- Alley, R. (2007) "Testimony before Committee on Science, US House of Representatives", 8 February 2007
- Amos, J. (2006) "Arctic sea ice 'faces rapid melt'", *BBC News*, 12 December 2006, [news.bbc.co.uk/go/pr/fr/-/1/hi/sci/tech/6171053.stm](http://news.bbc.co.uk/1/hi/sci/tech/6171053.stm)
- Amos, J. (2007a) "Deep ice tells long climate story", *BBC News*, 4 September 2006, news.bbc.co.uk/2/hi/science/nature/5314592.stm
- Amos, J. (2007b) "Arctic summers ice-free 'by 2013'", *BBC News*, 12 December 2007, news.bbc.co.uk/1/hi/sci/tech/7139797.stm
- Andreae, M. O., C. D. Jones, et al. (2005) "Strong present-day aerosol cooling implies a hot future", *Nature* 435: 1187-1190
- Andronova, N. and M. E. Schlesinger (2001) "Objective estimation of the probability distribution for climate sensitivity", *Journal of Geophysical Research* 106: 22605
- Annan, J. D. and J. C. Hargreaves (2006) "Using multiple observationally-based constraints to estimate climate sensitivity", *Geophysical Research Letters* 33: L06704
- AP (2007) "Climate change reshaping Arctic", *Associated Press*, 18 October 2007, asia.news.yahoo.com/071017/ap/d8sb3ba80.html
- Archer, D. (2006) "Global warming – Understanding the forecast", Blackwell Publishers: Oxford
- Arguez, A., A. M. Waple, et al. (2007) "State of the climate in 2006", *Bulletin of the American Meteorological Society* 88(6): 929-932
- AWEA (2007) "Wind energy and the environment", American Wind Energy Association, www.awea.org/faq/wwt_environment.html
- Azar, C., K. Lindgren, et al. (2006) "Carbon capture and storage from fossil fuels and biomass — Costs and potential role in stabilizing the atmosphere", *Climatic Change* 74(1-3): 47-79
- Baer, P. and T. Athanasiou (2004) "Honesty about dangerous climate change", www.ecoequity.org/ceo/ceo_8_2.htm
- Baer, P. and M. Mastrandrea (2006) "High stakes: Designing emissions pathways to reduce the risk of dangerous climate change", Institute for Public Policy Research: London
- Baer, P., T. Athanasiou and S. Kartha (2007) "The Right to Development in a Climate Constrained World: The Greenhouse Development Rights Framework", *EcoEquity*, www.ecoequity.org/GDRs/
- Barnola, J., D. Raynaud et al. (1987) "Vostok ice core provides 160,000-year record of atmospheric CO₂", *Nature* 329: 408-414
- Barras, C. (2007) "Rocketing CO₂ prompts criticisms of IPCC", *New Scientist*, 24 October 2007
- BBC (2007) "'Warm wind' hits Arctic climate", *BBC News*, 18 October 2007, news.bbc.co.uk/2/hi/science/nature/7050132.stm
- Beck, A. (2007a) "Arctic ice pack melting at record rate", *Sydney Morning Herald*, 14 December 2007, www.smh.com.au/news/environment/arctic-ice-pack-melting-at-record-rate/2007/12/13/1197135655544.html

- Beck, A. (2007b) "Carbon cuts a must to halt warming — US scientists", Reuters, 13 December 2007, www.reuters.com/article/latestCrisis/idUSN13267425
- Beeby, R. (2007a) "Climate of fear silencing scientists when they must be heard", Canberra Times, 4 January 2007, canberra.yourguide.com.au/news/opinion/opinion/climate-of-fear-silencing-scientists-when-they-must-be-heard/544528.html
- Beeby, R. (2007b) "Our emissions worst: UN Australia tops list of polluters", Canberra Times, 2 November 2007, canberra.yourguide.com.au/news/local/general/our-emissions-worst-un-australia-tops-list-of-polluters/1079692.html
- Behrenfeld, M. J., K. Worthington, et al. (2007) "Controls on tropical Pacific Ocean productivity revealed through nutrient stress diagnostics", *Nature* 442: 1025-1028
- Best, G. (2002) "Churchill: A study in greatness", Hambleton: London
- Bjornes, C. (2007) "International polar day", Cicero, www.cicero.uio.no/webnews/index_e.aspx?id=10868
- Blakemore, B. and C. Sandell (2006) "An ice-free Arctic happening before our eyes", ABC News, 9 June 2007, abclocal.go.com/kgostory?section=bizarre&id=4534375
- Blanco, S. (2007) "Rising soybean prices cramp biodiesel producers' style", *AutoblogGreen*, 22 August 2007, www.autobloggreen.com/2007/08/22/rising-soybean-prices-cramp-biodiesel-producers-style/
- Blas, J., C. Giles, C. and H. Weitzman (2007), "World food price rises to hit consumers", *Financial Times*, 16 December 2007, www.ft.com/cms/s/0/03de75c4-ac22-11dc-82f0-0000779fd2ac.html
- Borenstein, S. (2007) "Arctic sea ice gone in summer within five years?", *Associated Press*, 12 December 2007, news.nationalgeographic.com/news/pf/33860636.html
- Borger, J. (2007) "Climate change disaster is upon us, warns UN", *The Guardian*, 5 October 2007, www.guardian.co.uk/environment/2007/oct/05/climatechange
- Bradford, T. (ed.) (2006) "The economic transformation of the global energy industry", MIT Press: Cambridge MA
- Brahic, C. (2007a) "Sea level rise outpacing key predictions", *New Scientist news service*, 1 February 2007, environment.newscientist.com/article/dn11083
- Brahic, C. (2007b) "US temperatures 'could rise 10 degrees' by 2080", *New Scientist*, 10 May 2007
- Brahic, C. (2007c) "US set to violate its standards on CO₂ emissions", *New Scientist*, 24 September 2007
- Brahic, C. (2007d) "Shrinking ice means Greenland is rising fast", *New Scientist*, 2 November 2007
- British Antarctic Survey (2007) "Unexpected growth in atmospheric carbon dioxide", *Science Daily*, 23 October 2007, www.sciencedaily.com/releases/2007/10/071022171932.htm
- Brown, P. (2007) "Scientists fear ice caps melting faster than predicted", *The Guardian*, 7 September 2007, www.guardian.co.uk/international/story/0,,2164776,00.html
- Brown, L. (2008) "Plan B 3.0: Mobilizing to save civilization", WW Norton & Company: New York
- Butler, R. (2007) "Amazon rainforest fires 'worst' in memory", *Mongabay.com*, 16 October 2007, news.mongabay.com/2007/1016-amazon.html
- Butler, R. (2008) "Orangutan should become symbol of palm-oil opposition", *mongabay.com*, 2 January 2008, news.mongabay.com/2007/0102-palm_oil.html
- Caldeira, K., D. Archer, et al. (2007) "Comment on 'Modern-age buildup of CO₂ and its effects on seawater acidity and salinity' by Hugo A. Loáiciga", *Geophysical Research Letters* 38: L18608
- Calvin, W. H. (2002) "A brain for all seasons: Human evolution and abrupt climate change", University of Chicago Press: Chicago
- CANA (2007a) "Turning down the heat: A climate change action agenda for Australia", Climate Action Network Australia: Sydney
- CANA (2007b) "International climate change negotiations Bali COP13/MOP3: Brief to incoming government", 26 November 2007, Climate Action Network Australia: Sydney
- Canadell, J. G., C. LeQuere, et al. (2007) "Contributions to accelerating atmospheric CO₂ growth from economic activity, carbon intensity, and efficiency of natural sinks", *Proceedings National Academy Sciences*, 10.1073/pnas.0702737104, published online before print October 25, 2007
- Chandler, D. (2006) "Shorelines may be in greater peril than thought", *New Scientist*, 14 December 2006
- Chylek, P. and U. Lohmann (2005) "Ratio of the Greenland to global temperature change: Comparison of observations and climate modeling results", *Geophysical Research Letters* 32: L14705
- Cohen, D. (2007) "Earth's natural wealth: An audit", *NewScientist.com news service*, 23 May 2007, <http://environment.newscientist.com/channel/earth/mg19426051.200-earths-natural-wealth-an-audit.html>
- Colebatch, T. (2006) "The European solution", *The Age*, 24 October 2006, www.theage.com.au/news/tim-colebatch/the-european-solution/2006/10/23/1161455660470.html
- Colebatch, T. (2007) "Australia scores badly on emissions growth report", *The Age*, 1 November 2007, www.theage.com.au/news/federalelection2007news/australia-scores-badly-on-emissions/2007/10/31/1193618975747.html
- Collins, J. (2001) "Good to great: Why some companies make the leap and others don't", Random House: London.

Connor, S. (2007a) "If we fail to act, we will end up with a different planet", *The Independent*, 1 January 2007, environment.independent.co.uk/climate_change/article2116874.ece

Connor, S. (2007b) "Scientists warn Arctic sea ice is melting at its fastest rate since records began", *The Independent*, 15 August 2007, news.independent.co.uk/sci_tech/article2864214.ece

Connor, S. (2007c) "Expanding tropics 'a threat to millions'", *The Independent*, 3 December 2007, environment.independent.co.uk/climate_change/article3218026.ece

Connor, S. and M. McCarthy (2006) "Our worst fears are exceeded by reality", *The Independent*, 29 December 2006, environment.independent.co.uk/climate_change/article2110651.ece

Cowling, S., R. A. Betts, et al. (2004) "Contrasting simulated past and future responses of the Amazonian forest to atmospheric change", *Philosophical Transactions of the Royal Society B* 359: 539-47

Cox, P. M., R. A. Betts, et al. (2000) "Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model", *Nature* 408(6809): 184-187

DEFRA (2003) "The scientific case for setting a long-term emission reduction target", www.defra.gov.uk/environment/climatechange/pubs/pdf/ewp_targetscience.pdf

den Elzen, M. and M. Meinshausen (2006) "Multi-gas emission pathways for meeting the EU 2°C climate target" in H. J. Schellnhuber et al. (eds) "An overview of 'dangerous' climate change", Cambridge University Press: Cambridge

Diesendorf, M. (2007a) "Greenhouse solutions with sustainable energy," University of New South Wales Press: Sydney

Diesendorf, M. (2007b) a "The base load fallacy", www.energyscience.org.au/BP16/BaseLoad.pdf

Diesendorf, M. (2007c) "Paths to a low carbon future: Reducing Australia's greenhouse gas emissions by 30% by 2020", Greenpeace: Sydney

Doyle, A. (2007) "Arctic thaw may be at 'tipping point'", *Reuters*, 28 September 2007, www.reuters.com/article/latestCrisis/idUSL28151981

Dresner, S. and P. Ekins (2004) "The distributional impacts of economic instruments to limit greenhouse gas emissions from transport", Policy Studies Institute: London

Dunlop, I. (2007) "Corporate governance and responsibility", comments at University of Technology Sydney book launch, 5 December 2007

Eilperin, J. (2006) "Growing acidity of oceans may kill corals", *Washington Post*, July 5, 2006, www.washingtonpost.com/wp-dyn/content/article/2006/07/04/AR2006070400772.html

Enting, I., T. Wigley, et al. (1994) "Future emissions and concentrations of carbon dioxide: Key ocean/atmosphere/land analyses", Technical Paper No. 31, CSIRO Division of Atmospheric Research: Melbourne.

European Union (2007) "World energy technology outlook 2050", European Union, January 2007 ec.europa.eu/research/energy/

FEASTA (2003) "Domestic tradable quotas as an alternative to carbon taxation: A submission by Feasta to the Department of Finance, October 2003", www.feasta.org/documents/energy/dtqsoc2003.htm

Flannery, T. (2006) "Climate's last chance", *The Age*, 28 October 2006, www.theage.com.au/news/opinion/climates-last-chance/2006/10/27/1161749313108.html

Fleming, D. (2005) "Energy and the common purpose: Descending the energy staircase with tradable energy quotas (TEQs)", www.teqs.net

Fournier, J. (2007) "Climate emergency", PlanetWork, 9 May 2007, www.planetwork.net/climate/emergency.html

Furevik, T. (2005) "Feedbacks in the climate system and implications for future climate projections", presentation to Climate, Oceans and Policies, Washington DC, 1 November 2005, www.norway.org/NR/rdonlyres/3F179CEC-67E4-4512-8229-701B48B5E54E/36279/furevikore1.pdf

Garrett, P. (2006) "Labor's greenhouse reduction target: 60% by 2050 backed by the science", Media statement, 2 May 2007, parlinfoweb.aph.gov.au/piweb//view_document.aspx?TABLE=PRESSREL&ID=139151

Gibbs, T. (2008) "Switched-on India: How can India address climate change and meet its energy needs?", Institute for Public Policy Research: London

Gregory, J. M., P. Huybrechts, et al. (2004) "Climatology: Threatened loss of the Greenland ice-sheet", *Nature* 426: 616

Hall, A. (2007) "Arctic heat wave worries scientists", *ABC News*, 4 October 2007, www.abc.net.au/news/stories/2007/10/04/2051118.htm

Hannam, P. (2007) "New Stern climate warning", *The Age*, 28 March 2007, www.theage.com.au/news/national/new-stern-climate-warning/2007/03/27/1174761470838.html

Hansen, J. (2003) "Can we defuse the global warming time bomb?", *Natural Science*, 1 August 2003, naturalscience.com/ns/articles/01-16/ns_jeh.html

Hansen, J. (2005a) "A slippery slope: How much global warming constitutes 'dangerous anthropogenic interference'? An editorial essay", *Climate Change* 68: 269-279

Hansen, J. (2005b) "Earth's energy imbalance: Confirmation and implications", *Science*, 308: 1431-1435

Hansen, J. (2005c) "Is there still time to avoid 'dangerous anthropogenic interference'?"

with global climate? A tribute to Charles David Keeling", Presentation U23D-01 at Fall Meeting of American Geophysical Union, 6 December 2005, www.columbia.edu/~jeh1/

Hansen, J. (2006a) "The threat to the planet: Actions required to avert dangerous climate change", presentation at SOLAR 2006 Conference on renewable energy, Denver, 10 July 2006, www.columbia.edu/~jeh1/

Hansen, J. (2006b) "The threat to the planet: How can we avoid dangerous human-made climate change?", remarks on acceptance of WWF Duke of Edinburgh Conservation Medal at St. James Palace, 21 November 2006, www.columbia.edu/~jeh1/

Hansen, J. (2006c) "Declaration of James Hansen", US District Court for District of Vermont, Association of International Automobile Manufacturers v. Torti, Case nos 2:05-CV-302 and 304, 14 August 2006

Hansen, J. (2006d) "Can we still avoid dangerous human-made climate change?" Presentation at New School University, New York City, February 10, 2006, www.columbia.edu/~jeh1/

Hansen, J. (2007a) "Scientific reticence and sea level rise", Environmental Research Letters 2: 024002

Hansen, J. (2007b) "Interview", www.grist.org/news/maindish/2007/05/15/hansen/index.html

Hansen, J. (2007c) "Huge sea level rises are coming — unless we act now", New Scientist, 28 July 2007

Hansen, J. (2007d) "e-list message", 29 March 2007

Hansen, J. (2007e) "Direct testimony of James E. Hansen", State of Iowa before the Iowa Utilities Board, docket no. GCU-07-1, 22 October 2007, www.columbia.edu/~jeh1/IowaCoal_071105.pdf

Hansen, J. (2008) "Tipping point: Perspective of a climatologist" in E. Fearn and K.H. Redford (eds) "The state of the wild 2008 – A global portrait of wildlife, wildlands and oceans", Wildlife Conservation Society/Island Press

Hansen, J., R. Nazarenko, et al. (2006) "Earth's energy imbalance: Confirmation and implications", Science 308: 1431-1435

Hansen, J., M. Sato, et al. (2006) "Global temperature change", Proceedings National Academy Sciences 103: 14288-14293

Hansen, J., M. Sato, et al. (2007a) "Dangerous human-made interference with climate: a GISS modelE study", Atmos. Chem. Phys. 7: 2287-2312

Hansen, J., M. Sato, et al. (2007b) "Climate change and trace gases", Philosophical Transactions Royal Society 365: 1925-1954

Hansen, J. and M. Sato (2007) "Global warming: East-West connections", in publication, September 2007

Hare, W. (2003) "Assessment of knowledge on impacts of climate change — Contribution to the specification of Art. 2 of the UNFCCC", WBGU: Berlin

Harvey, L. (2007) "Dangerous anthropogenic interference, dangerous climate change, and harmful climatic change: non-trivial distinctions with significant policy implications", Climatic Change 82(1-2): 1-25

Helweg-Larsen, T. and J. Bull (2007) "Zero carbon Britain: An alternative energy strategy", Centre for Alternative Technology, www.zerocarbonbritain.com

Hilton, E. (2007) "Greenland is now a country fit for broccoli growers", The Guardian, 14 September 2007, www.guardian.co.uk/commentisfree/2007/sep/14/comment.climatechange

Hirsch, R., R. Bezdek, et al. (2005) "Peaking of world oil production: Impacts, mitigation, and risk management", Novinka Books: New York.

HM Government (2006) "Climate change: The UK programme 2006", www.defra.gov.uk/environment/climatechange/uk/ukccp/pdf/ukccp06-all.pdf

Holland, M. and C. M. Bitz (2003) "Polar amplification of climate change in coupled models", Climate Dynamics 21(3-4): 221-232

Holland, M., C. Bitz, et al. (2006) "Future abrupt reductions in the summer Arctic sea ice", Geophysical Research Letters 33: L23503

Homer-Dixon, Thomas (2006) "The upside of down", Text: Melbourne

Hopkin, M. (2007) "Climate sensitivity 'inherently unpredictable'," Nature, 25 October 2007, www.nature.com/news/2007/071025/full/news.2007.198.html

Howden, D. and J. Steven (2007) "South America chokes as Amazon burns", The Independent, 5 October 2007, news.independent.co.uk/world/americas/article3028701.ece

IEA (2004) "World energy outlook 2004", International Energy Agency

Inman, M. (2007) "Global warming "tipping points" reached, scientist says", National Geographic News, 14 December 2007, news.nationalgeographic.com/news/2007/12/071214-tipping-points.html

Innovations Report (2007) "Global economy more carbon intensive, not less", Innovations Report, 22 May 2007, www.innovations-report.de/html/berichte/umwelt_naturschutz/bericht-84664.html

IPCC (2007a) "Climate change 2007: The physical sciences basis," Working group I report, IPCC: Geneva

IPCC (2007b) "Climate change 2007: Mitigation of climate change" Working group III report, Summary for Policymakers, table SPM.56, IPCC: Geneva

IPCC (2007c) "Climate change 2007: Synthesis report", IPCC: Geneva

IPCC (2007d) "Climate change 2007: Mitigation of Climate Change", Working Group III report, box 13.7,

Jackson, S.T., and C.Y. Weng (1999) "Late quaternary extinction of a tree species in eastern North America", Proceedings National Academy Sciences 96(24): 13847-13852

- Jenkins, G., R. Betts, et al. (2005) "Stabilising climate to avoid dangerous climate change — a summary of relevant research at the Hadley Centre", Met Office: Exeter
- Jones, C. D., P. M. Cox, et al. (2003a) "Strong carbon cycle feedbacks in a climate model with interactive CO₂ and sulphate aerosols", *Geophysical Research Letters* 30(9): 1479
- Jones, C. D., P. M. Cox, et al. (2003b) "Uncertainty in climate-carbon-cycle projections associated with the sensitivity of soil respiration to temperature", *Tellus Series B—Chemical and Physical Meteorology* 55: 642-648.
- Jones, R. N. and B. L. Preston (2006) "Climate change impacts, risk and the benefits of mitigation: A report for the Energy Futures Forum", CSIRO Marine and Atmospheric Research: Melbourne
- Jones, R. N. (2007b) "Keep cool is the message on climate", *Herald Sun*, 10 December 2007, www.news.com.au/story/0,23599,22897717-5007146,00.html
- Jones, T. (2007a) Interview with John Howard, ABC TV Lateline, 5 February 2007, www.abc.net.au/lateline/content/2006/s1840963.htm
- Jorgenson, M. T., Y. L. Shur, et al. (2006) "Abrupt increase in permafrost degradation in Arctic Alaska", *Geophysical Research Letters* 33(2): L02503
- Kahn, M. (2007) "Sudden sea level surges threaten 1 billion", *Reuters*, 19 April 2007, uk.reuters.com/article/scienceNews/idUKN1941671620070419
- Kallbekken, S. and J. S. Fuglestedt (2007) "Faster change means bigger problems", Centre for International Climate and Environmental Research: Oslo, www.cicero.uio.no/fulltext/index_e.aspx?id=5690
- Kilcrease, A. (2007) "Solar startup Ausra inks \$1b deal with PG&E", *Red Herring*, 5 November 2007, <http://www.redherring.com/Home/23116>
- Kleinman, R. (2007) "Warming turns Barrier Reef acidic", *The Age*, 18 October 2007, www.theage.com.au/news/climate-watch/warming-turns-barrier-reef-acidic/2007/10/17/1192300858496.html
- Knorr, W., W. Gobron, et al. (2007) "Impact of terrestrial biosphere carbon exchanges on the anomalous CO₂ increase in 2002–2003", *Geophysical Research Letters* 34: L09703
- Kolbert, E. (2006) "The darkening sea: what carbon emissions are doing to the ocean", *The New Yorker*, 20 November 2006
- Kump, L., J. Kastings, J. & R. Crane (1999) "The earth system", Prentice Hall: New Jersey
- Leemans, R. and B. Eickhout (2004) "Another reason for concern: regional and global impacts on ecosystems for different levels of climate change", *Global Environmental Change* 14: 219–228.
- Leggett, J. (2001) "The carbon war: global warming and the end of the oil era", Routledge: New York
- LeQuere, C., C. Rodenbeck, et al. (2007) "Saturation of the southern Ocean CO₂ sink due to recent climate change", *Science* 316(5832): 1735-1738
- Llewellyn, J. and C. Chaix (2007) "The business of climate change II: Policy is accelerating, with major implications for companies and investors", *Lehman Brothers*, 20 September 2007, www.lehman.com/who/intcapital/#
- Lovelock, J. (2006) "The revenge of Gaia", Allen Lane: London
- Lovelock, J. (2007) "Climate change on a living earth", lecture delivered to a public meeting of the Royal Society, 29 October 2007, www.jameslovelock.org/page24.html
- Lovelock, J. and L. Kump (1994) "Failure of climate regulation in a geophysiological model", *Nature* 369: 732-734.
- Lynas, M. (2007) "Six degrees: Our future on a hotter planet", Fourth Estate: London
- Mallon, K., and J. Reardon (2004) "Cost convergence of wind power and conventional generation in Australia", A report for the Australian Wind Energy Association, AusWEA: Melbourne, June 2004
- Mallon, K., G. Johnston, et al., (2007) "Towards a high-bandwidth, low-carbon future: Telecommunications-based opportunities to reduce greenhouse gas emissions", *Climate Risk: Sydney*
- Marris, E. (2006) "Black is the new green", *Nature News* 442:624-626, http://bestenergies.com/downloads/naturemag_200604.pdf
- Maslowski, W. (2006) "Causes of changes in Arctic sea ice", AMS ESSS Seminar, 3 May 2006
- Maslowski, W., J. Clement, et al. (2006) "On oceanic forcing of Arctic climate change", *Geophysical Research Abstracts* 8: 05892.
- Maslowski, W. (2007) private communication, 2 October 2007
- McCarthy, M. (2007) "Arctic sea ice melts to its lowest level ever", *The Independent*, 22 September 2007, environment.independent.co.uk/climate_change/article2987778.ece
- McKibben, B. (2007) "Remember this: 350 parts per million", *Washington Post*, 28 December 2007, www.washingtonpost.com/wp-dyn/content/article/2007/12/27/AR2007122701942.html
- McKinsey Quarterly (2007) "A cost curve for greenhouse gas reduction", http://www.mckinseyquarterly.com/article_abstract_visitor.aspx?ar=1911
- Mercer, J. (1978) "West Antarctic ice sheet and CO₂ greenhouse effect - threat of disaster", *Nature* 271: 321-325
- Metz, B., et al. (eds) (2005) "IPCC special report on carbon dioxide capture and storage", www.ipcc.ch/activity/srccs/index.htm
- Meinshausen, M. (2005) "On the risk of overshooting 2 degrees Celsius", *Proceedings from international*

- symposium on stabilisation of greenhouse gas concentrations — avoiding dangerous climate change, Exeter, 1-3 February 2005
- Meinshausen, M. (2006a) "What does a 2°C target mean for greenhouse gas concentrations? A brief analysis based on multi-gas emission pathways and several climate sensitivity uncertainty estimates" in H. J. Schellnhuber, et al. (eds) "An overview of 'dangerous' climate change", Cambridge University Press: Cambridge
- Meinshausen, M. (2006b) "Less than 2°C trajectories: a brief background note", KyotoPlus conference papers, 28-29 September 2006, Berlin.
- Miller, J. B. (2008) "Carbon cycle: Sources, sinks and seasons", *Nature* 451: 26-27
- Milliband, D. (2006) "The great stink: towards an environmental contract", speech by the Rt. Hon. David Miliband MP at the Audit Commission annual lecture, 19 July 2006, www.defra.gov.uk/corporate/ministers/speeches/david-miliband/dm060719.htm
- Minchin, L. (2007a) "Can climate change get worse? It has", *The Age*, 22 May 2007, www.theage.com.au/news/national/climate-change-bad-to-worse/2007/05/22/1179601340054.html
- Minchin, L. (2007b) "A climate of change", *The Age*, 5 May 2007, www.theage.com.au/news/national/a-climate-of-change/2007/05/04/1177788398904.html
- Minchin, L. (2007c) "Reef 'facing extinction'", *The Age*, 30 January 2007, www.theage.com.au/news/national/reef-facing-extinction/2007/01/29/1169919274339.html
- MMA (2006) "Renewable energy: a contribution to Australia's environmental and economic sustainability: Final report to Renewable Energy Generators Australia", McLennan Magasanik Associates, June 2006: Melbourne, www.rega.com.au
- Mollersten, K., J. Yan, et al. (2003) "Promising market niches for biomass energy with CO₂ removal and disposal: Opportunities for energy supply with negative CO₂ emissions", *Biomass and Bioenergy* 25: 273-285.
- Monbiot, G. (2006) "Heat: How to stop the planet burning", London: Allen Lane
- Monbiot, G. (2007a) "Giving up on two degrees", *The Guardian*, 1 May 2007, www.monbiot.com/archives/2007/05/01/1058/
- Monbiot, G. (2007b) "What is progress", *The Guardian*, 4 December 2007, www.monbiot.com/archives/2007/12/04/what-is-progress/
- Monbiot, G. (2007c) "The road well travelled", *The Guardian*, 30 October 2007, www.monbiot.com/archives/2007/10/30/the-road-well-travelled/
- NASA (2006) "Why does the Greenland ice sheet matter?", Earth Observatory, accessed 25 September 2007, earthobservatory.nasa.gov/Study/Greenland/greenland_sidebar.html
- NASA (2006b) "Oceans may soon be more corrosive than when the dinosaurs died", NASA media release, 20 February 2006, earthobservatory.nasa.gov/Newsroom/MediaAlerts/2006/2006022021812.html
- Nepstad, D., P. Lefebvre, et al. (2004) "Amazon drought and its implications for forest flammability and tree growth: a basin-wide analysis", *Global Change Biology* 10(5): 704-717
- New Scientist (2006) "Greenland's water loss has doubled in a decade", *New Scientist*, 25 February 2006
- New, M. (2006) "Arctic climate change with a 2°C global warming risk", in "2°C is too much: Evidence and implications of dangerous climate change in the Arctic", World Wildlife Fund, www.wwf.org.uk/filelibrary/pdf/dangerousclimatechange.pdf
- NIWA (2007) "Climate change weakens Southern Ocean carbon sink", media release, 18 May 2007, www.niwascience.co.nz/news/mr/2007/2007-05-18-1
- NOAA (2007) "Arctic report card 2007", National Oceanic and Atmospheric Administration, www.arctic.noaa.gov/reportcard/
- NSIDC (2007) "Arctic sea ice news Fall 2007", National Snow and Ice Data Centre, accessed 20 September 2007, nsidc.org/news/press/2007_seaiceminimum/20070810_index.html
- Oberstiner, M., C. Azar, et al. (2002) "Biomass energy carbon removal and permanent sequestration: A 'real option' for managing climate risk", Report no IR-02-042, International Institute for Applied Systems Analysis, Laxenburg: Austria, www.iiasa.ac.at/Admin/PUB/Documents/IR-02-042.pdf
- Oppenheimer, M. and R. Alley (2004) "The West Antarctic ice sheet and long-term climate policy: An editorial comment", *Climate Change* 64: 1-10
- Oppenheimer, M., B. C. O'Neill, et al. (2007) "The limits of consensus", *Climate Change* 317, 14 September 2007, doi:10.1126/science.1144831
- Osborne, H. (2007) "First zero-carbon home unveiled", *Guardian*, June 11, 2007, environment.guardian.co.uk/ethicalliving/story/0,,2100375,00.html
- Parkinson, C., D. Rind, et al. (2000) "The impact of sea ice concentration accuracies on climate model simulations with the GISS GCM", *Journal of Climate* 2606-2623
- Page, S., F. Siegert, et al. (2002), "The amount of carbon released from peat and forest fires in Indonesia during 1997", *Nature* 420: 61-65
- Parry, M., N. Arnell, et al. (2001) "Millions at risk: defining critical climate change threats and targets", *Global Environmental Change (Part A)* 11(3): 181-3.
- Pearce, F. (2006a) "Cities may be abandoned as salt water invades", *New Scientist*, 16 April 2006

- Pearce, F. (2006b) "The poor will pay for global warming", *New Scientist*, 11 November 2006
- Pearce, F. (2007a) "With speed and violence: Why scientists fear tipping points in climate change", Beacon Press: Boston
- Pearce, F. (2007b) "Too late to escape climate disaster", *New Scientist*, 18 August 2007
- Pearce, F. (2007c) "But here's what they didn't tell us", *New Scientist*, 10 February 2007
- Pearce, F. (2007d) "When the rivers run dry: Water - the defining crisis of the twenty-first century", Beacon Press
- Pearman, G. (2007) "Bali — high urgency", ABC online opinion, 3 December 2007, www.abc.net.au/unleashed/stories/s2108079.htm
- Pears, A. (2007) "Residential sector energy efficiency scenario", unpublished paper, February 2007
- Peddie, C. (2007) "Hell is about to break loose", *Adelaide Now*, 14 August 2007, www.news.com.au/adelaidenow/story/0,22606,22239280-5006301,00.html
- Perovich, D. K., J. A. Richter-Menge, et al. (2007) "Arctic sea ice melt in summer 2007: Surface and bottom ice ablation", *Eos Trans. AGU* 88(52) Fall Meet. Suppl., Abstract C21C-07
- Pickrell, J. (2005) "Soil may spoil UK's climate efforts", *New Scientist*, 07 September 2005,
- Pittock, B. (2006) "Are scientists underestimating climate change?" *Eos* 87: 34
- Pittock, B. (2007) "Ten reasons why climate change may be more severe than projected", www.green-innovations.asn.au/Risk-could-be-greater-Pittock-April07.doc
- Planning Portal (2007) "Code for sustainable homes", <http://www.planningportal.gov.uk/england/professionals/en/1115314116927.html>
- Queensland Government (2007) "Queensland's vulnerability to rising oil prices: Taskforce report", April 2007, www.epa.qld.gov.au/publications/?id=2190
- Rahmstorf, S. (2007) "Climate change fact sheet", Potsdam Institute for Climate Impact Research, www.pik-potsdam.de/~stefan/warmingfacts.pdf
- Rahmstorf, S., J. Cazenave, et al. (2007) "Recent climate observations compared to projections", *Science* 316: 709
- Randerson, J. (2008) "Forests battle to soak up carbon", *The Age*, 4 January 2008, www.theage.com.au/news/national/forests-battle-to-soak-up-carbon/2008/01/03/1198949985948.html
- Raupach, M. G. (2007) "Contributions to accelerating atmospheric CO₂ growth from economic activity, carbon intensity, and efficiency of natural sinks", *Proceedings National Academy Sciences*, published online before print, 23 October 2007
- Raupach, M. R. and J. G. Canadell (2008) "Observing a vulnerable carbon cycle" in H. Dolman, A. Valentini, et al. (eds) "Observing the continental scale greenhouse gas balance of Europe", Springer
- Raupach, M. G., G. Marland, et al. (2007) "Global and regional drivers of accelerating CO₂ emissions", *Proceedings National Academy Sciences*, published online before print 22 May, 2007
- Real Climate (2007) "Les chevaliers de l'ordre de la terre plate, Part I: Allègre and Courtillot", 18 November 2007, <http://www.realclimate.org/index.php/archives/2007/11/les-chevaliers-de-lordre-de-la-terre-plate-part-i-allgre-and-courtillot>
- Reich, R. (2007) "How capitalism is killing democracy", *Foreign Policy*, September/October 2007
- Register, R. (2006) "Ecocities: Rebuilding cities in balance with nature", New Society Publishers: Gabriola Island, British Columbia
- Rettalack, S. (2005) "Setting a long-term climate objective: A paper for the International Climate Change Taskforce", Institute for Public Policy Research: London
- Revkin, A. C. (2007) "Retreating Ice: A blue Arctic Ocean in summers by 2013?", *International Herald Tribune*, 1 October 2007, www.ihrt.com/articles/2007/10/01/sports/arcticweb.php
- Rhodes, J. S. and D. W. Keith (2005) "Engineering economic analysis of biomass IGCC with carbon capture and storage", *Biomass and Energy* 29: 440-450
- Rignot, E. and P. Kanagaratnam (2006) "Changes in the Velocity Structure of the Greenland Ice Sheet", *Science* 311: 5763
- Rijsberman, F. J., and R. J. Swart (eds) (1990) "Targets and Indicators of Climate Change", Stockholm Environment Institute: Stockholm
- Rive, N., A. Torvanger, et al. (2007) "To what extent can a long-term temperature target guide near-term climate change commitments", *Climatic Change* 82: 373-91
- Roberts, S. and J. Thumim (2006) "A rough guide to individual carbon trading: The ideas, the issues and the next steps: Report to Defra", Centre for Sustainable Energy, www.cse.org.uk/pdf/news1270.pdf
- Roe, G. H. and M. B. Baker (2007) "Why is climate sensitivity so unpredictable?", *Science* 318 (5850): 629-632
- Romm, J. (2007) "Hell and high water and what we should do", William Morrow: New York
- Roodhouse, M. (2007) "Rationing returns: a solution to global warming?", *History and Policy Journal*, March 2007
- Roy, R. and G. Mawer (2002) "Putting renewables on target: a 10% mandatory renewable energy target", Greenpeace Australia: Sydney
- Sarmiento, J. L. and N. Gruber (2003) "Sinks for anthropogenic carbon", *Physics Today*, August 2002, www.aip.org/pt/vol-55/iss-8/p30.html

- Saupe, E. (2007) "Snowmelt on the rise in Greenland", *GeoTimes*, 7 June 2007, www.geotimes.org/june07/article.html?id=WebExtra060707.html
- Sausser, B. (2007) "Ethanol demand threatens food prices", *MIT Technology Review*, 13 February 2007, www.technologyreview.com/Energy/18173/
- Scambos, T. (2007) "The Arctic sea ice collapse: implications for Greenland?", private communication, 21 September 2007
- Scheffer, M., V. Brovkin, et al. (2006) "Positive feedback between global warming and atmospheric CO₂ concentration inferred from past climate change", *Geophysical Research Letters* 33: L10702
- Schmitt, S. (2007) "Refrigeration system for the Earth's oceans threatens to break down", *Spiegel online*, 2 March 2007, www.spiegel.de/international/0,1518,469495,00.html
- Schneider, S. H. and J. Lane (2006) "An overview of 'dangerous' climate change" in H. J. Schellnhuber, et al. (eds) "An overview of 'dangerous' climate change", Cambridge University Press: Cambridge
- Schuster, U., and A.J. Watson (2007) "A variable and decreasing sink for atmospheric CO₂ in the North Atlantic", *Journal Geophysical Research*, in press, 2007.
- Seidel, D.J., Q. Fu, W.J. Randel, et al. (2007) "Widening of the tropical belt in a changing climate", *Nature Geoscience*, published online 2 December 2007
- Seidel, D.J., and W.J. Randel (2007) "Recent widening of the tropical belt: Evidence from tropopause observations", *Journal Geophysical Research* 112, D20113
- Serreze, M., M. Holland, et al. (2007) "Perspectives on the Arctic's shrinking sea ice cover", *Science* 315(5818): 1533-1536
- Shukman, D. (2007) "Greenland ice-melt 'speeding up'", *BBC News*. 28 July 2007, news.bbc.co.uk/1/hi/world/europe/3922579.stm
- Siegenthaler, et al. (2005) "Stable carbon cycle-climate relationship during the Late Pleistocene", *Science* 310 (5752): 1313-1317
- Sluijs, A., S. Schouten, et al. (2006) "Subtropical Arctic Ocean temperatures during the Palaeocene/Eocene thermal maximum", *Nature* 441: 61-613
- Smith, D. M., S. Cusack, et al. (2007) "Improved surface temperature prediction for the coming decade from a global climate model", *Science* 317(5839): 796-799
- Solovyov, D. and A. Doyle (2007) "Siberian thaw could speed up global warming", *Sydney Morning Herald*, 26 September 2007, www.smh.com.au/news/environment/siberian-thaw-could-speed-up-global-warming/2007/09/25/1190486311928.html
- Spotts, P. N. (2006) "Little Time to avoid big thaw, scientists warn", *Christian Science Monitor*, 24 March 2006, www.csmonitor.com/2006/0324/p01s03-sten.html
- Spratt, D. (2007) "The big melt: lessons from the Arctic summer of 2007", *Carbon Equity: Melbourne*, www.carbonequity.info/PDFs/Arctic.pdf
- Starkey, S. & K. Anderson (2005) "Domestic tradable quotas: A policy instrument for reducing greenhouse gas emissions from energy use", *Technical Report 39*, Tyndall Centre for Climate Change Research
- Steffen, W. (2007) "Climate change: science, impacts and policy challenges", *Policy Briefs 5*, Crawford School of Economics and Government, Australian National University: Canberra
- Steffen, W., R. Huff, et al. (2007) "Arctic warming, Greenland melt and moulines", *Eos Trans. AGU* 88(52) Fall Meet. Suppl., Abstract C21C-07 88(52)
- Stern, N. (2006a) "Launch presentation", *Stern Review on the Economics of Climate Change*, 30 October 2006, www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm
- Stern, N. (2006b) "Executive summary", *Stern Review on the Economics of Climate Change*, October 2006, www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_summary.cfm
- Stern, N. (2006c) "Review on the economics of climate change", *HM Treasury (UK) Part 3*. 2006, www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm
- Stroeve, J., M. Holland, et al. (2007) "Arctic sea ice decline: Faster than forecast?", *Geophysical Research Letters* 34: L09501
- Struck, D. (2007) "At the poles, melting occurring at an alarming rate", *Washington Post*, 22 October 2007, www.washingtonpost.com/wp-dyn/content/article/2007/10/21/AR2007102100761.html
- Styles, G. (2008) "The biofuel gap", *Energy Outlook blog*, 7 January 2008, energyoutlook.blogspot.com/2008/01/biofuel-gap.html
- Tedesco, M. (2007) "Snowmelt detection over the Greenland ice sheet from SSM/I brightness temperature daily variations", *Geophysical Research Letters* 34(L02504)
- Thuiller, W., S. Lavorel, et al. (2005) "Climate change threats to plant diversity in Europe", *Proceedings National Academy Sciences* 102: 8245-8250
- TREC/Club of Rome (2007) "Clean power from deserts", <http://www.desertec.org/>
- Tremblay, L. B., M. Holland, et al. (2007) "An ice-free Arctic? Opportunities for computational science", *Computing in Science and Engineering*, May/June 2007, 65-74

UNEP (2007) "Global environment outlook: Environment for development" (GEO-4), United Nations Environment Program, Progress Press: Malta, www.unep.org/geo/geo4/media/

UNESCO/Scope (2006) "The global carbon cycle", Policy briefs #2, October 2006, www.globalcarbonproject.org/misc/policyBrief.htm

UNFCCC (2007), "Synthesis of information relevant to the determination of the mitigation potential and to the identification of possible ranges of emission reduction objectives of Annex I Parties", Technical Paper FCCC/TP/2007/1, 26 July 2007, UNFCCC

University of Colorado (2007) "Arctic sea ice decline may trigger climate change cascade", media release, March 15, 2007, www.colorado.edu/news/releases/2007/109.html

Vidal, J. (2007) "The looming food crisis", The Guardian, 29 August 2007, www.guardian.co.uk/g2/story/0,,2157823,00.html

von Radowitz, J. (2007) "Ice cores hold threat of climate timebomb", The Age, 6 September 2006, www.theage.com.au/news/world/ice-cores-hold-threat-of-climate-timebomb/2006/09/05/1157222131704.html

Wade, T. (2005) "Amazon rainforest suffers worst drought in decades", Reuters, 11 October 2005, www.planetark.com/dailynewsstory.cfm/newsid/32912/story.htm

Walker, B. and D. Salt (2006) "Resilience thinking: Sustaining ecosystems and people in a changing world", Island Press: Washington

Walter, K. M., Zimov S. A., et al. (2006) "Melting lakes in Siberia emit greenhouse gas", Nature 443: 71-75

WBGU (1995) "Scenario for the derivation of global CO₂ reduction targets and implementation strategies", WBGU: Berlin

Weaver, A. J., K. Zickfield, et al. (2007) "Long term climate implications of 2050 emission reduction targets", Geophysical Research Letters 34: L19703

Weaver, P., L. Jansen et al. (2000) "Sustainable technology development", Greenleaf Publishing: Sheffield

Weber, B. (2007) "Boreal forest may be net greenhouse gas emitters", The Canadian Press, 1 November 2007, cnews.canoe.ca/CNEWS/Science/2007/10/31/4620836-cp.html

Weekes, P. (2007) "Storm clouds on the horizon", The Age, 22 December 2007, business.theage.com.au/storm-clouds-on-the-horizon/20071222-1imx.html

Wibberley, L., A. Cottrell et al., (2005) "Concentrating solar thermal for Australia", Cooperative Research Centre for Coal in Sustainable Development: Pullenvale

Wilkinson, M. (2007) "Climate change to take just years", Sydney Morning Herald, 15 November 2007, www.smh.com.au/news/environment/climate-change-to-take-just-years/2007/11/14/1194766770270.html

Williams, J. W., S. T. Jackson, et al. (2007) "Projected distributions of novel and disappearing climates by 2100 AD", Proceedings National Academy Sciences 10.1073/pnas.0606292104. 27

Williams, S. E., E. E. Bolitho, et al. (2003) "Climate change in Australian tropical rainforests: an impending environmental catastrophe", Proc. Biol. Sci. 270: 1887-1892

Wiki (2007) "United States home front during World War II", en.wikipedia.org/wiki/United_States_home_front_during_World_War_II, accessed 1 December 2007

Winton, M. (2006) "Does the Arctic sea ice have a tipping point?", Geophysical Research Letters 33:L23504,

Woodcock, A. (2007) "Scientists fear climate change speed-up as oceans fail to hold greenhouse gases", The Scotsman, 21 October 2007, news.scotsman.com/scitech.cfm?id=1678172007

Young, K. (2006) "Greenland ice cap may be melting at triple speed", New Scientist, 10 August 2006,

Young, K. (2007) "Canada's Inuit facing 'cultural genocide,' says Arctic expert", CanWest News Service, 23 November 2007, www.canada.com/topics/news/story.html?id=886e1d36-01c8-4ef6-8d60-a9460b815f62&k=34394

Zarembo, A. (2007) "A focus on meeting, not setting, climate goals", Los Angeles Times, 13 December 2007

Zeng, N., Q. Haifeng, et al. (2005) "Impact of the 1998-2002 mid-latitude drought and warming on terrestrial ecosystem and the global carbon cycle", Geophysical Research Letters 32(22): L22709

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hit the emergency button,

to plan with all our ingenuity how to survive and with unshakeable determination build a path for a

return to a safe-climate Earth

and to act with great speed and efficacy. Our life support systems — food, water, stable temperatures — are at

risk, and our consumption of fossil fuels is completely unsustainable. The voyage will be perilous and require

intense & innovative team-work

to find and mobilise technological and social answers to problems. Putting aside the “cost-too-much” mantras, our collective actions need to be driven by the imperative that

“Failure is not an option!”

If we do not succeed, we lose not just a small spacecraft but most of life on this planet.

ISBN 978-1-920767-08-2



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