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Senate Select Committee on Climate Policy

World Vision Australia

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Contents

Prepared by:

Dr. Brett Parris
Chief Economist
World Vision Australia

Endorsed by:

Rev. Tim Costello
Chief Executive Officer
World Vision Australia

World Vision Australia
1 Vision Drive
Burwood East, VIC, 3151
Tel: 03 9287 2233.

Executive Summary

The speed, scale and scope of climate change present us with a national and global emergency that requires an emergency response. Left unchecked or half-checked, its implications are dire for Australia, for developing countries and for the world's children.

From the islands of Papua New Guinea to the arid landscapes of Darfur, World Vision Australia (WVA) staff have observed that the poor are already suffering from climate change and they will continue to suffer the most. As a child-focused development agency, WVA is particularly concerned about the well-being of children and about international and inter-generational equity. Our view is that the failure of our generation to do all we can to avoid dangerous climate change would constitute one of the most egregious wholesale violation of child rights in human history. Addressing climate change is not just about our standards of living or economic costs and benefits. It is also about ethics and the rights of today's children and their future families to inherit a planet at least as stable and habitable as the world we inherited.

WVA is encouraged that the Australian Government has made progress in acting on climate change. We have serious reservations however, about some aspects of the proposed Carbon Pollution Reduction Scheme (CPRS). These concerns centre on:

- The scheme's inadequate reflection of the scale of the threat facing Australia and the international community as detailed in the most recent scientific and security assessments;
- Emissions reduction targets that are inadequate to solve the problem, and that will make achieving a global deal more difficult;
- Inadequate attention to adaptation and mitigation financing for developing countries.

Emissions reduction targets for Australia should be based on the best available science. At the time that the IPCC's Fourth Assessment Report was being written around 2005-2007 it was thought that to have about a 50% chance of keeping global warming to 2°C or less above pre-industrial levels, greenhouse gases needed to be stabilised at around 450 ppm CO_2-equivalent (CO_2-eq). That meant that the Kyoto Protocol's Annex I countries (including Australia) needed to reduce their annual greenhouse gas emissions to 25-40% below 1990 levels by 2020, and to 80-95% below 1990 levels by 2050.

Since 2007, every indication from scientists is that things are worse than we thought. In particular the Arctic sea-ice is much more vulnerable than expected. While this may seem a trivial concern from the point of view of our home in the Southern Hemisphere and from the point of view of the world's poor, it is not. The loss of Arctic sea-ice could see billions of tons of CO_2 and methane released from melting permafrost, greatly exacerbating and accelerating climate change.

The climate also appears to be more sensitive to greenhouse gases than was thought previously. The emissions reductions of the IPCC and Garnaut Review are based on the assumption that a doubling of CO_2 levels from pre-industrial concentrations of 278 ppm to 556 ppm would lead to temperature rises of around 3°C above pre-industrial temperatures.

However, as climate scientists have recently pointed out, this figure only takes into account 'fast' feedbacks such as cloud formation, water vapour, and sea ice. Once 'slow' feedbacks are also considered (on timescales of centuries or less) – including ice sheet disintegration, vegetation changes, and CO_2 and methane releases from soils, tundra and ocean sediments – the temperature rise from a doubling of CO_2 levels is likely to be more like 6°C. A global average rise of 6°C would lead to far higher temperatures at the poles and would lead to catastrophic changes.

This higher climate sensitivity suggests that a 300-325 ppm CO_2 target (or around 350-375 CO_2-eq) is what we need for a safe climate, with sea ice restored to its coverage of 25 years ago. Since CO_2 levels are now approaching 388 ppm, this implies not only drastically reduced emissions but an extended period of actually removing CO_2 from the atmosphere.

The Garnaut Review noted that under 'business as usual' scenarios, the world was headed for around 1000 ppm CO_2 by 2100 – more than three and a half times pre-industrial levels. The emissions reductions targets currently proposed by the Government, namely 5-15% below 2000 levels by 2020 and 60% below 2000 levels by 2050 are not commensurate with Australia's contribution to the problem, and are so weak that they undermine the global deal that is essential to secure Australia's future.

As part of this new global deal, rich countries must commit to ensuring that sufficient resources are made available to assist developing countries to build sustainable, low-carbon economies, and to support their efforts to adapt to the immediate and future impacts of climate change. These commitments should be made in addition to the original promise under the UN to raise aid levels to 0.7% of GNI.

Economists have shown that there is no economic impediment to strong emissions reduction targets, and that strong targets would position our economy and society well to benefit from the global shift to a low-carbon future.

What is needed now more than ever is the decisive moral leadership required to face down those who suggest that we should privilege short-term private interests above the greater public good of all Australians, above the poor in developing countries, and above the rights of our children to hope for a better future.

Summary of Recommendations:

WVA calls on the Australian Government to:

1. Give greater attention to the complex nonlinearities of the climate system and the need for prudent risk management by advocating emissions reduction targets that would give us a high probability of avoiding dangerous climate change.

2. Take full account of the most recent scientific developments in deciding on its climate change policy responses.

3. Recognise the dire implications of unmitigated climate change for the poor and for the potential for these impacts to spill over into international humanitarian, economic and security crises.

4. Recognise that current markets and industrial structures are highly distorted by the pervasive externality of the historic failure of prices to reflect the true costs of emissions. Correction of these distortions through a combination of market-measures, regulations, subsidies and standards should not be viewed as 'sub-market' but 'market correcting', ensuring that prices better reflect the true costs of emissions.

5. Ensure that Australia's net greenhouse gas emissions are reduced by at least 40% below 1990 levels by 2020, and at least 95% by 2050.

6. Ensure that Australia's domestic greenhouse emissions peak no later than 2010.

7. Support a strong global agreement to keep warming to below 1.5°C (after unavoidable overshooting), with a maximum greenhouse gas stabilisation goal of 350-375 ppm CO_2-equivalent as soon as possible. This implies convergence to equal per capita emissions as early as possible, (e.g. 2030) and a multi-decade drawdown of emissions from current levels which have overshot this target. Emissions reduction targets for developed countries should be at least 40% below 1990 levels by 2020, and at least 95% below 1990 levels by 2050.

8. Support and contribute to an *International Adaptation & Mitigation Assistance Fund* for adaptation and mitigation in developing countries and also an *International Low-Emissions Technology Fund* for the research, development and commercialisation of low-carbon technologies. For funds of A$150 billion per annum, Australia's fair contribution would be at least A$5 billion to each. This aid should be above and beyond the 0.7% of GNI pledged by donor countries to tackle poverty before climate change became a global emergency.

9. Ensure that the voices of children and youth – those whose inheritance we are determining – are heard in formulating Australia's climate policies.

1. Introduction

World Vision Australia (WVA) welcomes the opportunity to engage in the debate on Australia's climate change policy. WVA is part of the World Vision International Partnership, a Christian relief, development and advocacy organisation operating in more than 90 countries. WVA is one of the largest offices in the WV Partnership, and in 2008 raised $355 million, assisting more than 22 million people.

Climate change is fundamentally a development problem and a moral problem, not simply an environmental problem. Anthropogenic (human-induced) climate change has been caused by the past development of today's rich countries, and as the Intergovernmental Panel on Climate Change (IPCC) has shown, unless greenhouse gas emissions are cut drastically, it will be exacerbated by their continued economic growth and by the development of today's poor countries.

The poor are already suffering from climate change and they will continue to suffer the most. They are least able to protect themselves from its effects and they are least able to recover from climatic disasters. They tend to live in the most vulnerable areas, such as low-lying land prone to flooding, or marginal agricultural land prone to drought. They are the most vulnerable to the spread of tropical diseases. They are more likely to have to leave their homes in search of water or to escape flooding. They are the most vulnerable to the effects of the conflicts likely to arise from international tensions over water, energy and displaced people.

As a child-focused development agency, World Vision Australia (WVA) is particularly concerned about the well-being of children and about international and inter-generational equity. Today's children and their children should not have to bear an unfair share of the adjustment costs required to deal with climate change, and we have no right to leave them a legacy of a dangerously warm and unstable climate – with all the political and economic instabilities that such changes would entail.

Our failure to do all we can to avoid dangerous climate change would constitute one of the most egregious wholesale violation of child rights in human history. Addressing climate change is not just about our standards of living or economic costs and benefits. It is also about ethics and the rights of today's children and their future families to inherit a planet at least as stable and habitable as the world we inherited.

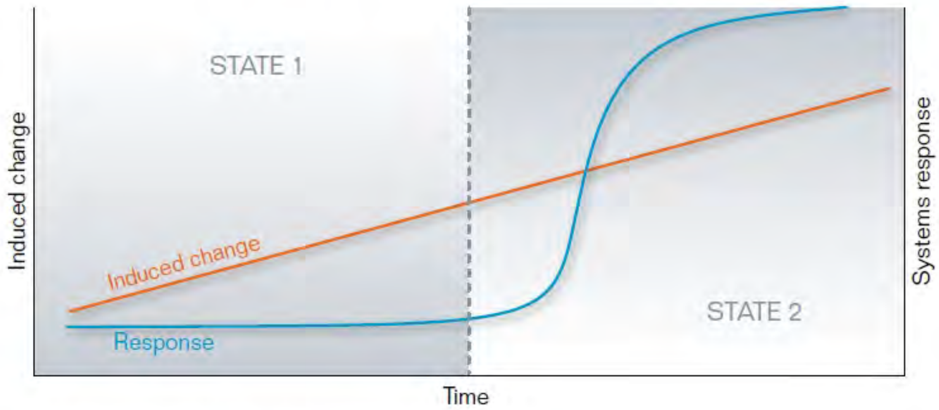
2. The nonlinearity of the climate system

World Vision is concerned that too many of the debates about climate change, including economic assessments of the risks, are conducted with insufficient appreciation of the differences between predictable linear systems and complex nonlinear systems.

With linear systems, a slow, gradual and predictable cause will tend to have a slow, gradual and predictable effect. But with nonlinear systems, slow, gradual causes can result in sudden and quite radical effects. The idea of the threshold, or tipping-point, is one of the most important concepts for understanding the behaviour of nonlinear systems. Often nothing much seems to be happening until a critical threshold is crossed, and then suddenly, the system 'tips' and rapid changes ensue. After a threshold is crossed, the system may tip into a new equilibrium, or it may endlessly cycle between two or more equilibria.[1] The figure below from the Garnaut Review illustrates the difference well.

Figure 1. Threshold illustration from the Garnaut Review
Source: Garnaut (2008), p. 97.

Figure 4.8 Abrupt or rapid climate change showing the lack of response until a threshold is reached



Source: Based on Steffen et al. (2004).

This distinction between linear and nonlinear systems is critical because we know that the Earth's climate is not a simple linear system, but a highly complex nonlinear system with the potential to lurch from one stable state to another. As one recent study put it: "Palaeoclimate data show that the Earth's climate is remarkably sensitive to global forcings. Positive feedbacks predominate. This allows the entire planet to be whipsawed between climate states."[2] The emergence from the last ice age for example, was characterised by dramatic oscillations, or 'flickering' between cold and warm periods.[3]

We know from annual bands in ice cores from Greenland that temperatures there rose by some 10°C within three years around 14,700 years ago.[4] This warming was interrupted by an abrupt cooling about 12,900 years ago known as the Younger Dryas, sending temperatures plummeting again in the Northern hemisphere. Overall it made the world drier, windier and dustier.[5] It ended suddenly around 11,700 years ago when temperatures in Greenland again rose some 8°C within 10 years.[6]

[1] On nonlinear climate change, see Lenton *et al.* (2008); Alley (2004); Buchanan (2007); Pearce (2007); Hansen (2004); and National Research Council (2002).
[2] Hansen *et al.* (2007a), p. 1925.
[3] Taylor *et al.* (1993).
[4] Steffensen *et al.* (2008), pp. 680-681.
[5] Pearce (2007), p. 149.
[6] National Research Council (2002), p. 27. See also: Pearce (2007), pp. 149-150; Alley (2000).

These abrupt climatic shifts are by no means unique, as three other recent studies on the ancient climatic records have shown:

> Paleoclimatic records show that large, widespread, abrupt climate changes have affected much or all of the earth repeatedly over the last ice-age cycle as well as earlier – and these changes sometimes have occurred in periods as short as a few years. Perturbations in some regions were spectacularly large: some had temperature increases of up to 16°C and doubling of precipitation within decades, or even single years.[7]
>
> Intense, abrupt warming episodes appeared more than 20 times in the Greenland ice records. Within several hundreds or thousands of years after the start of a typical warm period, the climate reverted to slow cooling followed by quick cooling over as short a time as a century. Then the pattern began again with another warming that might take only a few years.[8]
>
> Nitrogen and argon isotopes in air trapped in a Greenland ice core (GISP2) show two prominent peaks in the interval 11,800-10,800 B.P., which indicate two large abrupt warming events. The first abrupt warming (10 ± 4 °C) is the widely documented event at the end of the Younger Dryas. Here, we report on the second abrupt warming (4 ± 1.5 °C), which occurred at the end of a short lived cooler interval known as the Preboreal Oscillation (11,270 ± 30 B.P.). A rapid snow accumulation increase suggests that the climatic transition may have occurred within a few years.[9]

Sea levels have also risen and fallen dramatically in the past – sometimes quite rapidly. Between around 130,000 to 118,000 years ago for example, at the height of the last interglaciation (the period between ice ages) the sea levels were some four to seven metres higher than they are now.[10] This is around the same increase in level that would occur if the Greenland Ice Sheet were to melt. But more extreme levels have also occurred in the past. Sea levels were around 70 metres higher 45 million years ago when CO_2 levels were around 1000 to 1500 ppm and there was no permanent ice on the planet. More recently, they were around 130 metres lower during the Last Glacial Maximum 21,000 years ago when CO_2 levels were around 185 ppm.[11]

The complex nonlinearity of the climate system strongly suggests that we would be extremely unwise to countenance allowing emissions to continue on their current 'business as usual' trajectories – or to make only half-hearted attempts to rein them in. Overall we seem to have a reasonable grasp of the lower bounds of climatic changes and their impacts – but we still really do not have a clear picture of how bad things could get if luck is not with us: climate sensitivity to a doubling of CO_2 appears to be greater than 3°C; ice sheet dynamics mean the ice sheets are less stable than we had previously thought; and carbon-cycle feedbacks are likely to lead to positive feedback loops releasing more greenhouse gases as the world warms. The IPCC was very clear that the current models do *not* adequately account for

[7] National Research Council (2002), p. 153.
[8] Alley (2004), p. 64.
[9] Kobashi *et al.* (2008), p. 397.
[10] Overpeck *et al.* (2006), p. 1747.
[11] Alley *et al.* (2005), p. 456 ; Pagani *et al.* (2005).

carbon-cycle feedbacks or ice sheet dynamics, so their projections of effects such as sea level rise should be thought of as conservative estimates:

> Models used to date do not include uncertainties in climate-carbon cycle feedback nor do they include the full effects of changes in ice sheet flow, because a basis in published literature is lacking. [12]

It is often asserted that Australia's emissions are too small to be of much consequence. But when dealing with a complex nonlinear system with possibly sensitive thresholds, it is misleading to assert that a small incremental increase will necessarily have only a minor impact. Australia's emissions do matter since all emissions bring us closer to critical thresholds and while we know they are there, we do not know precisely where they lie. So while Australia's emissions trajectory *may* not affect environmental outcomes significantly, we cannot say definitively that it *will* not. Moreover strong Australian targets would promote technical innovations which can be exported and institutional innovations which can be copied, and would grease the wheels of international negotiations. Australian action (or inaction) may therefore have consequences far greater than those due to our emissions alone.

Recommendation 1: That the Australian Government gives greater attention to the complex nonlinearities of the climate system and the need for prudent risk management by advocating emissions reduction targets that would give us a high probability of avoiding dangerous climate change.

3. Recent scientific developments

The long time taken for the IPCC's deliberations and consensus-building make it difficult for the most recent research to be incorporated into the final reports. Each 'Summary for Policymakers' must also be agreed, line-by-line between scientists and representatives of every one of the IPCC's member governments. This process makes these summaries inherently conservative, since some governments are resistant to certain scientific conclusions for reasons which have little to do with science. There have been a number of studies released since the drafting process for this round of IPCC reports concluded which suggest that the IPCC erred on the side of caution, and if anything, has *under*estimated the pace of change.

3.1 Sea levels are rising faster than expected

In a recent study Stefan Rahmstorf and his colleagues warned that, "The satellite data show a linear trend of 3.3 ± 0.4mm/year (1993-2006) and the tide gauge reconstruction trend it slightly less, whereas the IPCC projected a best-estimate rise of 2 mm/year." They concluded that: "Overall, these observational data underscore the concerns about global climate change. Previous projections, as summarized by IPCC, have not exaggerated but may in some respects even have underestimated the change, in particular for sea level."[13]

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[12] IPCC (2007a), p. 14.
[13] Rahmstorf *et al.,* (2007), p. 709.

3.2 Ice sheets are more unstable than expected

Until quite recently it was thought that major ice sheets such as those in Greenland and Antarctica were relatively stable, melting slowly and predictably over centuries or millennia. However, this understanding has been challenged recently and there is growing concern among glaciologists that is not adequately reflected even in the latest models considered by the IPCC.[14] Accelerating ice sheet dynamics can produce major changes in much shorter periods than had been traditionally believed:

> The great ice sheets covering Antarctica and Greenland were, traditionally, believed to take thousands of years to respond to external forcing. Recent observations suggest, however, that major changes in the dynamics of parts of the ice sheets are taking place over timescales of years.[15]
>
> Rapid ice thinning in southeast Greenland, associated with accelerated ice flow, is not localized in confined outlet glaciers but is distributed well inland of the glaciers' main trunks. … Since most of the glacier acceleration in the northern half of the study area occurred in just the past several years, this indicates that drawdown within the outlets migrated rapidly to the interior, spanning 10's of km over that time. Continued changes in outlet glacier flow could therefore quickly impact ice sheet dynamics and mass balance.[16]

Once ice sheet dynamics are taken into account, sea-level rises are more likely to be at least 0.8 m and possibly even 2 metres by 2100.[17] As Vaughan and Arthern observe, "the IPCC's projections specifically exclude the contribution that could arise from rapidly changing flow in ice sheets, especially in Greenland and West Antarctica."[18] On sea level, another recent paper warned that:

> [I]ce sheets have contributed meters above modern sea level in response to *modest* warming, with peak rates of sea-level rise possibly exceeding 1 m/century. Current knowledge cannot rule out a return to such conditions in response to continued greenhouse gas emissions. Moreover, a threshold triggering many meters of sea-level rise could be crossed well before the end of this century, particularly given that high levels of anthropogenic soot may hasten future ice-sheet melting …, the Antarctic could warm much more than 129,000 years ago [when sea levels were 4-6 m higher] … and future warming will continue for decades and persist for centuries even after the forcing [the gas levels causing climate change] is stabilized.[19]

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[14] See: Alley *et al.* (2005); Shepherd & Wingham (2007); Truffer & Fahnestock (2007); Fricker *et al.* (2007) and Howat *et al.* (2007). For an earlier study see: Zwally *et al.* (2002).
[15] Bamber *et al.* (2007), p. 1.
[16] Howat *et al.* (2008), p. 1.
[17] Pfeffer *et al.* (2008).
[18] Vaughan & Arthern (2007).
[19] Overpeck *et al.*, (2006), p. 1750.

Recent evidence from Antarctica also indicates that the West Antarctic Ice Sheet (WAIS) has collapsed frequently in the past, leading to sea level rises of 7 m at temperatures of no more than 3°C higher than present and CO_2 levels of around 400 ppm:

> Our data provide direct evidence for orbitally induced oscillations in the WAIS, which periodically collapsed, resulting in a switch from grounded ice, or ice shelves, to open waters in the Ross embayment when planetary temperatures were up to 3 °C warmer than today and atmospheric CO_2 concentration was as high as 400 p.p.m.v.[20]

3.3 Warmer seas are making cyclones and storm surges stronger

The sea-level issue is particularly important since it is often assumed that sea-level rise represents a slow, progressive inundation that is relatively straightforward to manage. However, one of the greatest dangers from higher seas is the storm surge that accompanies a tropical storm, which can often be 5-6 metres high. For example, the storm surge accompanying cyclone Nargis in Myanmar on 2-3 May 2008 travelled some 35 km inland, killing around 140,000 people and flooding around 14,400 km^2, an area a third the size of Switzerland.[21] A recent study found that cyclone Nargis intensified very rapidly as it passed over unusually warm waters in the Bay of Bengal:

> On 2 May 2008, category-4 tropical cyclone Nargis devastated Myanmar. It was observed that just prior to its landfall, Nargis rapidly intensified from a weak category-1 storm to an intense category-4 storm within only 24 h. … it is found that Nargis' rapid intensification took place on a pre-existing warm ocean anomaly in the Bay of Bengal.[22]

Another recent study examined the relationship between hurricanes in the North Atlantic, Caribbean Sea and Gulf of Mexico between 1965 and 2005:

> Our results indicate that the sensitivity of tropical Atlantic hurricane activity to August–September sea surface temperature over the period we consider is such that a 0.5 °C increase in sea surface temperature is associated with a 40% increase in hurricane frequency and activity. The results also indicate that local sea surface warming was responsible for 40% of the increase in hurricane activity relative to the 1950–2000 average between 1996 and 2005.[23]

3.4 Arctic sea ice is declining faster than expected

The importance of the Arctic sea ice to climate trajectories can hardly be overstated. The Arctic sea ice acts as a giant mirror, reflecting a vast amount of the sun's energy. As the ice melts, the dark open ocean waters absorb far more heat, leading to more melting of sea ice and higher temperatures throughout the Arctic.

The extent of Arctic sea ice at the end of the melt season in September was shown in May 2007 to be declining much faster than expected. The observed trend from 1953 to 2006

[20] Naish *et al.* (2009), p. 322.
[21] Luetz, (2008), p. 12.
[22] Lin *et al.* (2009), p. 1.
[23] Saunders & Lea (2008), p. 557.

was stronger than the IPCC model predictions. In fact, Arctic sea ice reached its lowest recorded extent at the end of the September 2007 melt-season, opening the Northwest Passage between the Pacific and Atlantic Oceans. Sea ice extent was 43% less than in 1979 when satellite measurements first began.[24] The 2008 melt was also close to the record 2007 melting. Current summer minima are some 30 years ahead of average model predictions, making it likely that the Arctic Ocean will be ice-free each September well before the end of this century.[25] One recent analysis concluded that we could expect to see the Arctic to be free of sea ice by 2037, and possibly as early as 2028.[26] With higher temperatures the permafrost melts, releasing both CO_2 and methane. This is critical since the permafrost covers some 23 million km^3 in the Arctic region and possibly contains more than 950 billion tonnes of carbon – about 63% of the global soil carbon stock. Eastern Siberia alone contains some 500 billion tonnes of carbon, around 75% of which could be released over time.[27]

3.5 CO_2 emissions are rising faster than expected

The most recent estimates of global CO_2 emission rates have shown that we are pushing the upper bounds of the IPCC's previous projections:

> CO_2 emissions from fossil-fuel burning and industrial processes have been accelerating at a global scale, with their growth rate increasing from 1.1% y^{-1} [per year] for 1990-1999 to > [more than] 3% y^{-1} [per year] for 2000-2004. The emissions growth rate since 2000 was greater than for the most fossil-fuel intensive of the Intergovernmental Panel on Climate Change emissions scenarios developed in the late 1990s. … No region is decarbonizing its energy supply. The growth rate in emissions is strongest in rapidly developing economies, particularly China. Together, the developing and least-developed economies (forming 80% of the world's population) accounted for 73% of global emissions growth in 2004 but only 41% of global emissions and only 23% of global cumulative emissions since the mid-18th century. The results have implications for global equity.[28]

The implications of this increase were outlined by Ross Garnaut and colleagues:

> Rapid global economic growth, centred in Asia but now spread across the world, is driving rapid greenhouse-gas emissions growth, making earlier projections unrealistic. … we project annual emissions by 2030 to be almost double current volumes, 11 per cent higher than in the most pessimistic scenario developed by the Intergovernmental Panel on Climate Change (IPCC), and at a level reached only in 2050 in the business-as-usual scenario used by the Stern Review. This has major implications for the global approach to climate-change mitigation. The required effort is much larger than implicit in the IPCC data informing the current international climate negotiations. Large cuts in developed country emissions will be required, and significant deviations from baselines will be required in developing countries by 2020. It is hard to see how the required cuts could be achieved without all major developing as well as developed countries adopting economy-wide policies.[29]

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[24] Kerr (2007a).
[25] Stroeve *et al.* (2007), pp. 4-5. See also, Pearce (2009).
[26] Wang & Overland (2009).
[27] Khvorostyanov *et al.* (2008), p. 1.
[28] Raupach *et al.* (2007), p. 10288.
[29] Garnaut *et al.* (2008), p. 377.

3.6 We are probably already committed to 'dangerous' climate change

The acceleration in CO_2 emissions is especially concerning since a recent reassessment of the threshold for "dangerous" climate change suggests that warming greater than about 1°C above 2000 levels, or around 1.7°C above 1850 levels, "has effects that may be highly disruptive". Previously it had been thought that "dangerous" climate change would ensue only after the 2°C line had been crossed.[30] This is unfortunate because another study revealed that the warming we are committed to, due to past greenhouse gas emissions, could already be around 2.4°C, much higher than than previously suspected, and that the effect of the greenhouse gases was being masked by aerosols – fine pollutant particles in the atmosphere which reflect the sun's heat:

> The observed increase in the concentration of greenhouse gases (GHGs) since the preindustrial era has most likely committed the world to a warming of 2.4°C (1.4°C to 4.3°C) above the preindustrial surface temperatures. The committed warming is inferred from the most recent Intergovernmental Panel on Climate Change (IPCC) estimates of the greenhouse forcing and climate sensitivity. The estimated warming of 2.4°C is the equilibrium warming above preindustrial temperatures that the world will observe even if GHG concentrations are held fixed at their 2005 concentration levels but without any other anthropogenic forcing such as the cooling effect of aerosols. The range of 1.4°C to 4.3°C in the committed warming overlaps and surpasses the currently perceived threshold range of 1°C to 3°C for dangerous anthropogenic interference with many of the climate-tipping elements such as the summer arctic sea ice, Himalayan–Tibetan glaciers, and the Greenland Ice Sheet. IPCC models suggest that ~25% (0.6°C) of the committed warming has been realized as of now. About 90% or more of the rest of the committed warming of 1.6°C will unfold during the 21st century, determined by the rate of the unmasking of the aerosol cooling effect by air pollution abatement laws and by the rate of release of the GHGs-forcing stored in the oceans.[31]

If past emissions really have committed us to around 2.4°C above pre-industrial levels, it implies that mitigation strategies must focus on long-term reduction of greenhouse gases below current levels.

3.7 Antarctica is warming too

Contrary to the previous wisdom, Antarctica is also warming overall, not just on the Antarctic Peninsula:

> [S]ignificant warming extends well beyond the Antarctic Peninsula to cover most of West Antarctica, an area of warming much larger than previously reported. West Antarctic warming exceeds 0.1°C per decade over the past 50 years, and is strongest in winter and spring. Although this is partly offset by autumn cooling in East Antarctica, the continent-wide average near-surface temperature trend is positive.[32]

[30] Hansen *et al.* (2007b), p. 2287.
[31] Ramanathan & Feng (2008), p. 14245.
[32] Steig *et al.* (2009), p. 459.

3.8 Climate change is largely irreversible

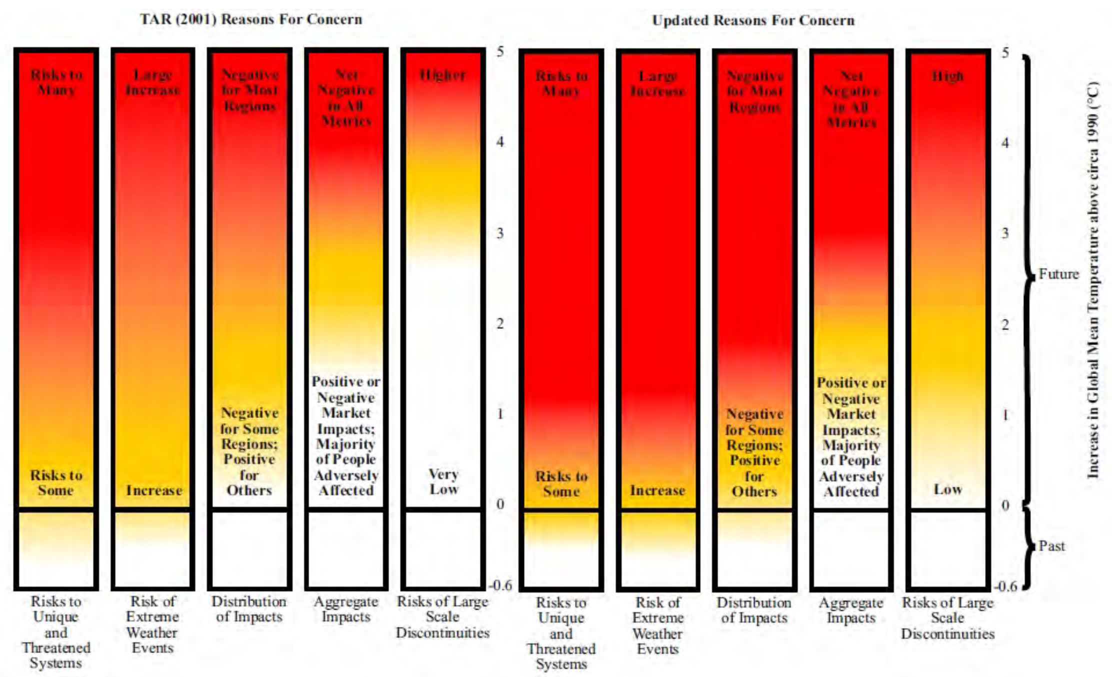
If we remain on current trajectories of rapidly increasing emissions, the warming we induce now appears to be irreversible on any timescale relevant to our civilization:

> The severity of damaging human-induced climate change depends not only on the magnitude of the change but also on the potential for irreversibility. This paper shows that the climate change that takes place due to increases in carbon dioxide concentration is largely irreversible for 1,000 years after emissions stop. Following cessation of emissions, removal of atmospheric carbon dioxide decreases radiative forcing, but is largely compensated by slower loss of heat to the ocean, so that atmospheric temperatures do not drop significantly for at least 1,000 years. Among illustrative irreversible impacts that should be expected if atmospheric carbon dioxide concentrations increase from current levels near 385 parts per million by volume (ppmv) to a peak of 450–600 ppmv over the coming century are irreversible dry-season rainfall reductions in several regions comparable to those of the "dust bowl" era and inexorable sea level rise.[33]

3.9 There are even graver 'reasons for concern'

In the 2001 IPCC Third Assessment Report, the IPCC identified five 'reasons for concern', illustrating them with what came to be called the 'burning embers diagram'. This was not updated for the 2007 IPCC report, but was updated in a recent paper showing that risks were now viewed as greater at lower levels of warming across all categories. See Figure 2 for a comparison of the 2001 and updated 2009 versions.

Figure 2: Risks from climate change, by reason for concern – 2001 & 2009
Source: Smith *et al.* (2009), p. 4134.



33 Solomon *et al.* (2009).

3.10 Carbon-cycle feedbacks are reinforcing warming

The interactions between climate change and the natural carbon-cycle (the uptake and release of carbon by the oceans, land and biosphere) is an active and critical area of research. Examples of carbon-cycle processes include the positive feedback effects that warming can have when more carbon is released through processes such as melting permafrost, burning forests, heat- and drought-stressed forests becoming net sources for carbon, rather than net sinks as is usually the case. Whether or not carbon-cycle effects are included in climate models makes a significant difference to the results.

The IPCC made it very clear in its 2007 *Synthesis Report*, that the projected temperature ranges for different gas concentration levels *did not* adequately reflect carbon cycle feedbacks (see Figure 3, footnote a). This is critical, since a growing number of studies suggest carbon cycle feedbacks are likely to be large. During the 2003 heatwave in Europe for example, at a time when we have only had about 0.8°C of warming, the affected forests became net sources of carbon. A 2005 study concluded that the heatwave led to a 30% reduction in gross primary productivity over Europe, which resulted in a strong net source, releasing carbon dioxide at the rate of 500 million tonnes per year to the atmosphere, and reversing the effects of four years of net carbon sequestration by the ecosystem.[34]

Figure 3: Table 5.1 from the IPCC's *Synthesis Report*

Note the omission of carbon cycle effects on temperatures (note a) and the contributions to sea-level rise of melting ice sheets, glaciers and ice caps (note f). Source: IPCC, (2007d), p. 67.

Table 5.1. Characteristics of post-TAR stabilisation scenarios and resulting long-term equilibrium global average temperature and the sea level rise component from thermal expansion only.[a] {WGI 10.7; WGIII Table TS.2, Table 3.10, Table SPM.5}

Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005=375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d,e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Notes:
a) The emission reductions to meet a particular stabilisation level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).
b) Atmospheric CO_2 concentrations were 379ppm in 2005. The best estimate of total CO_2-eq concentration in 2005 for all long-lived GHGs is about 455ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375ppm CO_2-eq.
c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios (see Figure 2.1).
d) The best estimate of climate sensitivity is 3°C.
e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilisation of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150 (see also Footnote 30).
f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low-resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere-Ocean General Circulation Model and EMICs to Earth System Models of Intermediate Complexity.)

[34] Ciais *et al.* (2005), p. 529. See also Baldocchi (2005) for a summary and discussion of this paper.

Dynamic Global Vegetation Models (DGVMs) are used to try to assess some carbon-cycle effects for long term climate change scenarios. Sitch *et al.* (2008) studied five DGVMs coupled to a climate model and set to simulate four of the IPCC SRES (Special Report on Emissions Scenarios): A1FI, A2, B1, B2.[35] They concluded that "all the DGVMs simulate cumulative net land carbon uptake over the 21st century for the four SRES emission scenarios. However, for the most extreme A1FI emissions scenario, three out of five DGVMs simulate an annual net source of CO_2 from the land to the atmosphere in the final decades of the 21st century."[36] In 2006 Friedlingstein *et al.* conducted a comparison of eleven coupled climate-carbon cycle models, concluding, "There was unanimous agreement among the models that future climate change will reduce the efficiency of the earth system to absorb the anthropogenic carbon perturbation."[37] More recently, several studies have confirmed this view, making it essential that policymakers take carbon-cycle effects into account:

> Using a coupled climate-carbon model, we show that including carbon-cycle feedbacks leads to large increases in extreme warming probabilities. .... CO_2 fertilization was found to exert little influence on the amount of future warming, since increased carbon uptake was partially offset by fertilization-induced surface albedo changes. The effect of positive carbon-cycle feedbacks on the likelihood of extreme future warming must be incorporated into climate policy-related decision making.[38]

> More frequent warm years "may lead to a sustained decrease in CO_2 uptake by terrestrial ecosystems."[39]

> Thawing permafrost and the resulting microbial decomposition of previously frozen organic carbon (C) is one of the most significant potential feedbacks from terrestrial ecosystems to the atmosphere in a changing climate. … We show that accounting for C stored deep in the permafrost more than doubles previous high-latitude inventory estimates, with this new estimate equivalent to twice the atmospheric C pool. The thawing of permafrost with warming occurs both gradually and catastrophically … making it likely that the net effect of widespread permafrost thawing will be a positive feedback to a warming climate.[40]

> There is strong evidence that the terrestrial biosphere has acted as a net carbon (C) sink over the last two and half decades. Its strength is highly variable year-to-year ranging from 0.3 to 5.0 Pg C yr–1 [billion tonnes per year]; an amount of significant magnitude compared to the emission of about 7 Pg C yr–1 from fossil fuel burning. In this paper we demonstrate that the underlying ecology of terrestrial biospheric CO2 sinks suggests that, despite having the potential for increased C sink owing to atmospheric and climate change over the next decades, most of the biological sinks will eventually level-off and subsequently decline to zero … whereby no further C will be removed from the atmosphere. Coupled with this sink decline, global warming and deforestation have the potential to destabilize large biospheric C pools … which would

[35] SRES stands for Special Report on Emissions Scenarios and refers to the special IPCC publication exploring various future climate scenarios (Nakicenovic & Swart, 2000).
[36] Sitch *et al.* (2008), p. 2015.
[37] Friedlingstein *et al.* (2006).
[38] Matthews & Keith (2007), p. 1.
[39] Arnone *et al.* (2008), p. 383.
[40] Schuur *et al.* 2008, p. 701.

> add CO2 to the atmosphere. This C source component will further diminish the net gains of C sinks and could even diminish the sink strength beyond zero, thereby moving from being a C sink to a source during this century.[41]
>
> Based on observed atmospheric CO_2 concentration and an inverse method, we estimate that the Southern Ocean sink of CO_2 has weakened between 1981 and 2004 by 0.08 PgC/y per decade relative to the trend expected from the large increase in atmospheric CO_2. This weakening is attributed to the observed increase in Southern Ocean winds resulting from human activities and projected to continue in the future. Consequences include a reduction in the efficiency of the Southern Ocean sink of CO_2 in the short term (~25 years) and possibly a higher level of stabilization of atmospheric CO_2 on a multicentury time scale.[42]

The Garnaut Review also acknowledged the possibility that carbon-cycle effects could lead to much higher temperatures than anticipated:

> There is a risk that temperature increases, and therefore all the impacts that are related to temperature, will be much greater than anticipated in the standard cases of the modelling because of positive feedback effects. These are difficult to quantify, but they are real and potentially significant. Once temperature increases above certain threshold points, massive carbon and methane stores on earth and in the oceans may be destabilised, leading to much greater volumes of greenhouse gas release from the natural sphere, and further temperature increases.[43]

3.11 The climate appears to be more sensitive than expected

'Climate sensitivity' refers to the surface temperature increase likely to ensue from a doubling of CO_2 from 278 ppm to 556 ppm. The IPCC concluded that: "It is *likely* to be in the range of 2°C to 4.5°C with a best estimate of about 3°C, and is *very unlikely* to be less than 1.5°C." But based on empirical geological evidence, James Hansen, Director of NASA's Goddard Institute for Space Studies in New York, and his team argues that the figure of 3°C for climate sensitivity used in most climate models only accounts for 'fast' feedback effects, such as cloud formation, water vapour, and sea ice. [44] That is only part of the story of how the Earth responds to higher CO_2 and temperature levels. Once 'slow' feedback effects are also accounted for (on timescales of centuries or less), such as ice sheet disintegration, vegetation changes, and CO_2 and methane releases from soils, tundra and ocean sediments, the climate sensitivity for a doubling of CO_2 above pre-industrial levels is likely to be more like 6°C. This higher climate sensitivity suggests that a 300-325 ppm CO_2 target is what we need for a safe climate with sea ice restored to its area of 25 years ago.[45] Since CO_2 levels are now approaching 388 ppm, this implies not only drastically reduced emissions but an extended period of actually removing CO_2 from the atmosphere.

[41] Canadell *et al.* (2007b), p. 59. See also Canadell *et al.* (2007a).
[42] Le Quéré *et al.* (2007), p. 1735. See also: Le Quéré *et al.* (2008).
[43] Garnaut (2008), p. 263.
[44] Hansen *et al.* (2008).
[45] Hansen *et al.* (2008), p. 226.

3.12 Developing country emissions must be reined in too

It has long been a core belief of most people engaged in the climate policy debates that while developing countries will need to adopt emissions trajectories significantly below 'business-as-usual', it is neither realistic nor fair to ask them to adopt actual emissions reductions. Ross Garnaut explicitly adopted convergence to equal per capita emissions as a central plank of his recommendations in his Review, showing that while some countries, such as India would increase their emissions per capita, others, such as China would need to decrease them over time from around 2020.[46] Garnaut's assessment reinforces the conclusions of a sobering study published a few months earlier.[47] Wheeler and Ummel used a carbon-cycle model to examine the consequences of different emissions paths for the 'North' and the 'South' (developing countries), and concluded:

> The South's cumulative carbon emissions are already large enough to jeopardize climatic stability and its own future growth, regardless of Northern emissions. By implication, a fossil-fueled South will undermine its own development long before it reaches Northern income levels. Sustainable development will therefore require a dramatic shift toward clean energy in the South, beginning immediately, as well as rapid reduction of Northern emissions. (Abstract)
>
> By 2025, cumulative CO_2 from the South is 91% of the North's (555 Gt vs 609 Gt), and the South takes the lead in about five more years. (p. 7)
>
> Our results reveal the dangerous fallacy in the notion that the South can utilize carbon-intensive growth to dramatically increase incomes – a kind of last-minute, fossil-fueled development push – before the onset of catastrophic climate change. The IPCC A1F1 scenario provides a useful illustration in this context, because it describes precisely such a development path: an economic boom in the South fueled by the continued use of cheap, carbon-based energy, coupled with slow population growth. In this scenario the South achieves rapid short-run development, but on a carbon-intensive path that virtually assures the crossing of critical climate thresholds, *even if there had never been any emissions from the North*. (p. 9)
>
> The South's population is over four times greater than the North's, so it has been trapped by the sheer scale of its emissions at a much earlier stage of development. The South finds itself weighed down by a mass of humanity, as well as the energy technologies and fuels of an earlier age. The question is not if the South will commit to emissions reductions – under any scenario it eventually must for its own sake – but whether it will do so in time, and how the costs of the transition are to be shared. We conclude that the conventional wisdom is dangerously misguided. The South cannot relegate mitigation to the North until it achieves prosperity. In fact, cumulative emissions from a carbon-intensive South have already reached levels that are dangerous for the South itself. They are more than sufficient to create a global climate crisis, even if the North eliminates all of its emissions immediately. So we face another inconvenient truth: A carbon-intensive South faces environmental disaster, no matter what the North does. For its own sake, the South must recognize this hard truth, accept the necessity of serious, costly mitigation, and immediately embark on a low-carbon development path. (p. 10)

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[46] Garnaut (2008), pp. 202-213.
[47] Wheeler & Ummel (2007).

The relentless arithmetic of rising emissions from developing countries implies that one of the world's most critical tasks is to help developing countries shift as fast as possible to a low-carbon development path.

3.13 Summary and implications for emissions targets

In summary, many of the most recent studies not only confirm the IPCC's bleak outlook, but suggest it was overly optimistic in its assessment.[48] In recognition of the recent rapid advances in climate science, an International Scientific Congress on Climate Change was held at the University of Copenhagen, with the explicit goal of bringing some of the findings since the 2007 IPCC report to the attention of policymakers.[49]

It is critical to recognise that any proposed emissions reductions targets that imply stabilisation at greenhouse gas levels significantly above pre-industrial levels, such as 550 or even 450 ppm CO_2-eq, presume that stabilisation at this level is actually feasible from an Earth-systems perspective. However, with the climatic equilibrium disturbed, positive feedbacks affecting the carbon cycle, nonlinear thresholds to be crossed, and the likelihood that the climate sensitivity is higher than 3°C, a level like 550 ppm CO_2-eq may well be too high to be a stable equilibrium. We may try to stabilise concentrations at that level, but by then the climate system itself may have taken over, driving concentrations even higher.

Even before the recent scientific developments suggesting the climate was more sensitive than previously thought, the Garnaut Review noted that stabilising at 550 ppm CO_2-eq has only about a 25% chance of holding warming to 2°C above pre-industrial levels, and is far more likely to deliver 2.2°C by 2050 and 2.5°C by 2100.[50] At equilibrium, 550 ppm CO_2-eq was thought likely to deliver around 3°C warming above pre-industrial levels with a 'best estimate' of climate sensitivity of 3°C.[51] But the upper range of the *likely* climate sensitivity considered by Garnaut (not the worst case), implies that 550 ppm CO_2-eq would be likely to bring temperature increases of 3.2°C by 2100.[52] This is well within the temperature range identified by Lenton *et al.* (2008) as being likely to trigger major climatic tipping points such as the loss of Arctic summer sea ice and the melting of the Greenland ice sheet.

Elsewhere the Garnaut Review noted that carbon-cycle feedbacks could add 0.2-1.5°C by 2100.[53] So if we are unlucky with both climate sensitivity and carbon-cycle effects, a 550 ppm CO_2-eq target could imply warming of 4.7°C by 2100 – which would be catastrophic since it would further fuel positive feedback effects such as the drying out and burning of tropical forests, the release of methane and CO_2 from melting permafrost and the reduced uptake of CO2 by the oceans. Using the same tables, and calculations, even the 450 ppm CO_2-eq target gives a best estimate by 2100 of 2.0°C, an upper likely bound of 2.6°C and a possible

[48] Kerr (2007b).
[49] See: http://climatecongress.ku.dk/
[50] Garnaut (2008), p. 89 and Table 11.1, p. 247. Note that Table 11.1 gives the temperatures above 1990 levels. To get the temperatures above pre-industrial levels, add 0.5°C.
[51] Garnaut (2008), p. 43.
[52] Garnaut (2008), Table 11.1, p. 247.
[53] Garnaut (2008), p. 98.

4.1°C if we're unlucky with carbon-cycle and slow-feedback effects. The Garnaut Review, to its credit, acknowledges these possibilities:

> There is a risk that temperature increases, and therefore all the impacts that are related to temperature, will be much greater than anticipated in the standard cases of the modelling because of positive feedback effects. These are difficult to quantify, but they are real and potentially significant. Once temperature increases above certain threshold points, massive carbon and methane stores on earth and in the oceans may be destabilised, leading to much greater volumes of greenhouse gas release from the natural sphere, and further temperature increases.[54]

The reason why so many scientists are now warning that even 1-1.5°C above pre-industrial temperatures is dangerously high, is that by 2°C and certainly by 3°C we may well lose control of the system completely, so that 2-3°C slides inexorably out to 4°C, 5°C and even 6°C and beyond, leading to catastrophic economic, social and ecological costs. In short, the premise that stabilisation at 500 ppm CO_2-eq or more is feasible, is likely to be false once carbon cycle feedbacks and the likely upper range of climate sensitivity are taken into account. As Section 6.2 discusses, the Australian Government's current targets imply a level of stabilisation of 510-550 ppm CO_2-eq by 2100.

Recommendation 2: That the Australian Government takes full account of the most recent scientific developments in deciding on its climate change policy responses.

4. Consequences of climate change for the poor

The conclusions of the 2007 *Fourth Assessment Report* from the Intergovernmental Panel on Climate Change (IPCC, 2007 a, b, & c) include:

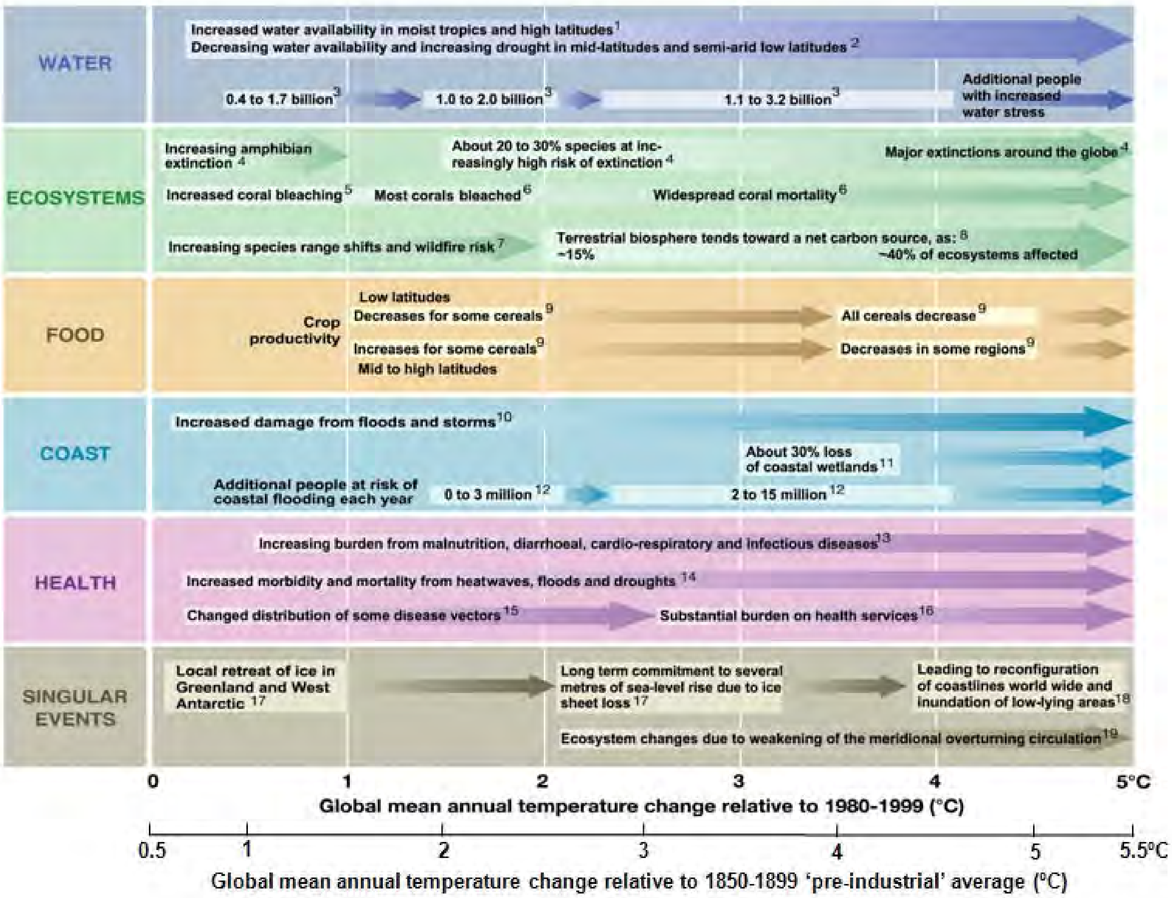
- Global average sea level rose at an average rate of 1.8 mm per year over 1961 to 2003. The rate was faster over 1993 to 2003, about 3.1 mm per year. The total 20th century rise is estimated to be 0.17 m.
- Dynamical processes related to ice flow not included in current models but suggested by recent observations could increase the vulnerability of the ice sheets to warming, increasing future sea level rise.
- Drought-affected areas will likely increase in extent. Heavy precipitation events, which are very likely to increase in frequency, will augment flood risk.
- Water supplies stored in glaciers and snow cover are projected to decline, reducing water availability in regions supplied by meltwater from major mountain ranges, where more than one-sixth of the world population currently lives.
- Approximately 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C.

[54] Garnaut (2008), p. 263.

- Many millions more people are projected to be flooded every year due to sea-level rise by the 2080s.
- In Africa: By 2020, between 75 and 250 million people are projected to be exposed to an increase of water stress due to climate change.
- In Asia: Freshwater availability is projected to decrease, which could adversely affect more than a billion people by the 2050s.
- In Latin America: By mid-century, increases in temperature and associated decreases in soil water are projected to lead to gradual replacement of tropical forest by savannah in eastern Amazonia.
- For small islands: Sea-level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities. … Climate change is projected by the mid-century to reduce water resources in many small islands … to the point where they become insufficient to meet demand during low rainfall periods.

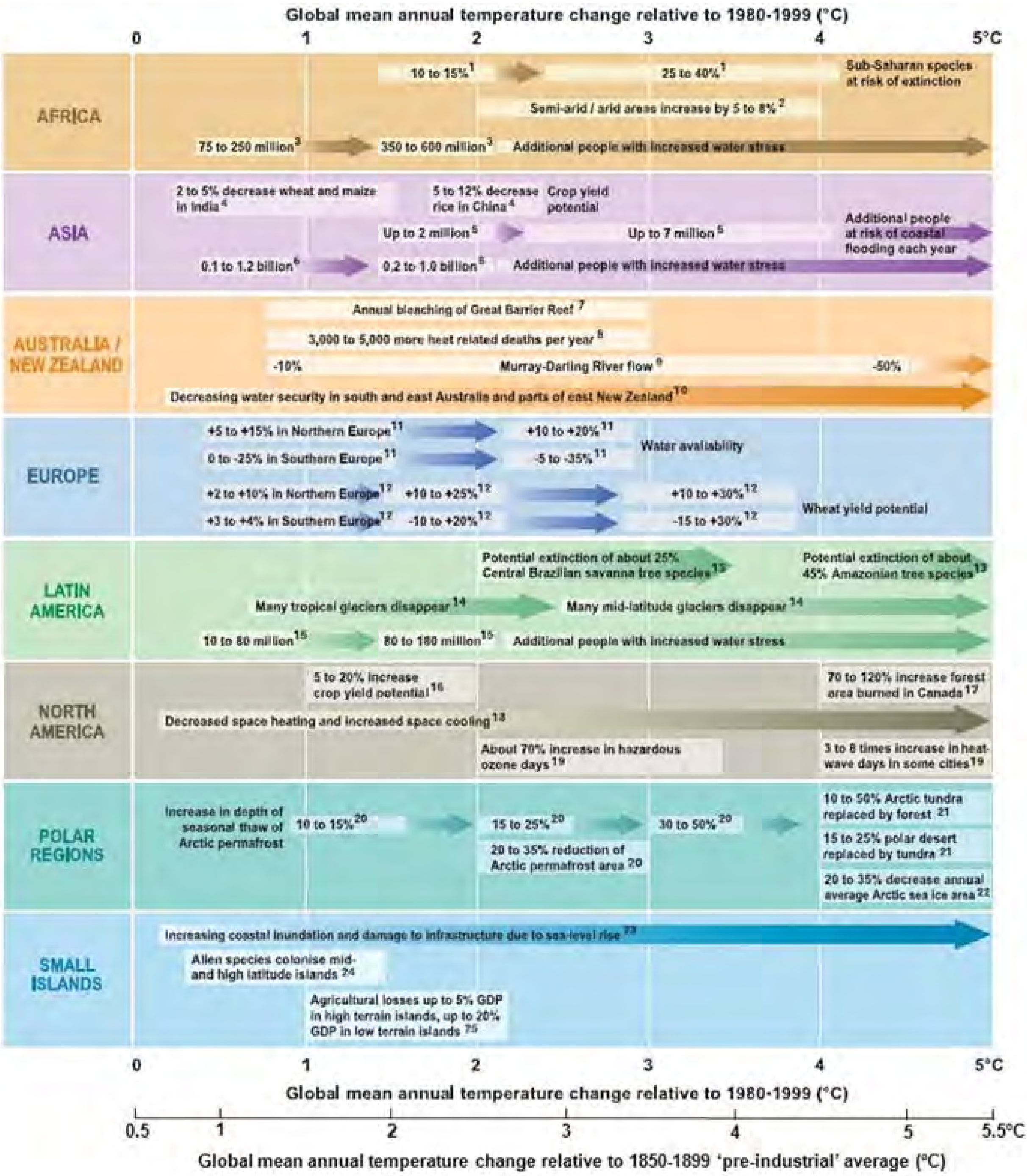
Further sectoral and regional implications of different temperature rises are shown in Figures 4 and 5 from the IPCC's report.

Fig. 4 Sectoral impacts from various warming temperatures[55]



[55] Source: Parry *et al.* (2007) Figure TS.3, p. 66. 'Pre-industrial' temperature scale added.

Fig. 5 Regional impacts from various warming temperatures[56]



The geopolitical implications of water projections in Asia for example, are extremely serious – as the Garnaut Review and others have discussed.[57] The glaciers of the Himalayas and Tibetan Plateau are the source for seven of Asia's most important rivers: the Ganges, which flows across northern India to join the Brahmaputra in Bangladesh; the Indus which flows

[56] Source: Parry *et al.* (2007) Figure TS.4, p. 67. 'Pre-industrial' temperature scale added.

[57] Garnaut (2008), Box 6.5, p. 147. See also DuPont (2008), DuPont & Pearman (2006) & Campbell (2008).

through Indian-controlled Jammu and Kashmir before becoming the lifeblood of Pakistan's agriculture; the Salween which flows through China and Burma into Thailand; the Mekong which flows though half a dozen countries and is critical to food supplies in Vietnam, Cambodia and Laos; and two of China's great rivers, the Yangtze and the Huang (Yellow River). Temperatures on the Tibetan Plateau have risen three times faster than the global average for the last 50 years.[58] Increased glacier melt in the next 20-30 years is likely to increase flooding, including sudden and catastrophic glacier lake outburst floods. But by the late 2030s, river flows are likely to decrease dramatically as the glaciers shrink from their 1995 extent of 500,000 km^2 to an expected 100,000 km^2 by 2035.[59]

By the 2050s more than a billion people in Central and South Asia could be suffering significant water shortages and crop yields could decrease by 30 per cent.[60] The Garnaut Review also warned, while "the Review has not undertaken detailed modelling to estimate the impacts that climate change may have on the cost of food production in the rest of the world"[61], food production in Asia was likely to drop:

> The Consultative Group on International Agricultural Research (2002) has predicted that food production in Asia will decrease by as much as 20 per cent due to climate change. These forecasts are in line with IPCC projections showing significant reductions in crop yield (5-30 per cent compared with 1990) affecting more than one billion people in Asia by 2050.[62]

The Draft Review of the Garnaut Report also noted though, in a passage that appears nowhere in the final version of the Review or the accompanying Technical Papers, that the international modelling with the GIAM model uses a 'highly simplified climate impact damage function' and is unable to account for the impacts of climate change on food production:

> … the results from GIAM are subject to a number of caveats. At this stage of its development, GIAM uses a highly simplified climate impact damage function. …Economic loss factors are applied as negative shocks to total factor productivity and do not differentiate between economic sectors in their impacts. As a result, impacts to agriculture from climate change are determined in the same way as impacts to services sectors. This means, for example, that detailed modelling cannot be applied to estimation of the impacts of climate change on food production.[63]

In 2008 there were food riots in more than 30 countries as the price of food staples skyrocketed due to several factors that included reduced harvests due to drought and diversion of land to first-generation biofuels. Food prices are closely tied to economic and political stability and so can have major humanitarian, economic and political impacts beyond their first-round effects.

The IPCC also noted that, "The gross per capita water availability in India will decline from about 1,820 m^3/yr in 2001 to as low as about 1,140 m^3/yr in 2050 … India will reach a state

58 Qiu (2008).
59 Cruz *et al.* (2007), p. 493
60 IPCC (2007b), p. 13
61 Garnaut (2008), pp. 273-274.
62 Garnaut (2008), p. 146
63 Garnaut Climate Change Review (2008), p. 257.

of water stress before 2025 when the availability falls below 1000 m^3 per capita".[64] There is substantial potential for tension between India and Pakistan over water since the Indus and several of its main tributaries, such as the Chenab, Ravi, Jhelum and Sutlej, pass through India before reaching Pakistan.[65] The Middle East and Mediterranean basin are also expected to be afflicted by severe water shortages.[66]

Often neglected are the implications of climate change for children. Children are already highly vulnerable and tend to suffer most during famines, wars and natural disasters. Unmitigated climate change would have devastating impacts on children in developing countries.[67]

Recommendation 3: That the Australian Government recognises the dire implications of unmitigated climate change for the poor and for the potential for these impacts to spill over into international humanitarian, economic and security crises.

5. Economic analysis of climate change

If the science of climate change is complex, understanding how economies and societies may respond to it is even more so. In the following sections a number of aspects of the economics are raised, but overall we commend to the Committee and to government economic advisers, Stephen DeCanio's 2003 book *Economic Models of Climate Change: A Critique*.[68] DeCanio's *Critique* is a brief but incisive analysis of the pitfalls of certain aspects of economic theory and of models built upon a simplistic application of that body of theory. These pitfalls are increasingly well known among economist and other policy analysts. He warns for example:

> As we shall see, the simplifications of neoclassical economics strip away essential information about the system, not just the inessential accidentals. The consequences for climate policy have been severe. … [T]he application of general equilibrium analysis to climate policy has produced a kind of specious precision, a situation in which the assumptions of the analysts masquerade as results that are solidly grounded in theory and data. This leads to a tremendous amount of confusion and mischief, not least of which is the notion that although the physical science of the climate is plagued by uncertainties, it is possible to know with a high degree of certainty just what the economic consequences of alternative policy actions will be. This myth, more than any other, has created the policy paralysis and public confusion that have so far impeded constructive action … to meet the climate challenge.

Some of these issues are canvassed in the Appendix to this submission. Here we discuss just a few issues that are critical to an economic analysis of climate change.

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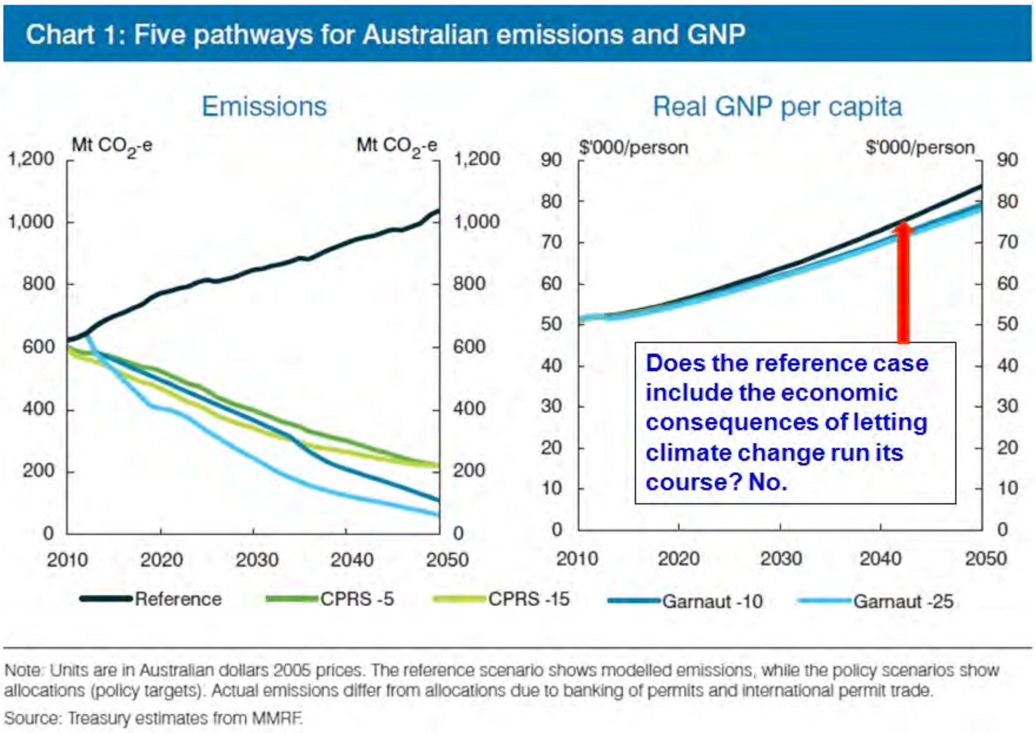
[64] Cruz *et al.* (2007), p. 484
[65] Klare, (2001), 182-189
[66] IPCC, (2007c), Fig 3.5, p. 49
[67] For more see: UNICEF (2007, 2008), UNICEF UK (2008) & Save the Children (2007, 2008).
[68] Ackerman (2008) is also recommended.

5.1 Reference scenarios should reflect the economic impacts of climate change

WVA is greatly concerned that the 'baseline' projections for GNP growth that are used to provide a benchmark against which to compare the 'costs' of mitigating climate change, generally do not take into account the economic costs of letting climate change run its course. CGE models are rarely well-integrated with dynamic climate models.[69] The Garnaut Review and Treasury analysis in *Australia's Low Pollution Future*, both used a 'Garnaut-Treasury Reference Case' in which emissions and GNP growth were projected as far as 2100.[70] Critically, the likely impacts of unmitigated climate change on world economies are *not* taken into account in the reference case (See Figure 6). For example, Treasury says,

> The modelling does not include the economic impacts of climate change itself, so does not assess the benefits of reducing climate change risks through mitigation.[71]
>
> The reference scenario … presents a plausible future path for economic growth, population levels, energy consumption and greenhouse gas emissions in a world without climate change. The reference scenario is not a prediction and does not include risks arising from climate change itself.[72]

Figure 6. The Garnaut-Treasury reference case with Treasury estimates of the 'costs' of mitigation.
Source: Australian Government (2008a), p. xii. (Text box and arrow added)



[69] See Hall & Behl (2006).
[70] Garnaut (2008), p. 59-62; Australian Government (2008a), Chapter 3.
[71] Australian Government (2008a), p. xi.
[72] Australian Government (2008a), p. 27.

Nor apparently, are the constraints of natural resources or sinks considered, since global output in the reference case is projected to be 17 times current levels by 2100.[73] The Garnaut Review further notes that, "By the end of the century, the concentration of long-lived greenhouse gases is 1565 ppm CO_2-e, and carbon dioxide concentrations are over 1000 ppm – more than 3.5 times higher than pre-industrial concentrations."[74]

While it is useful to conduct such a modelling exercise to get a sense of where global economic and emissions trends are leading us, it is quite another matter to suggest that comparison with such a 'reference case' constitutes a useful basis for estimating the 'costs' of mitigating climate change. The Garnaut Review, to its credit, acknowledged this problem and tried to estimate the costs of climate change on the economy, distinguishing four types of costs, only the first of which could be estimated with any confidence.[75] The Treasury analysis did not do this, instead presenting results as "Overall mitigation cost, 2010-2050" in Table 1 (p. xii) for the various scenarios, with the 'costs' of mitigation presented as being around 0.1 percentage points of annual GNP per capita growth. It also asserts:

> All scenarios show Australia, at the-whole-of-economy level, can achieve substantial emission reductions with relatively small *reductions* in economic growth.[76]
>
> The introduction of emission pricing will *reduce* Australia's GNP per capita compared with the reference scenario, but GNP per capita continues to grow across all the mitigation scenarios.[77]

These statements however, are quite misleading presentations of the results. While it is true that in the context of the model, emissions pricing reduces GNP relative to the reference scenario, this result cannot be transferred to the real world with any great relevance beyond the first few years. It cannot be asserted for example, on the basis of this modelling exercise, that Australia's GNP would be lower in 2050 with mitigation efforts (as part of a global effort) than it would have been without them. By 2050, the Garnaut Review noted that in the Murray-Darling basin we could expect to lose half the irrigated agriculture, and possibly as much as 72%, due to unmitigated climate change, and that "fundamental restructuring of the irrigated agriculture industry" would be required.[78]

The methodology used in the Treasury analysis guarantees by assumption that any serious mitigation efforts will look like a net cost because they are being compared with an imaginary economic growth trajectory in which climate change does not exist. In fact, the modelling approach used does not allow us to say anything about the *real world net costs* of mitigation since the exercise must be viewed over a multi-decade time frame, during which unchecked climate change would certainly lead to major economic impacts. The baseline 'reference case' cannot occur because it ignores the impacts of climate change on the economy. A model that fully integrated the global economic and climate systems would be

[73] Garnaut (2008), p. 69.
[74] Garnaut (2008), p. 86.
[75] Garnaut (2008), pp. 247-249.
[76] Australian Government (2008a), p. 137. Emphasis added.
[77] Australian Government (2008a), p. 144. Emphasis added.
[78] Garnaut (2008), p. 130.

far more likely to show that strong mitigation action is the only way to prevent catastrophic climate change and so ensure that we retain a living standard comparable to today, let alone global output being 17 times greater than today and Australian incomes per capita being US$137,000 in 2100 compared with US$36,000 in 2005.[79]

In summary, projecting a reference case for economic growth out to 2050 or 2100 based on past experience and 'business as usual projections', as if climate change was not happening, does not constitute an adequate basis for comparing the costs and benefits of mitigation measures. It is like deciding whether or not to hose a house down based purely on the cost of the water, ignoring the fact that the house is on fire.

5.2 Economic models need to integrate financial and insurance market effects

Many CGE models are simply 'real' models in which money, credit markets, financial markets and insurance play no role. This is a serious deficiency, particularly given the extent to which the current recession illustrates how powerfully the 'real' economy can be impacted by crises in financial markets. Considering financial and insurance effects can make a significant difference to the costs of climate change. One recent study for example, suggests that previous economic models may have very substantially underestimated the economic costs of episodic flooding from storm surges due to higher sea levels:

> This study uses a unique GIS database of three geographically diverse Chesapeake Bay communities that includes 1-ft elevation contours from remote sensing data, local tax assessment records, and aerial photographs of property location. Hedonic property value models estimate the loss from complete inundation, closely following the methodology of previous studies. Increased damage from episodic flooding is estimated using elevation-rated, actuarially fair flood insurance rates. *Using a 3-ft sea-level rise over 100 years scenario, damage from episodic flooding averages 9 times the estimated loss from complete inundation, and is an average of 28 times greater under a 2-ft sea-level rise scenario. Although the study areas are not representative of all coastal areas, the results suggest that current studies may substantially underestimate the cost of sea-level rise.*[80]

If the science relating to sea-level rise continues to consolidate over the next decade, as seems likely, the potential for future sea level rises and associated storm surges is likely to have very serious implications for coastal property values and insurance premiums. Properties used for loan collateral may be devalued by lenders, land taxes may become delinked from changing property values, and insurance premiums may climb across entire economies if losses in coastal areas and from extreme weather events are cross-subsidised by insurance companies from elsewhere. These effects are not captured well in the standard non-monetary economic models usually used to assess the potential costs of climate change.

5.3 Foregone GNP growth does automatically imply foregone improvements in wellbeing

A substantial body of research in the economic literature suggests that in the industrialised countries, 'wellbeing' or 'happiness' has actually become delinked from GDP growth. This is

[79] Garnaut (2008), p. 69.
[80] Michael (2007), p. 149. Emphasis added.

not the place to discuss that debate but it suggests that we should be wary of studies that simplistically equate foregone economic growth with foregone improvements in wellbeing.[81]

5.4 Uncertainty is poison to economies

Businesses and investors need a clear and predictable regulatory environment. A "long, loud and legal" framework to establish a carbon price signal, was in fact one of the central recommendations of the Australian Business Roundtable on Climate Change's report *The Business Case for Early Action.*[82] Businesses know that change is necessary. What they need from governments is a clear policy framework that takes the issues seriously and provides clear signals and incentives for innovation and positive responses. Without these signals, further investment will take place in inefficient and polluting technologies.

The CPRS in its current form with a price cap on permits gives certainty to major emitters, but the failure to ensure a price *floor* leaves investors in low-carbon energy efficiency and renewable technologies exposed to heightened risk which is likely to lead to under-investment in these critical areas.

5.5 Unfettered climate change will lead to very costly security challenges

Even relatively small sea level rises will result in the displacement of tens of millions of people, associated with severe economic and social costs and a high probability of conflict. A recent World Bank study of 84 developing countries showed that even a one-metre rise in sea levels would affect more than 56 million people. They concluded:

> Sea level rise (SLR) due to climate change is a serious global threat: The scientific evidence is now overwhelming. Continued growth of greenhouse gas emissions and associated global warming could well promote SLR of 1m-3m in this century, and unexpectedly rapid breakup of the Greenland and West Antarctic ice sheets might produce a 5m SLR. In this paper, we have assessed the consequences of continued SLR for 84 developing countries. Geographic Information System (GIS) software has been used to overlay the best available, spatially-disaggregated global data on critical impact elements (land, population, agriculture, urban extent, wetlands, and GDP) with the inundation zones projected for 1-5m SLR. *Our results reveal that hundreds of millions of people in the developing world are likely to be displaced by SLR within this century; and accompanying economic and ecological damage will be severe for many. … To date, there is little evidence that the international community has seriously considered the implications of SLR for population location and infrastructure planning in developing countries.*[83]

The world's political and humanitarian systems are unlikely to cope with mass movements of people on such a scale. The security risks are obvious.[84] The poor are likely to suffer most

[81] See Easterlin (2003), Layard (2005 & 2006) and Frey & Stutzer (2002) on 'happiness', Hamilton & Denniss (2005) on 'affluenza'.
[82] Roundtable, (2006), p. 19.
[83] Dasgupta *et al.* (2007), p. 2. Emphasis added.
[84] For more on the security implications and likely conflicts resulting from climate change, see Dupont & Pearman (2006), Dupont (2008), Campbell (2008), WBGU (2007), Chellaney (2007) and the Council of the European Union, (2008).

from climate change, just as they have suffered most from the terrible droughts and famines induced by severe El Niños in the past.[85]

As a child-focussed development agency WVA takes a long-term view of climate change. Much of the language in the IPCC reports, and much of the public debate, concerns projections out to 2100 – and devastating 'mega-droughts' and sea-level rises of the order of a metre or more are entirely possible within that time frame.

Human history will likely continue beyond 2100 though, and with ongoing warming there is substantial risk of melting from the Greenland and West Antarctic ice sheets leading to sea levels several metres higher than today. In such a world, tens of thousands of square kilometres of the world's best agricultural land would be lost, to say nothing of the homes of hundreds of millions of people. Vast swathes of territory would be under water, including much of Bangladesh, and the great river deltas of the Mekong, Irrawaddy, Indus, Ganges, Bramaputra, Yangtze, Amazon, Nile, and Mississippi.

In Box 6.5 the Garnaut Review also highlighted the dangers posed by the potential water shortages discussed above in Section 4:

> China's efforts to rectify its own emerging water and energy problems indirectly threaten the livelihoods of millions of people in downstream, riparian states. Chinese dams on the Mekong are already reducing flows to Myanmar, Thailand, Laos, Cambodia and Vietnam. India is concerned about Chinese plans to channel the waters of the Brahmaputra to the over-used Yellow River. Should China go ahead with this ambitious plan, tensions with India and Bangladesh would almost certainly increase … Any disruption of flows in the Indus would be highly disruptive to Punjabi agriculture on both sides of the India-Pakistan border. It would raise difficult issues in India–Pakistan relations. Any consequent conflicts between China and India, or India and Pakistan, or between other water-deficient regional states, could have serious implications for Australia, disrupting trade and people flows and increasing strategic competition in Asia.[86]

There are enormous humanitarian and security implications of probable widespread water shortages across Turkey, Israel, Lebanon, Syria, Iraq, Iran, the Caucasus, Pakistan, Afghanistan, India and parts of China. Water shortages and declining crop yields in the face of rising populations would lead to widespread food shortages, which would be likely to trigger large movements of people and potentially, if history is any guide, major armed conflicts with staggering humanitarian and economic costs. Four of these states already possess nuclear weapons. Iran seems to want them and Iraq may still have them by proxy with strong US security ties. The last thing the region needs is a series of 'threat multipliers' due to food and water shortages brought on by climate change. The Garnaut Review noted these concerns but downplayed their likely economic impacts:

> Climate change may lead to geopolitical instability, which will require an increase in the capability and requirements of Australia's defence force and an increase in the level of Australia's spending on emergency and humanitarian aid abroad. Previous Australian interventions in small neighbouring nations provide some indication of the potential size

[85] See Davis (2001).
[86] Garnaut (2008), p. 147.

> of future defence costs that may arise from climate change. The combined aid and defence budget for the five-year intervention in Timor-Leste has exceeded $700 million per year. Australia's intervention in Solomon Islands is estimated to cost around $200 million per year … This level of intervention is likely to continue until at least 2013. Climate change could lead to the involvement of larger countries through geopolitical pressures, and thus may lead to much higher spending than would be indicated by recent history. A 10 per cent increase in defence spending would be a cost of 0.2 per cent of GDP. Although extra defence spending does not automatically lead to reduced GDP, the Review treats it as a cost since it represents resources that would otherwise have been available for productive use elsewhere.[87]

It is of course extremely difficult to envisage the economic and social consequences of geopolitical instability, but the outlook for our region is sobering. Island states of the Pacific face increasing pressures, and in Asia, combinations of water and food shortages and climate refugees are likely to exacerbate existing tensions. Even if actual conflicts are avoided, it is likely that a deteriorating strategic outlook and an increasing need for military and disaster assistance in the Pacific will increase pressures for Australian defence spending, part of which must also be counted as a cost of climate change.

On balance it is seems likely that the total economic costs for Australia of future geopolitical tensions in the Asia-Pacific due to the effects of climate change will dwarf the costs of Australia's recent interventions in the Solomon Islands and Timor-Leste. The costs of Australian involvement in a major regional conflict would of course be far greater.

Such dramatic climatic changes, sea level rises and large-scale movements of millions of people across borders are ideal conditions for the emergence of protracted, bloody conflicts and human misery for today's children and their future families. Such conflicts could be extraordinarily expensive in both humanitarian and economic terms.

5.6 Markets are currently distorted by the failure to price emissions correctly

There is considerable concern among some policymakers and elected officials that measures to address climate change could be 'market distorting' or 'sub-market' interventions and therefore 'inefficient'. This perspective needs to be challenged because it rests on an unspoken assumption that the current market environment is in fact efficient. In fact, the entire problem of anthropogenic climate change has been caused by the most colossal market failure in history – the failure of prices to reflect the true costs of emissions for the last 150 years.

Our markets and our entire industrial structure are currently distorted by this long-term market failure and also by explicit subsidies to emission-intensive fuels and industries.[88] Professor Kirk Smith has described climate change as the world's biggest regressive tax – the poorest pay for the behaviour of the rich.[89]

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[87] Garnaut (2008), p. 260.
[88] Riedy & Diesendorf (2003).
[89] The Economist (2008), p. 57.

Markets do not exist in a vacuum. They rest on complex legal foundations that include standards, regulations, contract and employment law, human rights law, dispute resolution mechanisms and so on.[90] Real world markets are also characterized by imperfect information and information asymmetries, principal-agent problems (eg. lack of incentives for landlords to improve energy efficiency for tenants), imperfect credit and risk markets, coordination failures, rent-seeking by firms, rapidly evolving technologies, and natural monopolies (such as rail or fibre-optic network infrastructure).

Today, new low-carbon industries are trying to establish themselves and compete with established emissions-intensive industries on a playing field that is severely distorted in favour of heavy emitters. It is entirely appropriate that a raft of policy measures be used to correct this distortion. Such measures should include market measures such as emissions trading, but in the context of a highly distorted market, policymakers should not assume that others measures are 'market distorting' or 'sub-market'.

Measures such as higher efficiency standards, subsidies for low-emissions renewable technologies, public investment in network infrastructure and so on would, in fact, make the market more efficient by enabling the price signals it sends to better reflect the true costs of emissions.

Recommendation 4: That the Australian Government recognises that current markets and industrial structures are highly distorted by the pervasive externality of the historic failure of prices to reflect the true costs of emissions. Correction of these distortions through a combination of market-measures, regulations, subsidies and standards should not be viewed as 'sub-market' but 'market correcting', ensuring that prices better reflect the true costs of emissions.

6. Greenhouse gas reduction targets for Australia

6.1 Per capita targets and Australia's contribution to the problem

The Government argued in the *White Paper* that Australia's efforts in reducing emissions should be comparable with those of other developed countries.[91] This is the main justification for the emphasis on per capita targets, rather than absolute targets.

The problem with this line of argument is that Australia contributes far more per capita to the problem of climate change than almost every other country. The rankings vary depending on which year is being discussed, whether just CO_2 or all six Kyoto greenhouse gases are included, whether land use and forestry are included, and whether Kyoto or UNFCCC accounting conventions are used, but Australia is always ranked around the worst per capita emitter in the OECD and around the 4th or 5th worst in the world.

[90] For an early discussion see Commons (1924).
[91] Australian Government (2008b), pp. 3-9 – 3-10.

The following quotes and the table in Figure 7 from the Garnaut Review and Figures 8 and 9 from the Climate Analysis Indicators Tool give a sense of our position:

> Australia's per capita greenhouse gas emissions are the highest of any OECD country and are among the highest in the world. In 2006 our per capita emissions (including emissions from land use, land-use change and forestry) were 28.1 tonnes carbon dioxide equivalent (CO2-e) per person …. Only five countries in the world rank higher – Bahrain, Bolivia, Brunei, Kuwait and Qatar. Australia's per capita emissions are nearly twice the OECD average and more than four times the world average …[92]

Figure 7: Emissions per capita among OECD countries, 2005 and 2006
Source: Garnaut (2008), Table 7.1, p. 154.

Table 7.1 Comparison of the highest per capita emissions among OECD countries (tonnes per person per year)

	2005, excluding land use, land-use change and forestry[a]	2006, excluding land use, land-use change and forestry[b]	2006, including land use, land-use change and forestry[b]
Australia	30.3	26.0	26.7
United States	24.5	23.5	20.6
Luxembourg	24.0	26.6	26.1
New Zealand	22.6	19.0	13.4
Canada	22.5	22.1	23.1
Ireland	15.6	16.6	16.5
Czech Republic	14.3	14.4	14.1

Sources: a. IEA (2007a); b. For emissions data, UNFCCC (2008); for population data, Population Reference Bureau (2008).

> The emissions intensity of Australia's electricity supply is the highest of any OECD country. It is 98 per cent higher than the OECD average, and 74 per cent higher than the world average … There are only eight countries in the world with an electricity system that is more emissions-intensive than Australia's – Bahrain, Botswana, Cambodia, Cuba, India, Kazakhstan, Libya and Malta.[93]

> The emissions intensity of Australia's primary energy supply is the second highest among OECD countries. It is more than 30 per cent higher than both the OECD average and the world average. There are only five countries in the world with a more emissions-intensive energy supply than Australia's – Bosnia Herzegovina, the Democratic People's Republic of Korea, Estonia, Mongolia and Poland.[94]

[92] Garnaut (2008), p. 153.
[93] Garnaut (2008), p. 160.
[94] Garnaut (2008), p. 158.

Figure 8: Top 40 per capita emitters of greenhouse gases in 2005

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0., Washington, DC: World Resources Institute, 2009 http://cait.wri.org/ * non-parties to the UNFCCC, Annex I countries to the Kyoto Protocol in red; [1] CH4 & N2O data not available. [2] PFC, HFC & SF6 data not available.

Total GHG Emissions in 2005
(excludes land use change)
CO2, CH4, N2O, PFCs, HFCs, SF6

Country	MtCO2	Rank	% of World Total	Tons CO2 Per Person	Rank
Qatar [1,2]	44.2	(75)	0.12%	55.5	(1)
United Arab Emirates	159.1	(36)	0.42%	38.8	(2)
Kuwait	88.7	(51)	0.23%	35.0	(3)
Luxembourg	12.6	(100)	0.03%	27.5	(4)
Australia	548.6	(17)	1.45%	26.9	(5)
Bahrain [1,2]	18.4	(94)	0.05%	25.4	(6)
United States of America	6,963.8	(2)	18.44%	23.5	(7)
Canada	731.6	(9)	1.94%	22.6	(8)
Trinidad & Tobago [1,2]	26.0	(83)	0.07%	19.6	(9)
Turkmenistan	91.4	(50)	0.24%	18.9	(10)
New Zealand	77.6	(57)	0.21%	18.8	(11)
Ireland	69.3	(60)	0.18%	16.7	(12)
Saudi Arabia	374.3	(23)	0.99%	16.2	(13)
Estonia	19.3	(93)	0.05%	14.4	(14)
Brunei* [1,2]	5.2	(123)	0.01%	13.9	(15)
Netherlands	224.4	(30)	0.59%	13.8	(16)
Czech Republic	140.1	(40)	0.37%	13.7	(17)
Russian Federation	1,960.0	(4)	5.19%	13.7	(18)
Belgium	138.0	(41)	0.37%	13.2	(19)
Finland	68.3	(61)	0.18%	13.0	(20)
Uruguay	42.0	(77)	0.11%	12.7	(21)
Kazakhstan	192.0	(32)	0.51%	12.7	(22)
Oman [1,2]	30.0	(82)	0.08%	12.0	(23)
Mongolia	30.3	(81)	0.08%	11.9	(24)
Germany	977.4	(8)	2.59%	11.9	(25)
Taiwan* [1,2]	271.2	(27)	0.72%	11.8	(26)
Denmark	63.3	(64)	0.17%	11.7	(27)
Israel	79.8	(56)	0.21%	11.5	(28)
Greece	128.0	(44)	0.34%	11.5	(29)
Austria	94.8	(48)	0.25%	11.5	(30)
Korea (South)	548.7	(16)	1.45%	11.4	(31)
Singapore	48.3	(72)	0.13%	11.3	(32)
Norway	52.0	(67)	0.14%	11.2	(33)
Iceland	3.3	(131)	0.01%	11.1	(34)
Nauru [1,2]	0.1	(175)	0.00%	11.0	(35)
United Kingdom	639.8	(10)	1.69%	10.6	(36)
Japan	1,342.7	(6)	3.56%	10.5	(37)
Cyprus [1,2]	7.9	(114)	0.02%	10.5	(38)
European Union (27)	5,047.7	(3)	13.37%	10.3	(39)
Ukraine	484.7	(18)	1.28%	10.3	(40)

Australia's contribution to the problem does not end with our domestic emissions though. Australia is also the world's biggest coal exporter, exporting 252 million tonnes of coal in FY2007-08.[95] When coal burns, each carbon atom (atomic weight 12) combines with two atoms of oxygen (atomic weight 16 each) to form CO_2 (atomic weight 44). So 1 tonne of pure carbon with complete combustion would produce 44/12 = 3.67 tonnes of CO_2.[96]

[95] ABARE (2008), p. 247.
[96] Hong & Slatick (1994).

Australian sub-bituminous and bituminous coals have carbon contents ranging from 71-91%.[97] If we assume the mid-range of about 80% carbon content for Australia's 252 million tonnes of exported coal, that implies emissions of the order of 740 million tonnes of CO_2.[98] This is approximate of course, but it is worth noting that this figure is larger than Canada's 2005 CO_2 emissions (559.1 Mt) but smaller than Germany's (828.8 Mt). If our coal exports were a separate country (and other countries' emissions were unchanged), our coal would rank as the 8th largest CO_2 emitter in the world. If we combine that figure with Australia's domestic CO_2 emissions from the CAIT database shown in Figure 9, it would yield 1121.6 Mt, overtaking Germany into 7th slot, just short of India.

Figure 9: Top 15 per capita CO_2 emitters in 2005

Source: Climate Analysis Indicators Tool (CAIT) Version 6.0., Washington, DC: World Resources Institute, 2009 http://cait.wri.org/ Annex I countries to the Kyoto Protocol in red.

Total GHG Emissions in 2005
(excludes land use change)
CO2

Country	MtCO2	Rank	% of World Total	Tons CO2 Per Person	Rank
United States of America	5,891.6	(1)	21.40%	19.9	(6)
China	5,577.3	(2)	20.26%	4.3	(70)
European Union (27)	4,102.3	(3)	14.90%	8.4	(37)
Russian Federation	1,568.0	(4)	5.70%	11.0	(19)
Japan	1,248.9	(5)	4.54%	9.8	(27)
India	1,221.6	(6)	4.44%	1.1	(124)
Germany	828.8	(7)	3.01%	10.0	(25)
Canada	559.1	(8)	2.03%	17.3	(9)
United Kingdom	538.6	(9)	1.96%	8.9	(32)
Italy	477.1	(10)	1.73%	8.1	(39)
Korea (South)	474.5	(11)	1.72%	9.8	(26)
Iran	447.0	(12)	1.62%	6.5	(50)
Mexico	410.6	(13)	1.49%	4.0	(73)
France	399.0	(14)	1.45%	6.6	(47)
Australia	381.6	(15)	1.39%	18.7	(8)

So not only is Australia one of the highest emitters in the world just with its domestic emissions, it also makes an even greater contribution to global emissions with its coal exports. Australia's high population growth is in part a deliberate policy to help mitigate the effects of an ageing population.[99] As the ANU's Andrew Macintosh put it: "To say that Australia's population growth should be factored into the allocation method is essentially asking the world to give Australia a benefit for receiving a benefit."[100] These factors imply that Australia should be making a *greater* effort per capita than other developed countries because we are a greater per capita contributor to the problem.

[97] http://www.australiancoal.com.au/coal-and-its-uses_coal-classification.aspx
[98] 252 Mt x 0.8 x 3.67 = 739.2 Mt
[99] Australian Treasury, (2007).
[100] Macintosh (2008), p. 5.

6.2 What targets are needed to prevent very dangerous climate change?

Figure 10, tells us that the IPCC's best estimate in 2007 was that to prevent warming above 2.0°C, greenhouse gas concentrations should be stabilised at around 445 ppm CO_2-eq and global emissions must be reduced by 50-85% by 2050.

Figure 10: Table SPM.5 *Characteristics of post-TAR [Third Assessment Report] Stabilization Scenarios*
Source: IPCC (2007c), p. 15.

Category	Radiative Forcing (W/m^2)	CO_2 Concen-tration (ppm)	CO_2-eq Concen-tration (ppm)	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity (°C)	Peaking year for CO_2 emissions (year)	Change in global CO_2 Emissions in 2050 (% of 2000 emissions)	No. of assessed scenarios
I	2.5 – 3.0	350 – 400	445 – 490	2.0 – 2.4	2000 - 2015	-85 to -50	6
II	3.0 – 3.5	400 – 440	490 – 535	2.4 – 2.8	2000 - 2020	-60 to -30	18
III	3.5 – 4.0	440 – 485	535 – 590	2.8 – 3.2	2010 - 2030	-30 to +5	21
IV	4.0 – 5.0	485 – 570	590 – 710	3.2 – 4.0	2020 - 2060	+10 to +60	118
V	5.0 – 6.0	570 – 660	710 – 855	4.0 – 4.9	2050 - 2080	+25 to +85	9
VI	6.0 – 7.5	660 – 790	855 – 1130	4.9 – 6.1	2060 - 2090	+90 to +140	5
						Total:	177

The IPCC's Working Group III report further indicated that the *minimum* reductions in greenhouse gas emissions appropriate for Annex I countries to achieve that goal are at least 25% below 1990 levels by 2020 and at least 80% below 1990 levels by 2050 (see Figure 11 below).

The problem we face now however, is that while even two years ago 2°C of warming seemed an 'acceptable', albeit not ideal, target, it is increasingly recognised that even 2°C will result in very dangerous and damaging impacts. As discussed in Section 3, climate scientists are increasingly of the view that even with only 0.8°C of warming realised so far we are already seeing damaging impacts such as shifting rainfall patterns, acidification of the oceans, stronger hurricanes, and perhaps most alarmingly, the possible loss of summer Arctic sea ice before 2020 leading to greatly accelerated Arctic warming and carbon-cycle feedback effects. Long-term stabilisation targets closer to 1°C of warming are likely to be far more prudent, making it untenable to opt for the lower ends of the ranges in Figure 11 below.

As discussed above, Jim Hansen and his colleagues argue that to restore the Arctic sea ice to its stable extent of 25 years ago, we should be aiming to reduce CO_2 from its current levels of around 388 ppm to 300-325 ppm.[101] This is equivalent to about 350-375 ppm CO_2-

[101] Hansen *et al.* (2008), p. 226.

eq, taking into account the other greenhouse gases.[102] That would require not only stabilization of global emissions by 2020, but a sustained drawdown of greenhouse throughout this century and possibly beyond.

Figure 11: ***Box 13.7 from the IPCC's Working Group III Report***
Source: Gupta *et al.* (2007), p. 776.

Box 13.7 The range of the difference between emissions in 1990 and emission allowances in 2020/2050 for various GHG concentration levels for Annex I and non-Annex I countries as a group[a]

Scenario category	Region	2020	2050
A-450 ppm CO_2-eq[b]	Annex I	−25% to −40%	−80% to −95%
	Non-Annex I	Substantial deviation from baseline in Latin America, Middle East, East Asia and Centrally-Planned Asia	Substantial deviation from baseline in all regions
B-550 ppm CO_2-eq	Annex I	-10% to -30%	-40% to -90%
	Non-Annex I	Deviation from baseline in Latin America and Middle East, East Asia	Deviation from baseline in most regions, especially in Latin America and Middle East
C-650 ppm CO_2-eq	Annex I	0% to -25%	-30% to -80%
	Non-Annex I	Baseline	Deviation from baseline in Latin America and Middle East, East Asia

Notes:
[a] The aggregate range is based on multiple approaches to apportion emissions between regions (contraction and convergence, multistage, Triptych and intensity targets, among others). Each approach makes different assumptions about the pathway, specific national efforts and other variables. Additional extreme cases – in which Annex I undertakes all reductions, or non-Annex I undertakes all reductions – are not included. The ranges presented here do not imply political feasibility, nor do the results reflect cost variances.
[b] Only the studies aiming at stabilization at 450 ppm CO_2-eq assume a (temporary) overshoot of about 50 ppm (See Den Elzen and Meinshausen, 2006).

Numerous studies have indicated that 60% reductions below 2000 levels by 2050, or 50% by 2040, are readily achievable.[103] Another study by WWF has shown how 30% reductions by 2030 could be managed.[104] Mark Diesendorf has outlined what would need to change for reductions of up to 33% below 1990 levels.[105] This study is a valuable contribution to the debate in that it demonstrates that there are no technological barriers to reducing Australia's emissions very substantially. More recently, McKinsey & Company reported that 30% reductions below 1990 levels were entirely possible without major impacts on consumption patterns or quality of life:

> A significant reduction in Australian GHG emissions is achievable - 30 percent below 1990 levels by 2020 and 60 percent by 2030 without major technological breakthroughs or lifestyle changes. These reductions can be achieved using existing approaches and by deploying mature or rapidly developing technologies to improve the carbon efficiency of our economy. They require significant changes to the way we operate in key sectors, for example, changes in our power mix, but can be achieved without major impact on consumption patterns or quality of life.

[102] Dr Malte Meinshausen, Potsdam Institute for Climate Impact Research, pers. comm. 8 April 2009.
[103] Saddler *et al.* (2004, 2007), Allen Consulting, (2006), Hatfield-Dodds & Adams (2007), Turton *et al.* (2002).
[104] WWF (2006).
[105] Diesendorf, (2007).

> Reducing emissions is affordable - with an average annual gross cost of approximately A$290 per household to reduce emissions in 2020 to 30 percent below 1990 levels. This compares to an expected increase in annual household income of over A$20,000 in the same time period. Such a reduction would require implementing all opportunities with a cost of A$65 or less per tonne of carbon dioxide equivalent (CO_2e), at a gross cost to the Australian economy of approximately A$2.9 billion per year in 2020.[106]

Another report released by Greenpeace and the European Renewable Energy Council shows how Australia could reduce its energy-related emissions by 37% below 1990 levels by 2020.[107]

By contrast, the Government proposed an exceedingly modest 5-15% reduction in our emissions below 2000 levels by 2020. Even the 15% targets that would leave Australian's with per capita emissions of 18.9 tonnes of CO2-eq per person – the highest in the OECD and far above those of the EU25 (6.6), UK (8), Japan (5.7) and even the US (12.3).[108]

In the *White Paper*, the Government noted what this implies for emissions if comparably weak targets were to be adopted by other countries:

> Australia's low pollution future locates CPRS -5 in a global scenario that would stabilise global atmospheric greenhouse gases at around 550 ppm CO_2-e by the end of the century; and CPRS -15 in a global scenario with stabilisation at around 510 ppm CO_2-e.[109]

As discussed in Section 3.13, stabilisation at 550 ppm CO_2-e would imply temperatures by 2100 ranging anywhere from about 2.5°C to 4.7°C depending on climate sensitivity and carbon-cycle effects. For 510 ppm CO_2-e, the equivalent range is around 2.3°C to 4.5°C. Such targets could not be considered adequate to give any real confidence of preventing dangerous climate change.

Another very concerning aspect of the Government's framework is that it has explicitly stated that it will only consider stronger targets *after* 2020 even if the world moves before then:

> These commitments are complemented by *an unambiguous statement that Australia's national interest will be best served by a comprehensive global agreement to stabilise atmospheric concentrations of greenhouse gases at around 450 parts per million of carbon dioxide equivalent (ppm CO_2-e) or lower*, and that should such an agreement emerge, Australia would establish *post-2020* targets to ensure that it makes its full contribution to more ambitious global action.[110]

This statement summarises well the Government's extraordinary approach to this issue: It very clearly acknowledges the conclusion of the Garnaut Review that Australia's national interests (to say nothing of those of poor countries) was best served by a target of 450 ppm CO_2-e *or lower*. But then rather than taking this as a reason to push strongly for Australia's

[106] McKinsey & Company (2008), p. 6.
[107] Teske & Vincent (2008).
[108] Australian Government (2008b), p. 3-10.
[109] Australian Government (2008b), p. 4-11.
[110] Australian Government (2008b), p. 4-1. Emphasis added.

own national interests with the 25% reduction below 2000 levels recommended by Garnaut, it settles on far weaker targets and shuts the door on adjusting those 2020 targets even if an agreement on 450 ppm CO_2-e 'should emerge' (without Australia's help). The Government's current position is to countenance higher targets only *after* 2020 even if the world tries to move in a direction that is closer to Australia's interests. The main reason given for the weak targets is that:

> A very ambitious target or a steep trajectory holds out the prospect of greater environmental benefits, but if they are too ambitious or too steep there is a risk that society will decide that sacrifices to reach the target are not worth making. An overambitious target that is not achieved has less environmental integrity (and effectiveness) than a realistic target that can be achieved and built upon in future years.[111]

Are proposals such as the 25% target or the 40% target 'too ambitious'? The modelling for the 25% target concluded that it would shave approximately 0.1 percentage points each year off real per capita economic growth, even for the 450 ppm CO_2-eq target of 25% reductions below 2000 levels.[112] Recall that this is all in the context of continued strong growth and rising living standards – it is not a reduction from current income levels. Elsewhere the *White Paper* states:

> GNP is 1.3 per cent to 1.7 per cent below the reference case in 2020 in the CPRS scenarios, and up to 2.0 per cent below the reference case in the Garnaut Final Report scenarios. *These impacts are equivalent to about four months of economic growth*, implying that the level of economic activity achieved in January 2020 in the reference case would be achieved in April 2020 in the CPRS scenarios.[113]

The Government's warning against 'overambitious targets' is therefore implying that Australians would be unwilling to forego an extra 0.1percentage points of economic growth per year in order to improve our chances getting a global deal to avert extremely dangerous climate change. WVA does not believe this is an adequate reflection of the character of the Australian people.

To put our efforts so far in context, in 1935-36 – about four years year before the beginning of World War II, the Australian government increased spending on defence to about 9% of the federal budget because it became concerned at rumblings in the Mediterranean and in Germany. By 1942-43 we were spending equivalent to 40% of national income on the war.[114] In the 2008-09 federal budget, defence spending was a little over 6% of the total budget – about $17.9 billion. In that same budget, the government allocated $2.3 billion over five years to tackle climate change.[115] If it is spread evenly over the five years, that amounts to about 0.16% of the federal budget each year to tackle arguably the greatest challenge humanity has faced. Put another way, each year the government is allocating around 39 times more to defence than to meeting the challenge of climate change.

[111] Australian Government (2008b), p. 4-2.
[112] Australian Government (2008a), p. xii.
[113] Australian Government (2008b), p. 4-12. Emphasis added.
[114] Long, (1973), pp. 5 & 474.
[115] http://www.budget.gov.au/2008-09/content/at_a_glance/html/at_a_glance.htm
http://www.budget.gov.au/2008-09/content/overview/html/overview_40.htm

In the *White Paper*, the Government also argued that economic efficiency was critical for mitigation efforts:

> Achieving emissions reductions at the lowest long-term cost maximises our ability to respond to climate change. It is important to achieve our environmental goals as efficiently as possible and get the maximum value out of our mitigation efforts.[116]

This is of course true – but only if the measures are actually sufficient to prevent climate change. Otherwise what we imagine to be 'efficiencies' are more likely to be false economies that will by no means maximise our abilities to respond to climate change. Again we see the problem that many policymakers and elected officials do not yet appear to grasp how dire the implications of unmitigated or half-mitigated climate change could actually be.

6.3 What does a 'responsible' response look like?

The so-called climate sceptics have lost the debate over whether climate change is real and whether humans are contributing to it, but we are left with the legacy of their campaign in one very important respect: it has framed the debate in terms of what a 'sensible', 'balanced' and 'responsible' response to climate change should be – as opposed to one that was 'reckless', 'radical' or 'economically irresponsible'. For example, in the White Paper we read:

> The Government has decided on a medium-term target range to reduce emissions by between 5 and 15 per cent below 2000 levels by 2020, balancing the need to make a strong contribution to international efforts with ensuring a balanced and measured start to the Scheme.[117]

A response can only be judged to be 'responsible', 'measured' or 'balanced' however, by comparing it with the scale of the threat it is intended to address. A tepid response to an impending invasion could hardly be said to be 'responsible' simply because it was slow.

The IPCC's 2007 report showed that we are facing a threat of staggering proportions – and since then the prognosis has only gotten worse. The gradual, 'responsible' plans of our Australian state and federal governments so far are totally inadequate to deal with the scale of the threat we are facing. Far from being 'economically conservative', they are in fact being recklessly radical by failing to take the scale of the threat more seriously. Climate scientists now seem to be almost beside themselves with concern and frustration. Instead of being listened to as sentries warning franticly of an impending catastrophe, they are being treated as lobbyists pushing an agenda to be 'balanced' with every other lobbyist's agenda.

The economists have shown that there is no economic impediment to strong targets, and that strong targets would position our economy and society well to benefit from the global shift to a low-carbon future. What is needed now more than ever is the decisive moral leadership required to face down those who suggest that we should privilege short-term private interests above the greater public good of all Australians, above the poor in developing countries, and above the rights of our children to hope for a better future.

[116] Australian Government (2008b), p. 4-2.
[117] Australian Government (2008b), p. xx.

6.4 An emergency demands an emergency response

If we compare then, the resources that were mobilised to fight World War II with the struggle over whether we can 'afford' to forego 0.1% of annual growth, we can see that we have barely begun to take climate change seriously. We are still treating it like a moderately significant economic reform, not a national and global emergency.[118]

Clearly there is a lot of room between the relatively minor impacts of the 450 ppm CO_2-eq target and a full wartime mobilisation. It is important to remember that in his terms of reference, Ross Garnaut was not asked to examine what economic policies would be needed to prevent dangerous climate change. On targets, he was directed to examine the 450 ppm and 500 ppm CO_2-eq options, not any pathways below 450 ppm that would have a better chance of reining in climate change.[119]

Garnaut concluded that the extra cost, the 'premium', to the economy of aiming for a 450 ppm CO_2-eq target rather than a 550 ppm target was "less than 1 per cent of GNP more through the 21st century for the insurance value and the avoided market and non-market impacts of the 450 scenario", concluding: "the Review judges that it is worth paying less than an additional 1 per cent of GNP as a premium in order to achieve a 450 result."[120] We do not know what the premium would be for aiming for 350 CO_2-eq. It could be more in upfront costs, but less in net costs over time. In any case, it should be looked upon as a long-term investment in our future, not a short-term expenditure.

What would be possible if we took the climate change emergency and the dire threat it poses to the world's poor seriously and launched a General Mobilisation? Could we achieve at least 40% reductions in our emissions by 2020? What if we did make some sacrifices? What if we did undertake massive investments in public transport? What if we invested hugely in solar, geothermal and wind generation parks connected to world class 'smart grids' by high voltage direct current (HVDC) cables.[121] We could roll out the necessary grid upgrades at the same time as the fibre-optics are rolled out for the national broadband network creating thousands of 'green jobs'. A comprehensive 'green stimulus package', could ensure the rapid decarbonisation of the Australian economy, could create jobs and could improve productivity and efficiency.[122] Rather than losing our best technology to the US, Europe or China, Australian industries could be nurtured and positioned to ride the wave of global refitting and renewable low-carbon technologies in the 2020s and 2030s.

For these reasons World Vision argues that Australia should strive to reach the upper end of the IPCC's target ranges: namely at least 40% below 1990 levels by 2020 and at least 95% below 1990 levels by 2050.

[118] One of the best books to make the case for emergency action is Spratt & Sutton (2008). See also: http://www.climateemergencynetwork.org/

[119] http://www.garnautreview.org.au/terms.htm

[120] Garnaut (2008), p. 272.

[121] See: Strahan (2009), Marris (2008), Brown (2008), Friedman (2008), Newman *et al.* (2009), and Diesendorf (2007).

[122] For more along these lines see: ACTU & ACF (2008), McKinsey & Company (2008), UNEP *et al.* (2008).

Recommendation 5: That the Australian Government ensures the reduction of Australia's net greenhouse gas emissions by at least 40% below 1990 levels by 2020, and at least 95% by 2050.

Recommendation 6: That the Australian Government ensures that Australia's domestic greenhouse emissions peak no later than 2010.

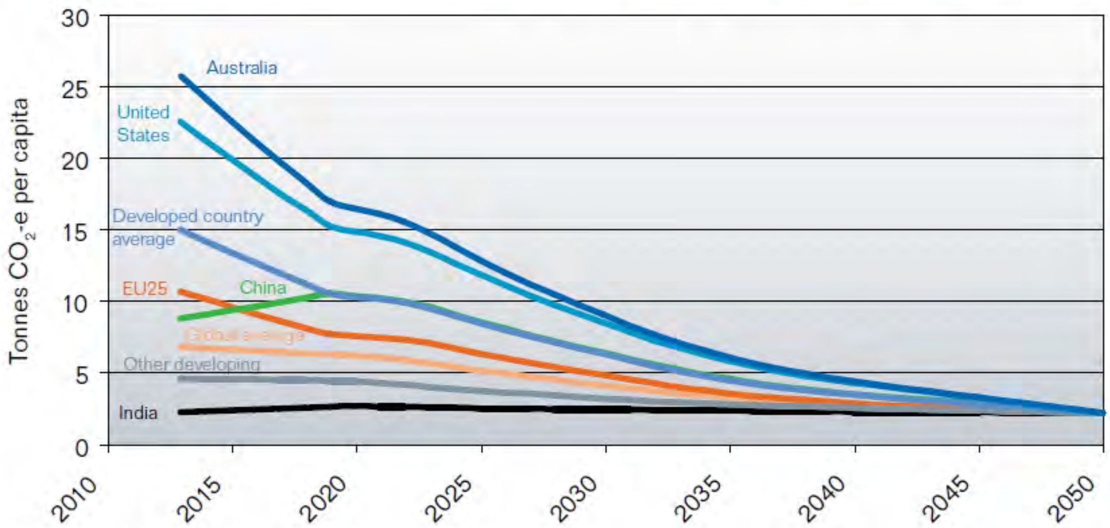
7. We need a global deal

The challenge of climate change will not be met without a global deal that includes developing countries. These countries are understandably frustrated that they are likely to be denied the historic opportunity that we in the rich countries had to grow their economies and lift their people out of poverty without having to take account of the real costs of greenhouse gas emissions.

The convergence to equal per capita emissions is a simple idea and therefore one which could have a chance of being implemented. Ross Garnaut proposed a version of this approach (see Figure 12 below) with 'headroom' for developing countries so that they have a time of adjustment before converging linearly.[123] For the poorest developing countries convergence would mean an increase in their emissions entitlements.

Figure 12: Per capita emissions paths under convergence to equal per capita emissions
Source: Garnaut (2008), p. 208.

Figure 9.5 Per capita emissions entitlements for the 450 scenario, 2012–2050



Note: The graph starts in 2012. Australia's 2012 starting value assumes Kyoto compliance, as do those for the EU25. Other countries start at their emissions level given by the reference case (the no-mitigation scenario) in 2012.

[123] Garnaut (2008), pp. 203, 206-207.

While equal per capita emissions is an important goal, the rate of convergence and the amount 'headroom' given to developing countries has important ethical and economic implications.

For developing countries to agree to a global deal in which they take on differentiated convergence targets, the date and rate of convergence of the rich countries would need to consider the historical responsibility of the rich countries for the bulk of the problem and also their far greater capacity to pay for the adjustment costs. Another factor that is frequently neglected is that proposals such as the one illustrated in Figure 12, imply continued multi-decade economic growth of the rich countries with per capita emissions far above average. There is no alternative to this given where we are of course, but this needs to be considered in weighing the contributions the rich countries should make to a global deal.

To summarise, the following factors should be considered in negotiating the date and trajectories of contraction and convergence proposals:

- Historical responsibility for the problem
- Capacity to pay relative to poorer countries
- The lost opportunity for developing countries
- The continued multi-decade high per capita emissions economic growth of rich countries during the convergence period.

Together these considerations imply that the convergence date should be sooner than 2050 – say 2030, and that the rich countries such as Australia that will continue to benefit from high per capita emissions growth should assist developing countries with very substantial aid for adaptation and mitigation and transfer of low-carbon technologies.

Recommendation 7: That the Australian Government supports a strong global agreement to keep warming to below 1.5°C (after unavoidable overshooting), with a maximum greenhouse gas stabilisation goal of 350-375 ppm CO_2-eqivalent as soon as possible. This implies convergence to equal per capita emissions as early as possible, (e.g. 2030) and a multi-decade drawdown of emissions from current levels which have overshot this target. Emissions reduction targets for developed countries should be at least 40% below 1990 levels by 2020, and at least 95% below 1990 levels by 2050.

Recommendation 8: Supports and contribute to an *International Adaptation & Mitigation Assistance Fund* for adaptation and mitigation in developing countries and also an *International Low-Emissions Technology Fund* for the research, development and commercialisation of low-carbon technologies. For funds of A$150 billion per annum, Australia's fair contribution would be at least A$5 billion to each. This aid should be above and beyond the 0.7% of GNI pledged by donor countries to tackle poverty before climate change became a global emergency.

8. The voices of children and youth need to be heard

The debates on climate change continually refer to the 'market failure' that led to the problem – namely the failure of markets to incorporate the environmental externalities into prices. But we also face a 'political failure' in the same technical sense of that phrase. The vast majority of those who will be affected by the consequences of climate change, namely youth, children and their future children, have no say whatsoever in what policies we adopt today. They are wholly disenfranchised from decisions that will determine the habitability of the planet they will inherit.

Policy on such a fundamentally inter-generational issue should not be decided purely by those who happen to be currently over 18 years old – and more particularly, by those who are older and in established positions of power and influence.

Children too, should have a voice in these matters. As they grow up, wanting to have families of their own, they will learn about the ethics of those in power at the beginning of the 21st century and the decisions they made. As Lester Brown, founder of the Worldwatch Institute warns, if we squander this opportunity by adopting targets which fail to rein in climate change, we risk not only climatic devastation, but the fracturing of our societies:

> It could trigger a fracturing of society along generational lines … How will we respond to our children when they ask "How could you do this to us? How could you leave us facing such chaos?"[124]

Recommendation 9: That the Australian Government ensures that the voices of children and youth – those whose inheritance we are determining – are heard in formulating Australia's climate policies.

9. Conclusions

The issues canvassed in this submission have a very real influence on how climate change and its likely impacts are understood, the policies that Australia is likely to adopt, and ultimately on whether we are able to rein in climate change sufficiently to avoid devastating consequences for the poor and vulnerable.

We are at a turning point in history. We will either solve the problems of poverty and climate change together, or we will solve neither of them. The current proposals of the Australian Government are not adequate to meet these challenges. But the hard work that has been undertaken provides a base which could be improved to ensure that Australia plays a key role in ensuring a prosperous and sustainable future for children in Australia and in developing countries.

[124] Brown (2008), p. 266.

Appendix 1. Approaches to modelling the economics of climate change

A.1 The economic modelling framework

Computable General Equilibrium (CGE) models are the standard work-horses for much economic policy analysis and as such, were used by both the Garnaut Review and the Australian Treasury for their economic modelling. There are however some very well-known and serious problems with CGE models that have been described in the economic literature over the past several decades.[125] DeCanio (2003) and Ackerman (2008) discuss some of these problems. Here is not the place for a full elaboration of this important issue, but several limitations should be mentioned:

- CGE models usually rely on a 'representative agent' to represent the population, but the preferences and welfare changes accruing to a representative agent may have little in common with the preferences and welfare changes of a population of heterogeneous individuals.[126]

- CGE models rely on very strong assumptions to exclude multiple equilibria and chaotic dynamics, when in fact these are common in all but the most restrictive analytic models.[127]

- CGE models presume perfect information, when in fact information imperfections and uncertainty are pervasive in real economies, affecting everything from the type and function of institutions to the development of credit and risk markets.[128]

- CGE models are generally 'real' models, effectively barter models, without a sophisticated model of money or of financial, credit, risk and insurance markets – all of which are crucial to modelling economic dynamics, including climate change policy.[129]

- CGE models are generally comparative static models, rather than truly dynamic evolutionary models. Even so-called 'dynamic' CGE models are usually just a series of comparative-static steps. But comparative statics is a mathematical exercise that by using highly restrictive mathematical assumptions, engineers a unique equilibrium. It has nothing to say about the disequilibrium transition dynamics that an economy undergoes once a real-world equilibrium (if such a thing exists) is disturbed, and there are no sound theoretical reasons to believe that the new equilibrium posited by comparative static analysis could actually be found once the system entered a state of disequilibrium.[130]

[125] For some key books, papers and quotes see: http://www-personal.buseco.monash.edu.au/~BParris/BPEconomicTheory.html
[126] See Kirman (1992)
[127] See Kehoe (1985, 1998), Saari (1995, 1996), Ackerman (2002).
[128] See Radner (1968), Greenwald & Stiglitz (1986), Stiglitz (2002).
[129] See Dillard (1988), Minsky (1982), Schumpeter (1934).
[130] See Fisher (1983, 1987, 1989, 2003), Kehoe (1987), Hallegatte *et al.* (2007).

- The expectations-formation processes modelled within CGE models are usually very primitive, relying on a long-discredited 'rational expectations' approach.[131] But the formation of expectations about the future is a crucial dynamic affecting revaluation of existing assets as well as consumption, saving and investment decisions.

- The modelling of firms in CGE models is frequently undertaken in terms of a single 'representative firm' representing an entire industry. This makes no allowance for firm heterogeneity and it presumes that all firms are on the technological frontier – so by definition there are no gains to be had from further efficiencies. Firms are also usually assumed to follow a primitive profit-maximization model that bears little relation to the more sophisticated modern behavioural theories of the firm. As a result CGE models are also generally very poor at modelling processes of genuine innovation and creativity – particularly those involving adaptive responses to government policies, incentives and disincentives. Since innovation is so central to addressing climate change, this is a serious deficiency.[132]

- CGE models generally presume complete markets for all goods, services, land, labour, capital and risk (if the latter is considered at all). These complete markets are founded upon the *existing* structure and distribution of rights, particularly property rights – a step with its own ethical implications. But incomplete and spatially and temporally separated markets are a pervasive feature of real economies. Relaxing the assumption of complete markets generally undoes the notion of a unique equilibrium. Multiple equilibria prevail.[133]

Agent-based modelling is a newer approach that potentially offers a far more flexible and powerful framework for evaluating the economic and social dimensions of climate change policies.[134] Agent-based models (ABMs) are computer simulations based on object-oriented programming, in which discrete 'agents' (objects) interact in real time with each other and their environment according to certain rules. Agents can represent individuals, households, firms, governments or even land types, pathogens, livestock, power grids etc. ABMs still use mathematics, but the mathematics is embedded in the rules governing agents' properties, behaviours and interactions, instead of governing and restricting the entire system and requiring it to converge to an equilibrium. ABMs permit the economic, social, legal, political, geographic, environmental, epidemiological and ethical dimensions of development policies to be integrated to a far greater degree than is possible with purely mathematical models. Agent-based modelling using object-oriented code libraries is also ideally suited to the development of theory based on taxonomical classification of different system components and their interactions.

[131] See Arrow (1987), Lewis (1985), Akerlof & Yellen (1985)
[132] See Nelson (1994 a & b), Nelson & Nelson (2002), Lundvall *et al.* (2002), Dosi (1988, 2002), Fagiolo & Dosi (2003), Dawid (2006), Cartier (2004), Gilbert *et al.* (2007), Demsetz (1997), Dew *et al.* (2008), Radner (1996), Teitelbaum & Dowlatabadi (2000), Edenhofer *et al.* (2006).
[133] See Hahn (1982), p. 3, Hart (1975), p. 442, Arrow (1987), p. 72-73.
[134] See Tesfatsion (2002, 2003, 2007), Tesfatsion & Judd (2006), and the websites at:
http://www.econ.iastate.edu/tesfatsi/ace.htm
http://www-personal.buseco.monash.edu.au/~BParris/BPAgentBasedModelling.html

ABMs are ideally suited to acting as a bridge between disciplines, an essential feature of integrated modelling for climate change policy. They have opened up a new interdisciplinary research frontier spanning: anthropology, climate change, combat, development and natural resource management, ecology, economics, epidemiology, finance, geography, innovation and organisation theory, migration, operations research, peacekeeping, political science, terrorism and transport. Active research is also being undertaken on methodological issues such as ABM design and the verification and validation of ABM results.

Unfortunately agent-based models have only been developed in the last decade or so and while they are growing rapidly in popularity in the United States and Europe. The European Commission for example, has supported the development of an ABM of the European economy.[135] ABMs are still relatively unknown in Australia though – particularly among economists. The CSIRO has undertaken some very good agent-based modelling work[136] and this should be applauded, but overall, ABMs have yet to be implemented at the scale required for the problems confronting Australian policy makers. But in our view ABMs offer the most promising framework for integrating the multiple interacting dimensions required for sound policy modelling in the future.

We are not alone in this view. Boulanger and Bréchet recently evaluated six different approaches to modelling sustainable development policy, namely macro-econometric, general equilibrium, optimisation, Bayesian networks, system dynamics and multi-agent (agent-based) models. Their conclusion was unequivocal:

> Unambiguously, the most promising modelling approach seems to be the multi-agent simulation model. … It is our opinion that public scientific and R and D policy-makers and advisers should foster their development and use in universities, schools and research institutions.[137]

A useful service that the Committee could provide, not just to Australia, but to the global community of climate change policy analysts, would be to clearly articulate the fact that current economic models have very serious limitations. Conversely, it would be quite unhelpful to pass over these limitations and leave people with the mistaken impression that our economic models are as sophisticated as the climate models. They are not. There is an urgent need for more sophisticated integrated models that take account of the many problems well documented in the economic literature.

Given that CGE models are pervasive in the debates on climate change however, we make a number of remarks in the following sections that presume their use.

[135] Deissenberg *et al.* (2008).
[136] http://www.csiro.au/science/CABM.html
[137] Boulanger & Bréchet (2005), p. 349.

A.2 Low discount rates are appropriate for climate modelling

Sir Nicholas Stern's report for the British government on *The Economics of Climate Change* was both lauded and condemned by economists.[138] Stern advocated early action and deep emission cuts. The report was criticised for using low discount rates, in contrast to the higher discount rates favoured by some.[139] But within the framework of Stern's analysis, a low discount rate is appropriate. His analysis involved broad social considerations such as inter-generational equity and numerous externalities which are not adequately captured in private benefits, prices and market rates of return on capital.[140]

Stern was also right to emphasise in his Richard T. Ely lecture to the American Economic Association in January 2008, that modeling was useful for illuminating certain aspects of the problem, but that it should not be the primary focus[141]:

> This type of modeling does have an important supplementary place in an analysis, but all too often it has been applied naively and transformed into the central plank of an argument. (p. 3).

For Stern, the two primary considerations in reaching policy conclusions should be a clear-eyed assessment of the *risks* and an explicit discussion of the *ethics* of different approaches:

> We come back again to a basic conclusion: the notions of ethics, with the choice of paths, together determine endogenously the discount rates. There is no market-determined rate that we can read off to sidestep an ethical discussion. (p. 13)
>
> What do we conclude about ethics and discounting in this context when we clear the various confusions out of the way? The answer is fairly simple. First, we must address the ethics directly. There is no simple market information from intertemporal choices or otherwise that can give us the answers. (p. 17)
>
> … the key assumptions influencing damage estimates concern risk and ethics. It is surprising, however, that these two issues did not occupy until recently the absolutely central position that the logic of the analysis demands. The result is that – given the recent evidence on emissions, carbon cycles, and climate change sensitivity – most of the studies prior to a year or two ago grossly underestimated damages from BAU [Business as Usual]. (p. 18)
>
> In this type of modeling, results are highly sensitive to assumptions on both structural risks and ethics, suggesting that great care should be exercised in choosing the key parameters. … Both risks and ethics are crucial to any serious assessment of policy toward climate change and, in particular, assessment of damages from BAU [Business as Usual]. (p. 19)

[138] Stern (2007).
[139] See for example, Nordhaus (2007).
[140] See DeCanio (2003), pp. 58-93 on discounting and the treatment of time, Stern & Taylor's (2007) response to Nordhaus (2007), and Voinov & Farley's (2007) discussion of sustainability, systems theory and discounting.
[141] Stern (2008).

> … within aggregate modelling, we have learned still more clearly that the key issues are ethics and risks and that we have to look at them together to form a serious view on damages. (p. 23)

Eric Neumayer moreover, makes a compelling case that the discounting debate is really a side issue compared with the more fundamental point that too many models falsely assume perfect substitutability between economic and natural capital.[142] Unfettered climate change would lead to substantial, irreversible and irreplaceable losses of natural capital and environmental services. Despite the impressive degree of consensus among scientists on climate change, significant areas of uncertainty still exist, including: the climate sensitivity (the average surface temperature change induced by a doubling of CO_2), the dynamics of the ice sheets, the effects of meltwater from Greenland on the Atlantic thermohaline circulation which maintains northern Europe's temperate climate, and the possibilities of dieback in the Amazonian rainforest and northern boreal forests. These uncertainties are of little comfort though because they generally tell us that the climatic and economic risks of no action or late action to reduce emissions may well be far larger than we had previously thought. It seems that we have a reasonable grasp of the minimum likely effects of climate change, with considerable uncertainty about its maximum effects.

Even the minimum known impacts of climate change however, are likely to have severe economic consequences. Allowing climate change to run its course would be certainly catastrophic. It would seem entirely appropriate then, not simply to assume that our descendents will be far better off than we are today. The discount rate used for policy models like Stern's should therefore be closely linked to the likelihood of continued strong economic growth – a likelihood which climate change diminishes.

[142] Neumayer (1999, 2007).

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