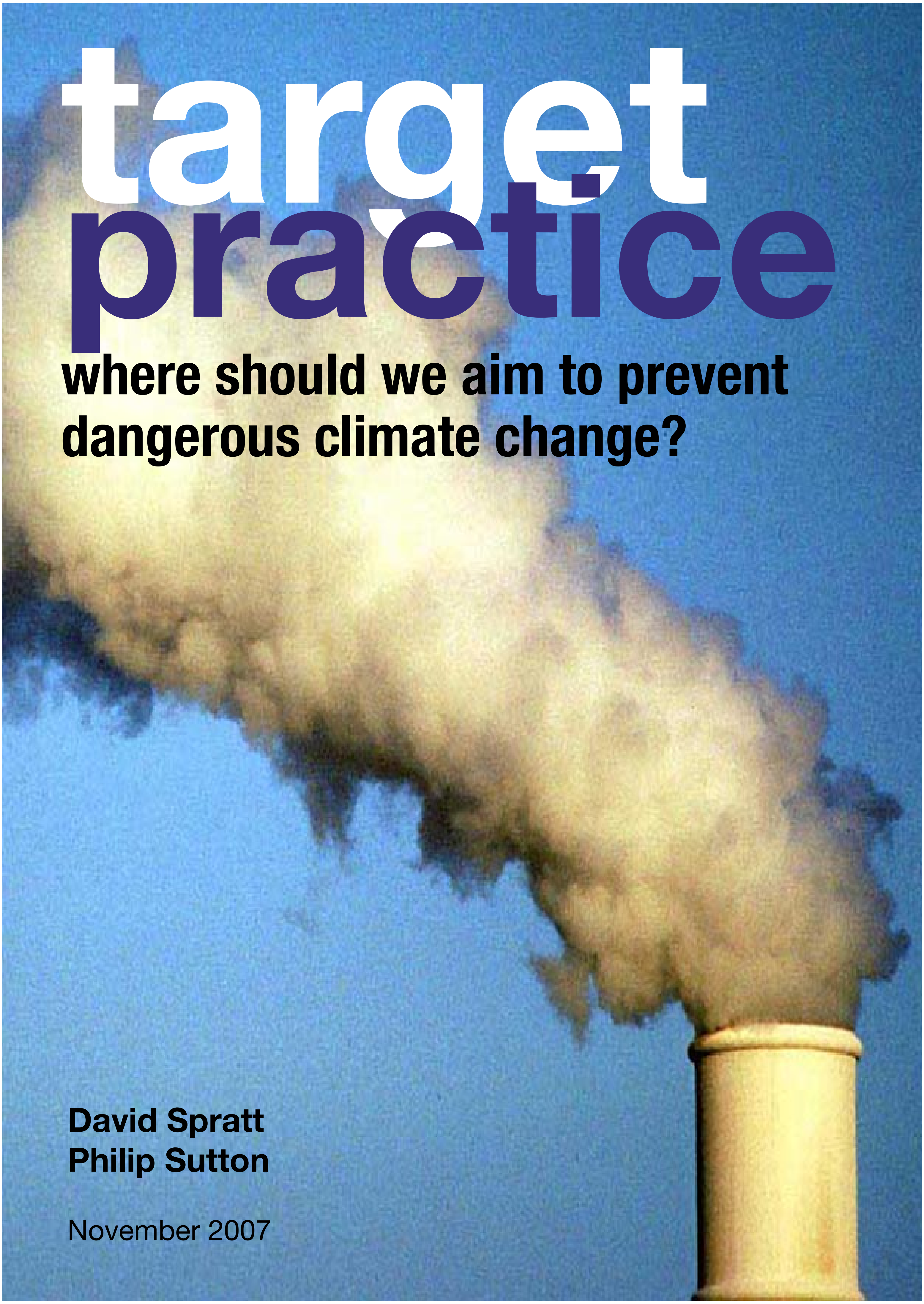

target practice

where should we aim to prevent dangerous climate change?

David Spratt
Philip Sutton

November 2007

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Target practice is the second in a 3-part series

"Climate code red: the case for a sustainability emergency""

The complementary reports are:

- "The big melt: lessons from the Arctic summer of 2007"

  http://www.carbonequity.info/PDFs/arctic.pdf

- "Rising to the challenge: constructing the fast path to a safe-climate world"

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Introduction

> "When starting a journey it makes sense to know where you are going"
> – Jonathan Pershing and Fernando Tudela (Aldy et al., 2003)

How hot is too hot? It's a simple question that seems too hot to handle. Neither of Australia's major political currents – Labor or the Coalition – have ever said what temperature increase should not be exceeded if we are to avoid what it is termed "dangerous climate change", even though it should be the first step on the ladder in constructing a global warming policy.

Perhaps the problem is that it requires a definition or an exposition of what "dangerous climate change" is, and that means getting specific about what is acceptable and what is not. How many species or ecosystems can be lost before it constitutes a danger? How far do the seas levels need to rise before they become dangerous? Is triggering the disintegration of the Greenland ice sheet dangerous?

Perhaps the problem is having to name a temperature cap above which the thermometer should not go if we are to avoid "dangerous climate change". Neither of the major political currents in Australia have named a temperature target, though there is an undertone in public discussion that the widely-supported, though far too high, international target of 2ºC is too big an ask, so let's go for 3ºC instead. The fact that the maximum temperature about 3 millions year ago was 2–3°C greater than now and sea levels were 25 metres higher and the northern hemisphere free of continental glaciers seems not to matters that we need to take into account.

The Labor-appointed Garnaut Climate Change Review was asked to consider "the weight of scientific opinion that developed countries need to reduce their greenhouse gas emissions by 60 percent by 2050 against 2000 emission levels, if global greenhouse gas concentrations in the atmosphere are to be stabilised to between 450 and 550ppm by mid-century" in order to avoid dangerous climate change.

In order to answer that proposition, a number of questions must be asked and systematically answered, and that is the purpose of this report. Where would we aim to avoid dangerous climate change? Is a reduction in emissions of 60% by 2050 going to do the job?

Our conclusions are very different from what most readers would expect if they have been guided by the talk of the political parties or most mainstream commentators.

If we are to stop global warming becoming "dangerous", we suggest in this report that it is not a question of how much higher will be OK, but rather by how much do we need to lower the existing temperature if we are return our planet to the safe-climate zone.

We have attempted to be rigorous in our analysis and the conclusions we draw from the data interpreted through a logical framework. It is from a firm base like this that the question should be answered.

Plucking figures out of the air because they are politically convenient or someone else said they might be OK is not a good enough answer.

David Spratt

Philip Sutton

11 November 2007

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 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 Intergovernmental Panel on Climate Change (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, 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, four questions need answers:

- what is "dangerous climate change" and what level of risk are we prepared to take?
- what are the temperature caps not to be exceeded to avoid "dangerous climate change" in the short and the long term?
- below what levels do greenhouse gases in the atmosphere need to be kept in order to achieve those temperature caps; how much do global emissions need to be reduced and what principles should be applied in the allocation of emissions reductions and the financial cost of emission reduction efforts (e.g. financial) between nations?
- what actions will achieve these emissions scenarios?

Dangerous climate change and risk

> "'Dangerous' has become something of a cliché when discussing climate change"
> (Schneider and Lane, 2006: 7).

What risk is acceptable in establishing "safe" global warming goals, policies and actions? The precautionary principle suggests that if an action (or inaction) might cause severe or irreversible harm to the public or the environment, in the absence of a well-informed scientific consensus that harm would not ensue, 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 that 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 – an 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% chance of large-scale species loss, 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 that 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 guide us in getting 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 stabilization 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".

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 (2206) also propose 'five numeraires':

- market system costs in dollars per ton of carbon (C);
- human lives lost in persons per ton C;
- species lost per ton C;
- distributional effects (such as changes in income differentials between rich and poor) per ton C; and
- quality of life changes, such as heritage sites lost per ton C or refugees created per ton 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". 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., 2007). "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 sea ice, 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 means 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 overshot this goal, 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. 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 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. This year (2007) the United Nation's emergency relief coordinator, Sir John Holmes warned that 12 of the 13 major relief operations were climate related and said this amounted to a climate change "mega disaster" (Borger, 2007)

Reviewing available state-of-the-environment data for a broad range of metrics, it is clear that ecosystems are not adapting and biodiversity is declining at an alarming rate, food production is threatened, there are risks to unique, large-scale geophysical systems, millions of people are at peril, water stress is rising, we are at or close to triggering an irreversible chain of events, and we are producing impacts at a pace beyond the capacity to adapt. So really, no matter what metric one chooses, it already is starting to flash red.

Climate change is *already* dangerous.

2.3 A safe temperature

It has been demonstrated (Spratt, 2007) that with a rise of less than 1ºC[1] the Arctic floating 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. This "non-linear event" was unexpected by most scientists and the 2007 IPCC reports, though James Hansen had repeatedly warned that the "'Albedo-flip' trigger mechanism over large portions" of ice sheets could lead to "eventual non-linear ice sheet disintegration" (Hansen, 2007a) and models used by

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[1] 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. CO2e refers to CO2e (total) not CO2e (Kyoto) unless specified.

Wieslaw Maslowski using US military submarine mapping of the Arctic sea-ice over many decades had allowed predictions since 2004 of an ice-free Arctic as early as 2013.

Both publicly and privately, 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 the window. What constitutes dangerous climate change needs to be and is being urgently re-interrogated.

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 metres this century, and perhaps as much as five metres by 2100 (Hansen, 2007c). 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 (Stern, 2006b).

> "…the loss of the Arctic sea ice, in all likelihood at an increase of less than 1ºC 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 sea ice, in all likelihood at an increase of less than 1ºC in global average temperature compared to pre-industrial levels[2], unambiguously represents dangerous human interference with the climate; and 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 so much 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 can we draw down the current levels of greenhouse gases to a safe level?"

To reiterate, we contend that at a rise of 0.8ºC over pre-industrial levels, we now stand at the point of dangerous climate change and further temperature rises of 0.6ºC already locked into the system (through thermal inertia) mean 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 melts 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", but that 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-to-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. 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.

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[2] Black soot from industrial and domestic emissions and bushfires most likely are also playing an important role in accelerating the melting of the Arctic ice.

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

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 by expert elicitations, but have been shaped by the world of diplomacy, political tradeoffs and compromises driven by narrow, short-term and national needs.

In addition to the impacts in the polar north already surveyed earlier, at 1°C of warming 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 five per cent 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 per cent 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 islands 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 per cent 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 per cent 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 the question as to 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 2ºC of warming to carbon dioxide (CO_2) 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).

Getting the third degree

The rapid Arctic melt now underway helps 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 (Spratt, 2007).

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 CO_2 levels were 360-400ppm, 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 per cent 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 CO_2 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 1.5ºC. It is suggested than 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 between 10 to 40 per cent 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 50 per central. 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, Yangtse and Yellow rivers – will fall dramatically. If global temperatures rise by 3°C (and that's becoming the un-official target for the rich-country governments), water flow in the Indus is predicted to drop by 90 per cent by 2100. The lives of two billion people are at stake.

For all this, the 3ºC 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 CO_2 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 3ºC target in his 2006 report to the UK government. Stern said that constraining greenhouse gas levels to 450ppm CO_2e "means around a 50:50 chance of keeping global increases below 2°C above pre-industrial (and) is unlikely [3] that increases will exceed 3°C," but keeping levels to 450ppm CO_2e is "already nearly out of reach" because "450ppm 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 550ppm CO_2e", but his policy proposals demonstrate that he has the higher figure in mind as a practical goal: "It is clear that stabilising at 550ppm [CO_2e] or below involves strong action… but such stabilisation is feasible" even though "550ppm is risky". So his policy framework is focused on constraining the increase to 550ppm, at which level "there is around a 50:50 chance of keeping increases below 3°C (and it is) unlikely [4] that increases would exceed 4°C" (Stern, 2006a, 2006b).

It is beyond reasonable doubt that Stern identifies a 2ºC cap with 450ppm CO_2e and a 3ºC cap with 550ppm CO_2e, 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 3ºC cap was reiterated during Stern's March 2007 visit to Australia…"

The 60/2050 link to a 3ºC 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 per cent emissions reductions" because "the planet would be left with about 550ppm of CO_2 equivalent by 2050" and this would "leave us roughly a 50/50 chance of being either side of 3ºC 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 2ºC 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 3ºC is looking more likely" (Minchin, 2007b).

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[3] 'Unlikely' does not mean that there would be a negligible chance (eg. less than one in a million). Instead it means that there is a15% chance.

[4] See the previous footnote.

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 2–2.4ºC. By contrast, 118 covered the range of 3.2–4ºC, which suggest that the IPCC scientists, following the lead of the politicians, have also largely shifted focus from 2ºC (IPCC, 2007c: 22).

This whole dialogue about 450ppm or 550pmm, 2ºC or 3ºC needs to be considered from another perspective. The Stern considerations are wholly dependent on the assumption that climate sensitivity – the equilibrium rise in temperature for a doubling of CO_2 from 280ppm to 560ppm – is around 3ºC. But this is true when only fast feedbacks are considered and the long-term sensitivity is in fact 6ºC (Hansen and Sato, 2007b), reaffirmed in Hansen's testimony in the Iowa coal case: "This higher climate sensitivity, 6°C for doubled CO_2, 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" (Hansen, 2007e).

To be utterly clear, a doubling of CO_2 levels will in the end produce a 6°C increase; Stern's 550ppm target is a 6°C increase; contemplating a 550ppm 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).

In peer-reviewed research published in "Nature", it was demonstrated that it is likely that when CO_2 exceeds 500ppm, the global temperature suddenly rises 6°C and becomes stable again despite further increases or decreases of atmospheric CO_2 (Lovelock and Kump, 1994). This contrasts with the IPCC models that predict that temperature rises and falls smoothly with increasing or decreasing CO_2. 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 comprise most of the ocean's plant life, are the world's greatest CO_2 sink, pumping down CO_2, 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 less 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 CO_2 abundance approached 500ppm, 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 warms 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 1ºC, we are now getting the third degree (in reality, the sixth degree) as 2ºC 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 established science 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 one degree Celsius 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 CO_2 amount, ~383ppm, 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 CO_2 amount and climate simulations consistent with empirical data on climate sensitivity both indicate that atmospheric CO_2 amount when an ice sheet first formed on Antarctica (34-35 My BP) was probably only 400-600ppm. This information raises the possibility that today's CO_2 amount, ~383ppm, 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 ºC (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 3ºC hangs in the air as "looking more likely". One could imagine that in another decade, 3ºC will be looking "impractical" and 4ºC will be "looking more likely". Like heating a frog slowly, with one certain outcome.

Emissions scenarios to avoid dangerous climate change

What are the global emissions scenarios consistent with a safe-climate temperature cap and what principles should be applied in the allocation of emissions reductions between nations?

Atmospheric CO_2 levels have risen from a pre-industrial level of 280ppm CO_2 to 383ppm CO_2 today. This is the highest CO_2 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).

Methane (CH_4) and nitrous oxide (N_2O) have increased by 150% and 16% since 1750 respectively, so that the CO_2 equivalent for all the Kyoto-defined greenhouse gases – referred to as CO2e (Kyoto) – is around 455ppm. When the effect of subtracting the cooling effect of aerosols (small particles in the atmosphere from smoke, dust, manufacturing and other sources) from the CO_2e (Kyoto) level is taken into account, the current total CO_2 equivalent – CO_2e (total) – is around 370ppm, though this figure in not well established due to uncertainty in quantifying aerosols cooling.

This has produced an increase in average global temperature of 0.8°C over pre-industrial levels with another 0.6°C in the pipeline due to thermal inertia[5]. The CO_2 level is now increasing by 2ppm annually, which will result in a temperature increase of around 0.2°C per decade. Atmospheric CO_2 has grown 35% faster than expected since 2000 due in part to deterioration in the land and oceans' ability 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, the suggestion that the annual rate may be 3-4ppm by mid-century if the world continues produces emissions "business as usual" (Hansen, 2005b) – ultimately resulting in a 1°C temperature increase every 25 years or an ecosystem-destroying 0.4°C per decade – may be conservative.

Global annual human CO_2 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

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[5] 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. 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_ per W/m2 ± 0.25_ (Hansen 2005b), so the imbalance is 0.85 X 0.75 = 0.6°C

emissions to be absorbed by the earth's carbon sinks (Jones 2003), although this is climate sensitive and decreasing. So, for example, if humans tomorrow reduced their total emissions by 60% to 4GtC CO_2 the level of atmospheric CO_2 would not continue to increase if the carbon cycle maintains its present pattern. If the non-CO_2 gases were also appropriately reduced, the temperature would not exceed 1.4°C. A safe-climate target requires further action: for example, reducing carbon emissions to zero so that the sinks could slowly draw down CO_2 levels (by about 1–1.5ppm annually) plus action on non-CO_2 emissions would result in a stabilisation temperature lower than 1.4°C. If we can find the way to engineer further drawdowns of CO_2, that will also help.

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

The 2°C scenarios

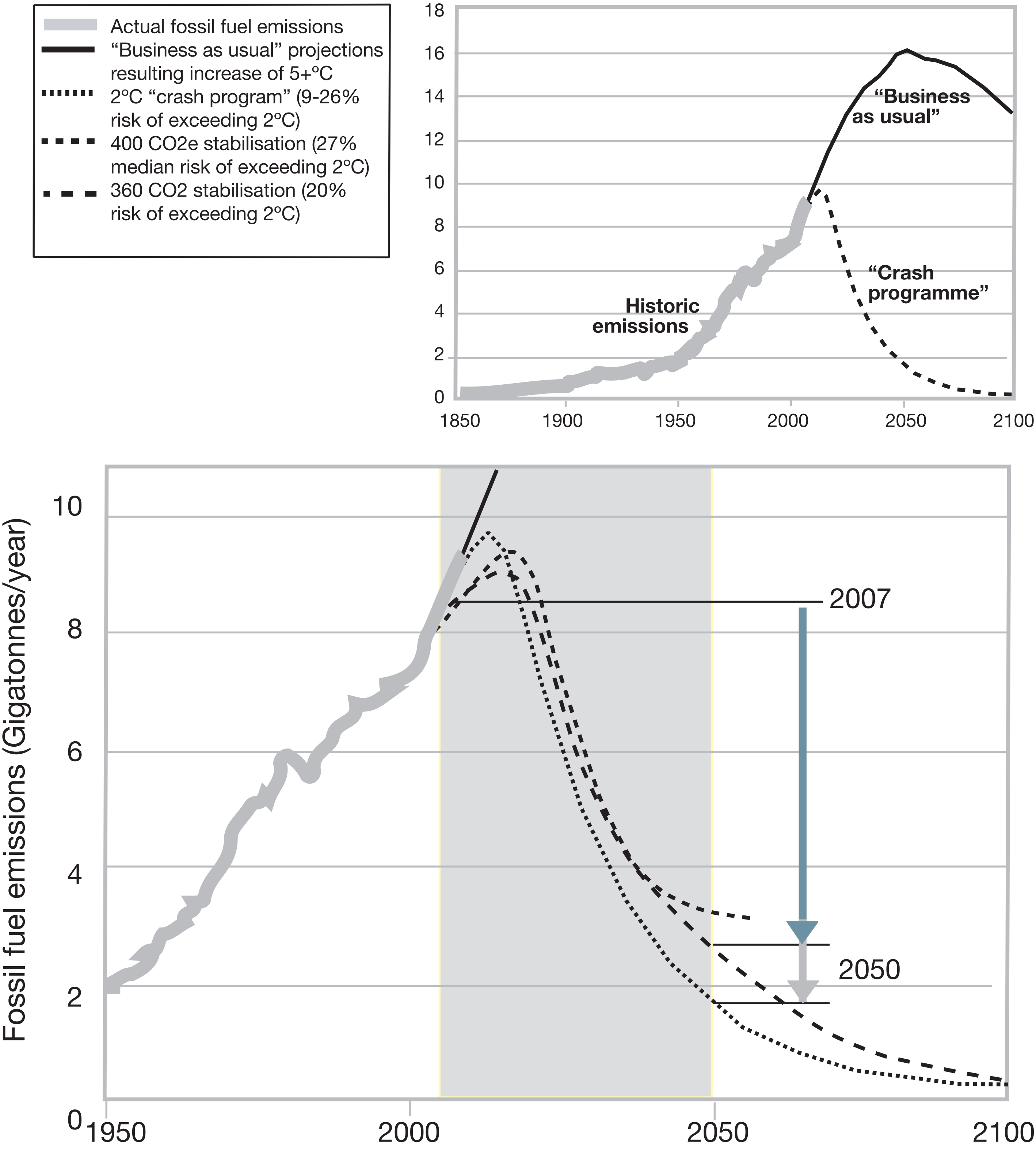
If we accept that the present rise of 0.8°C is dangerous, the scale of the problem we face is qualitatively different from the widely-advocated 2°C cap which allows another 40 years to reduce emissions to 60-80% below 1990 levels (by which time we would have added a further net amount of 80–100 GtC to the atmosphere). Nevertheless even the 2°C scenarios require Australian per capita emissions to be reduced from their current levels by more than 95%, 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 (discussed in our next report: Rising to the Challenge).

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 CO_2e (total) needs to be below 400pmm, 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 400ppm CO_2 equivalence will likely [85% probability] allow us to keep global mean temperature levels below 2°C in the long term"
- Rettalack (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 450-500ppm CO_2-equivalent in the next 50 years and thereafter should rapidly be reduced to about 400ppm CO_2-equivalent".
- To have a 'very low to low risk' (a 9-32% chance) of exceeding the 2°C threshold, "global emissions of carbon dioxide (CO_2) ...which stand at 380ppm today, peak at between 410-421ppm mid century, before falling to between 355- 366ppm (CO_2) by 2100" (Baer and Mastrandrea, 2006). This scenario is equivalent to about 400ppm CO_2e.

In addition, a number of other greenhouse gases, including methane and nitrous oxide, contribute to global warming, whilst human-induced aerosols produce a 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-CO_2 forcings and their future emission paths. Additional uncertainty arises if climate sensitivity is greater than 3°C, in which case the emissions cap of 400ppm CO_2e 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 at al, 2007). So in putting numbers to these emissions scenarios, we recognise that this is, in the end, a less than precise business.

Global emissions reductions by 2050 for < 2 degrees



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) *400pmm CO2e stabilisation:* Meinshausen, M. (2006), "On the Risk of Overshooting 2°C" (www.stabilisation2005.com/14_Malte_Meinshausen.pdf) *360ppm CO2 stabilisation:* Retallack, 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 stablisation at 400ppm CO2e has a peak of approx 480ppm CO2e, which is very similar to Hansen's peak of 450pp CO2 with declining non-CO2 forcings.

Figure 1

> "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."

But with the numbers we have, a number of 2°C scenarios are illustrated in Figure 1. 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 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 requires 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 400ppm CO_2e have a 33% probability of exceeding 2ºC, a 3% chance of passing 3ºC and a 1% chance of exceeding 4ºC (Stern, 2006c: Box 8.1). Application of the precautionary principle would lead us to not accept a long-term target of 400ppm CO_2e for a 2ºC cap because of the unacceptable risk of hitting temperatures from 2–4ºC.

Because today's figure of 370ppm CO_2e is close to the long-term cap of 400ppm CO_2e, 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 CO_2 concentrations can be reduced by lowering annual emissions below the level of CO_2 which is absorbed by global carbon sinks…" (Baer and Mastrandrea, 2006). This is illustrated in Figure 1 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, go higher than the long-term allows to buy time to get emissions well below the earth's net carbon sink, thus compensating for the carbon binge before the day of reckoning arrives.

Meinshausen describers the process: "Fortunately, the fact that we are most likely to cross 400ppm CO_2eq 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 400ppm, 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 220C" and thus for a 70-90% chance [i.e. 10–30% failure risk] of staying below 2°C Meinshausen maps an "initial peak at 475ppm CO_2eq " for the long-term return to "400ppm CO_2eq stabilization scenario" (Meinshausen, 2006a; Meinshausen, 2006b).

The 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 2ºC/400ppm CO_2e scenario, how much would emissions have to be cut?

- Baer and Mastrandrea (2006) say that "global emissions of CO_2 would need to peak between 2010 and 2013, achieve a maximum annual rate of decline of four to five per cent 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 etal. (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 be cut by around 95% by 2050 [6] based on the principle of "contraction and convergence". And all that for a 2ºC cap that is nowhere near sufficiently risk-averse!

A 2007 report for the UNFCCC leads, by inference, to similar conclusions: it shows that for a stabilisation scenario of 445–490 CO_2e (which is too high!) leading to an equilibrium temperature increase (using best estimate climate sensitivity) of 2–2.4ºC (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 Fourth Assessment report Working Group III report from which it draws the data, both fail to set out stabilisation scenarios of less than 445ppm CO_2e despite the basis in the literature to do so for stabilisation levels of 2ºC, again suggesting that for these institutions the 2ºC target is off the agenda, though stabilisation levels of up to 6.1ºC are considered worthy of inclusion!

> "Because Australian emissions are five times the global average, the 2°C scenarios require Australian per capita emissions 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 2ºC 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 in the present.

From this vantage point, Labor's advocacy of a 60% cut in total Australian emissions between 2000 and 2050 is not with coo-ee of a 2ºC, and it can demonstrated not to be too close to a 3ºC target either.

As to the proposal floated in Labor's May 2007 policy statement that it may be reasonable to limit emissions to 550ppm CO_2e (total), we note that the Hadley Centre data ensemble finds that at this level there is a 99% probability of exceeding 2ºC, a 69% chance of passing 3ºC and a 24% probability of exceeding 4ºC and a 7% risk of passing 5ºC (Stern, 2006c: Box 8.1). No further discussion is required.

A number of other shortcomings in Labor's 60/2050 policy statement are reviewed in Appendix 1.

Equity and emissions reduction

For the sake of exposition, the above discussion used the "contraction and convergence" model as advocated by the Global Commons Institute (www.gci.org.uk) to put figures to Australian emissions reductions for a 2ºC world. It is well recognised that "contract and converge", where every global citizen regardless of the level of development or capacity to construct a low-carbon life is allocated

[6] Taking the more lower-effort case of an overall 50% cut with emissions per person to converging everywhere to the global average, this requires 1990 global emissions of 6 GtC to be reduced by 2050 to 3GtC. Spread over an estimated population of 9 billion people by 2050, this is a per person target in 2050 of 0.33 tonnes of carbon per year based on the principle of "contract and converge", or an average global reduction from now of 80% per person. Australian emissions in 2004 were 5.63 tonnes 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 564.7m X 73.5%/20.2 X 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 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.

the same emissions quota or ration, is not a practical possibility on equity grounds, or politically. The developed economies are responsible for most historic atmospheric carbon emissions (and indeed most emissions since 1990), and they have a greater responsibility and a greater 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 CO_2 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 have been but for their actions ... [T]hose nations responsible for the bulk of the release of CO_2 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 stabilization program 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 2ºC 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 catalyzing and then supporting an emergency climate program that could actually meet the long-term challenge before us" (Baer, Athanasiou et al., 2007).

Under this framework, the GDR Responsibility and Capacity Index allocates Australia's share of the total global cost of meeting the 2ºC cap at 1.7% (page 54), not an outrageous proposition. For the developed economies, the GDRs framework requires CO_2 emissions to reach zero between 2020 and 2025. We urge the Review to consider this framework, if only because any politically viable international emissions-reduction agreement will have to be based on principles much more closely aligned to GDRs than the "contract and converge" method.

Drawing the threads together: 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 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 program 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 life 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 sea ice.

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

- many climate impacts have been assessed to be so bad past 2ºC that the arguments for preventative action seem overwhelming;
- models suggest that many self-reinforcing positive feedbacks are well entrenched past 2ºC; and
- the earth has not been warmer than 2ºC 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 is 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 2ºC 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 sea ice 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.

Defining the safe zone: So how should we define 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 that the global average temperature has not been more than 1ºC above the present temperature, that is, more than 1.8 ºC over the pre-industrial level, that CO_2 levels take many decades to produce their full (equilibrium) warming effect, and that we have another at least 0.6ºC of warming still to come from the greenhouse gases in the air now. We also know that over the last million years the CO_2 level in the atmosphere has not been more than 300ppm, and that while temperatures have been somewhat higher before, CO_2 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, with the atmospheric CO_2 level at 383ppm we are clearly already well outside the CO_2 paleohistory precautionary boundary of 300ppm, and with a warming of 1.4 ºC already largely locked in (0.8ºC current + 0.6ºC in the pipeline) we are very close to the temperature paleohistory precautionary boundary of 1.8 ºC over the pre-industrial level.

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 fire intensity, frequency and geographical spread. The increasing incidence of major natural disasters associated with climate change – described as being 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 extend 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 sea ice 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 means that the Arctic Ocean will no longer reflect most of the incoming solar radiation, but instead will become an effective absorber of most of the that energy. This physically very large "albedo switch" will lead to further warming in the Arctic of several degrees which will contribute to the destabilization of the Greenland ice sheet, adding to positive feedbacks already operating (such as the release of methane and CO_2 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 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 0.5ºC above the pre-industrial level. So it seems reasonable, based on concern to maintain the solar reflector value of the Arctic sea ice, that we must keep temperatures to no more than 0.5ºC warming over the pre-industrial level. Furthermore, taking this as the maximum warming cap, we can determine using the 3ºC climate sensitivity standard that the long-run maximum level of CO_2e needs to be no more than 320ppm.

The world is already 0.3 ºC warmer than our recommended maximum temperature cap and we are 50ppm CO_2e over the maximum greenhouse gas cap. So it is clear that:

- we are already into 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; and
- this means that no further greenhouse gases should be added to the air and there needs to be a very significant decay in the level of the short-residence-period greenhouse gases and other positive forcing (warming) agents in the atmosphere (e.g. soot) and a major draw down of CO_2 using natural carbon sinks and deliberate human capture and sequestration.

> "The world is already 0.3 ºC warmer than our recommended temperature cap and we 50ppm CO_2e over the maximum greenhouse gas cap… to return to the safe zone we need to bring the temperature and the greenhouse gas levels down."

Taking into account the further 0.6ºC 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 CO_2, 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, since 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 to the smallest time-period possible. Given past experiences across the world 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, CO_2 levels are rising in the atmosphere so fast that the oceans are less able to absorb CO_2 from the air because the process of transfer of CO_2 to the deep ocean cannot keep the pace. So there is both a faster growth in CO_2 in the air and also a faster rise in surface ocean acidity (due to dissolved CO_2) than would otherwise be the case.

Already with temperatures growing at 0.2ºC per decade ecosystems are finding it hard to adapt or migrate to keep pace with the moving isotherms. If temperatures rise by 0.4ºC per decade or more, isotherms will be moving towards the poles at 100–120 km per decade, and virtually all ecosystems will not cope, and will break down.

Setting specific climate action goals

In summary, the proposed actions goals should be to:

- apply a risk management regime that applies 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 0.5ºC above the pre-industrial level;
- reduce the current level of greenhouse gases in the air and keep them to less than 320ppm CO_2e (total);
- make the massive structural adjustments in as close to zero time as can be made humanly possible with the application of considerable human creativity and other resources;
- restrict the rate of climate change to less than 0.1 ºC per decade.[7]

[7] If the other goals are achieved then the rate of upward temperature increase shouldbe 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.

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 mind about whether they are technically, logistically or politically feasible.

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 happened as soon as 2013) 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 CO_2 as much as possible and also trapping CO_2 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.

For the duration of the adjustment program, this would almost certainly significantly constrain normal discretionary expenditure and it is hard to see such a constraint being applied, or 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 the climate crisis will be different in important ways to other emergencies. It will require coordinated global actions. It will be a long emergency – conceivably lasting as long or longer than the Second World War. 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 program 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.

Both the cooling strategy and the notion of declaring a sustainability emergency are the subject of the next report in this series "Rising to the Challenge".

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 and for carbon and/or energy taxation, 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 anticipated 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-taxes 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 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 0.5ºC, 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 --- if we don't find the will and the way to take the earth back into the safe-climate zone.

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 CO_2 to 550ppmv" (CSIRO), a target range of 450–550ppm CO_2 (Stern), the impacts of a 3C 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 550ppmv is unlikely to be achieved unless developed nations reduce their CO_2 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 550ppm CO_2. 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 450ppm CO_2. 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 550ppm CO_2e as the Royal Commission suggested, there is a 63-99% chance (with an average value of 82%) that global warming will exceed 2ºC (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 CO_2 stabilisation concentration of 550ppm, 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 450ppm or even lower, might be more appropriate to meet a 2°C stabilisation limit' (HM Government, 2006)". (Monbiot, 2007)

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 CO_2 alone. If other greenhouse gases are included, this is equivalent to 666ppm carbon dioxide equivalent (CO_2e). According to the Stern Report, at 650ppm CO_2 there is a 60–95% chance of 3ºC of warming (Stern, 2006c: 194).

Labor's May 2007 statement include the following: "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 CO_2 to 550ppmv, 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 550ppmv CO_2 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 550ppm. This clearly would clearly 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 550ppmv may not be a sufficient stabilisation goal for preventing DAI. Emission reductions beyond 60% by 2050 would leave the option for stabilising at 450ppmv 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 450ppm is "more consistent" that 550ppm in avoiding dangerous climate change. This key paragraph, which contradicts the sentence quoted by Labor, was omitted from the ALP policy release.

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