Concerns with the Garnaut Review's Recommendations on Emissions Targets

DRAFT, 26 September 2008[1]

Dr Brett Parris,
Chief Economist, World Vision Australia
Research Fellow, Monash University

Introduction

Both the Garnaut Review's *Draft Report* (DR) and the *Targets and Trajectories Supplementary Draft Report* (T&T) are major contributions to the public policy debate on climate change, not just in Australia but internationally. The quality and clarity of the Review's policy analysis has been a great public service and should help lift the quality of public debate, clearing the undergrowth of so many of the myths that have accumulated in recent years. The Review's strong conclusions on the seriousness and urgency of climate change are welcome and should be applauded.

Given the importance of the Review's upcoming final report though, the T&T report's conclusion (p. 46) that, "The only option for Australia at this time is to pursue global agreement to stabilise atmospheric greenhouse gas concentrations at 550 ppm" is of serious concern.

The DR (p. 5) argued that "it is neither rational nor helpful to reject conclusions because we do not like them. The conclusions will only be 'wrong' if the premises or logic leading to them are wrong." This is a useful starting point. If some of the premises which led to the 550 ppm target are wrong, the conclusion to recommend that target rather than the 450 ppm target should be rejected. I argue here, based mainly on evidence presented by the Review itself, that five of the premises leading to that conclusion are very likely to be wrong individually, and jointly are almost certainly wrong.

Premise 1: A 550 ppm CO_2-eq stabilisation is feasible

The recommendation to stabilise greenhouse gas concentrations at 550 ppm CO_2-eq assumes that stabilisation at this level is feasible (T&T p. 9). But with the climatic equilibrium disturbed, positive feedbacks affecting the carbon cycle, nonlinear thresholds to be crossed, and the possibility that the climate sensitivity is higher than 3°C, 550 ppm may be too high to be a stable equilibrium. We may try to stabilise concentrations at 550 ppm, but by then the climate system itself may be driving concentrations even higher.

[1] Please send comments, suggestions or corrections to:
Brett.Parris@worldvision.com.au or Brett.Parris@buseco.monash.edu.au

The DR notes (p. 127) that stabilising at 550 ppm has only about a 26% chance of holding warming to 2°C above early industrial levels, and is far more likely to deliver 2.2°C by 2050 and 2.5°C by 2100 (T&T, Table 8.1, p. 31) and 3°C at equilibrium (DR, p. 77). Nicholas Stern further noted recently of 550 ppm that:

> This level is nevertheless rather dangerous, with a 7 percent probability of being above 5°C and a 24 percent probability of being above 4°C. (Stern, 2008, p. 6).

But the upper range of the *likely* climate sensitivity (not the worst case), noted in the T&T report (Table 8.1, p. 31) implies that 550 ppm would be likely to bring temperature increases of 3.2°C by 2100. Elsewhere the DR notes that carbon-cycle feedbacks could add 0.2-1.5 °C by 2100 (p. 135). So if we are unlucky on both counts, the 550 ppm 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 CO_2 by the oceans. The Review, to its credit, acknowledges these possibilities (T&T, 34):

> There is a risk that temperature increases, and therefore all of 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 real and potentially large. Once temperature increases above some 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 (see Section 5.4.1 of the Draft Report). (p. 34)[2]

The IPCC was very clear in its recent *Synthesis Report*, that the projected temperature ranges for different gas concentration levels did not adequately reflect carbon cycle feedbacks (see Figure 1, overleaf). This is critical as a growing number of studies suggest carbon cycle feedbacks are likely to be large:

> The 2003 heatwave in Europe turned Europe's vegetation into a net source of carbon, releasing some 500 million tonnes (Ciais *et al.* 2005, Baldocchi, 2005)
>
> More frequent warm years "may lead to a sustained decrease in CO_2 uptake by terrestrial ecosystems" (Arnone *et al.* 2008, p. 383)
>
> "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." (Schuur *et al.* 2008, p. 701)

---

2 On the sentence "These are difficult to quantify, but real and potentially large", Dr Andrew Glickson from ANU comments: "It is not possible to understand the glacial terminations through the Pleistocene unless major feedbacks occurred, raising CO_2 by about 100 ppm and temperatures by 4 – 5 degrees, i.e. much higher than a climate sensitivity of 3°C per doubling of CO_2. This can not be explained by the greenhouse effect alone and is mostly attributable to ice sheet melt feedbacks, i.e. disintegration of the ice sheets, lowered Earth/ice albedo and open water absorption of infrared." (Glickson, personal communication, 19 September 2008).

In a comparison of five Dynamic Global Vegetation Models (DGVMs), "for the most extreme A1FI emissions scenario, three out of five DGVMs simulate an annual net source of CO2 from the land to the atmosphere in the final decades of the 21st century. For this scenario, cumulative land uptake differs by 494 Pg C [494 Gt] among DGVMs over the 21st century. This uncertainty is equivalent to over 50 years of anthropogenic emissions at current levels." (Sitch *et al.* 2008, p. 2015)

"Eleven coupled climate–carbon cycle models used a common protocol to study the coupling between climate change and the carbon cycle. … 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." (Friedlingstein *et al.* 2006, p. 3337).

Figure 1: Table 5.1 from the IPCC's *Synthesis Report* noting 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). (IPCC, 2007c, 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.)

The reason why so many scientists have warned against warming beyond 2°C (acknowledging that even that is probably too high) is that by 3°C we may well lose control of the system completely, so that 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 550 ppm CO_2-eq stabilization is feasible is likely to be false once carbon cycle feedbacks and the likely upper range of climate sensitivity are taken into account.

Premise 2: A global agreement is more likely if the rich countries choose targets in line with 550 ppm stabilisation

The T&T report (p. 14) acknowledges the challenges of bringing the big developing county emitters into a global deal:

> What is outlined is probably at the limits of acceptability to developing countries—it demands a modest departure from developing countries' current emissions growth path in the short term, and strong deviations in the medium term.

It is no secret that the developing countries are furious about this issue and about the refusal so far of many of the rich countries to countenance serious emissions cuts. The rich countries have taken up vastly more than their fair share of the global emissions budget both historically and today.

It is not at all obvious that we are more likely to get a strong global deal with developing country involvement if the rich countries such as Australia argue for relatively weak targets. The T&T report made it clear that the net present cost to Australia of adopting the 450 ppm target rather than the 550 ppm target was less than 1% of GNP (p. 38), concluding:

> The Review recommends that Australia commit itself to a goal of stabilising emissions at 450 ppm, and express its willingness to play its proportionate part in an effective global agreement to achieve this outcome. (T&T, p. 40)

To have any hope of a global deal, the developing countries want to see three things from the rich countries:

1. The strongest possible domestic targets the rich countries can manage
2. Substantial funds to assist them to adapt to the climate change that is inevitable over the coming decades
3. Substantial funds and technology transfer to help them mitigate their own emissions

Recommending that Australia does not adopt the targets implied by a 450 trajectory undermines requirement 1 and pushing for the 550 ppm target as a starting point implies much greater funds needed in future for 2 because climate change will be worse – with a risk that the funds are not delivered and the deal falls apart.

It may be that a deal on 450 ppm is not possible. But that conclusion should be drawn only after a deal has been attempted, not before. At the very least, the rich countries should be offering to adopt the strongest possible targets they can manage. The weaker the targets of the rich countries, the stronger the targets of the poor countries have to be for the same mitigation. Stronger targets for poor countries however imply lower growth for them – at least as long as their ratios of emissions to GNP remain high. That would be a particularly unfortunate outcome for Australia since as the Review noted: "Australia … is the country whose terms of trade would be damaged most by any setback to income growth in developing countries" (T&T, p. 26).

Premise 3: The modelling captures 65-85 per cent of market impacts

The DR helpfully distinguishes between four types of costs, making it clear that certain important costs cannot be modeled (DR, 32-34). The Review should be commended for its transparency and honesty in the way the draft reports have articulated what could be modeled and what could not be. Nevertheless, the Review claims that the modeling approach captures around 65-85 per cent of market impacts:

> Based on the above discussion and simple calculations, it is possible … that the omitted market impacts could contribute an additional 1 to 3 percentage points to the loss of welfare, as measured by household consumption. This suggests that the Review's modelling of median climate change outcomes may have captured in the range of 65 per cent to 85 per cent of market impacts. (DR, p. 260)
>
> For the reasons put forward in the Draft Report (see Chapter 10) it is estimated that the 'avoided expected climate change impacts', as modelled in MMRF, cover about 75 per cent of total avoided expected climate change impacts. (T&T, p. 35)

Even leaving aside some of the serious concerns that have been raised *within* the economics profession about the kinds of economic models used for this type of analysis (DeCanio, 2003), there are good reasons to be skeptical of this claim to cover 65-85 per cent of market impacts. From Table 7.1 in the DR (pp. 163-164) we can see what was not able to be modelled:

- Fisheries and aquaculture
- Forestry
- Mining
- Horticulture
- Viticulture and the wine industry
- Australia's World Heritage properties
- Alpine zone of south-east Australia
- South-west Western Australia
- Great Barrier Reef
- Roads and bridges
- Telecommunication
- Ross River virus
- Health of remote northern Australian Indigenous communities
- Rural mental health
- Ecosystems and impacts on plants and animals
- Geopolitical instability in the Asia–Pacific region and the subsequent aid and national security response from Australia
- Catastrophic events as affect Australia
- Severe weather events in Australia

The DR also noted that even in assessing the market impacts:

> We do not examine the more serious implications of climatic tipping points, due to the high degree of uncertainty associated with these and the limited time available to the Review to explore the breadth of potential impacts. (DR, p. 162)

The nature of the modelling undertaken by the Review does not allow for feedback of impacts from climate change in an internally consistent or integrated way. The domestic economic modelling framework is a traditional market model. It does not explicitly account for feedback from environmental changes to changes in economic factors or activity. (DR, p. 226)

The Review used the MAGICC model (Wigley 2003) and the A1FI emissions profile to generate global average surface temperature change for 2090-99 of around 4.3°C above 1980-99 levels (DR, p. 245, footnote 7). The new Garnaut-Treasury global reference case conversely was linked with the CSIRO Mk3L model (Phipps 2006) yielding global surface temperatures for 2090-99 of just 3.0°C, a 1.3°C difference. It is these results from the CSIRO Mk3L model that were fed into the ABARE/CSIRO Global Integrated Assessment Model (GIAM) to derive the 'international effects' that were in turn fed into the Monash Multi Regional Forecasting (MMRF) model.

Why the difference in temperature outcomes? The CSIRO Mk3L uses a lower climate sensitivity than MAGICC, and only covers CO_2, CH_4 and N_2O. MAGICC includes these gases, but also the effects of CFCs and aerosols. As a result, the Review notes:

Taken together, these differences mean there could be some downside conservatism in the estimates of the international impacts of climate change. (DR, p. 245).

The fact that some "downside conservatism in the estimates of the international impacts of climate change" seem to be built into the modeling is of concern – not least because, as it is, the models are not able to capture adequately the effects of climatic tipping points, feedback from climate change on the economies, the effects of declining agricultural productivity in Asia, the effects of geopolitical upheaval, or the short terms effects of the impacts of extreme climatic events such as major cyclones.

The DR determined that the direct economic consequence of sea level rise was 'low' (Table 10.1, p. 252). But the assessment uses the 0.59 metre figure and "assumes there is no significant sea-level rise this century [due to] deglaciation." The IPCC made it quite clear however, that its upper estimate of 0.59 m sea-level rise this century did not take into account the effects of ice sheet dynamics and declaciation (IPCC 2007a, p. 14; and see Figure 1). But recent studies have shown that Greenland's climate has changed rapidly in the past (Steffensen *et al.* 2008; Kobashi *et al.* 2008) and that 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 (Bamber *et al.* 2007)

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. (Howat *et al.* 2008)

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 (Pfeffer *et al.* 2008). The Review noted that even a one metre sea-level rise would impact 105 million people in Asia (DR, p. 191). But the paper by Anthoff *et al.* (2006) from which this figure comes noted that the global total would be more like 145 million. The Review further notes that:

> Most of Asia's densest aggregations of people and productive lands are on coastal deltas, including the cities of Shanghai, Tianjin, Guanzhou, Hong Kong, Tokyo, Jakarta, Manila, Bangkok, Singapore, Ningbo, Mumbai, Kolkata and Dhaka. The areas under greatest threat are the Yellow and Yangtze river deltas in China; Manila Bay in the Philippines; the low-lying coastal fringes of Sumatra, Kalimantan and Java in Indonesia; and the Mekong, Chao Phraya and Irrawaddy deltas in Vietnam, Thailand and Myanmar respectively. (DR, p. 191)

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. But one of the greatest dangers from higher seas are the storm surges which accompany tropical storms and which can often be 5-6 metres high. 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 (Luetz, 2008, p. 12).

Periodic inundations by storm surges have also been shown to be of the order of 9-28 times more expensive than permanent inundation because of factors such as repeated rebuilding and repair costs and higher insurance costs. (Michael 2007).

As the science relating to sea-level rise continues to consolidate over the next decade, the potential for future sea level rises and associated shoreline erosion and storm surges are likely to have very serious implications for coastal property values and insurance premiums around the world. A critical point is that the sea-level rises do not have to have taken place yet for projected rises to have immediate economic effects. Properties used for loan collateral may be devalued by lenders and land taxes may become delinked from falling property values. Over time 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 climate system-financial market links do not appear to be either captured by the modeling or discussed in the Review.

Questions are already being raised in Australia about the legal liability of local councils and government planning bodies for the effects of coastal planning regulations on property values in the context of likely sea-level rise (Millar, 2008; Greenblat & Craig, 2008). Indeed, one issue that is likely to be exercising the minds of lawyers in the coming decades is that of the legal liability of decision makers who knew, or had the responsibility to know, beyond reasonable doubt, the grave risks of allowing certain developments or policies to proceed, and allowed them anyway.

Other major international impacts noted by the Review with potentially large economic repercussions include:

> The key Australian export markets in China, India, Indonesia and elsewhere in Asia are projected to have significantly lower economic activity as a result of climate change (DR, p. 186)

Weather extremes and large fluctuations in rainfall and temperatures have the capacity to refashion Asia's productive landscape and exacerbate food, water and energy scarcities in Asia and the south-west Pacific. Australia's immediate neighbours are vulnerable developing countries with limited capacity to adapt to climate change. Climate change outcomes such as reduced food production, water scarcity and increased disease, while immensely important in themselves, also have the potential for destabilisation of domestic and international political systems in parts of Asia and the south-west Pacific. (DR, p. 186)

There are serious security risks from climate change through infectious disease. … A study by the World Health Organization (2002) estimated that 154 000 deaths annually were already attributable to the ancillary effects of climate change due mainly to malaria and malnutrition. The study suggests that this number could nearly double by 2020 (DR, p. 189)

In the future … climate refugees could constitute the fastest-growing proportion of refugees globally, with serious consequences for international security (BP, p. 192)

The Review discusses geopolitical stability (DR, pp. 186-189) but does not seem to give due weight to this consideration in recommending the 550 ppm target. The geopolitical implications of water projections in Asia for example, are extremely serious. 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 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 Ho (Yellow River). Temperatures on the Tibetan Plateau have risen three times faster than the global average for the last 50 years (Qiu, 2008). 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 (Cruz *et al.* 2007, p. 493, 481).

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 (IPCC, 2007b, p. 13). The DR also warned that 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 (DR, p. 188).

The DR also noted though, that the international modeling with GIAM 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. Regional climate change damages are assumed to be a function of regional changes in average temperature (relative to 2000) and the vulnerability of a region to potential climate change. 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. (DR, p. 257)

This year there have been 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 economic 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 of water stress before 2025 when the availability falls below 1000 m^3 per capita" (Cruz *et al.* 2007, p. 484). 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 (Klare, 2001, 182-189). The Middle East and Mediterranean basin are also expected to be afflicted by severe water shortages (IPCC, 2007c, Fig 3.5, p. 49). In Box 7.5 (p. 189) the DR highlighted the dangers posed by some of these likely sources of tension:

> 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.

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 US bases on its soil. The last thing the region needs is a series of 'threat multipliers' due to food and water shortages brought on by climate change.

The DR noted these concerns but downplayed their likely economic impacts:

> … food security issues, severe weather events, sea-level rise, climate refugees, and energy and water security issues can contribute to increases in geopolitical instability.
>
> It is likely that an increase in geopolitical instability in the Pacific region, and the globe generally, will require an increase in the capability and requirements of Australia's defence forces, and an increase in the level of Australia's spending on emergency and humanitarian aid abroad. These measures will reduce the income available to households and consequently reduce consumption.
>
> In 2006–07 total expenditure on defence was approximately $17 billion. If climate change caused defence expenditures to increase by 10 per cent, this would imply the

> need for an additional $1.7 billion to be raised by government. In 2004–05 total household consumption was around $580 billion. Therefore, an increase in defence expenditure in the order of 10 per cent might reduce household consumption by around 0.3 per cent.
>
> Previous Australian interventions in small neighbouring nations may also provide an indication of the potential size of future defence costs that may arise from climate change. It is likely, however, that climate change could lead to geopolitical pressures involving larger countries, and thus may lead to much higher spending than would be indicated by recent history.
>
> The combined aid and defence budget for the five-year intervention in Timor-Leste, starting in 1999–2000, has exceeded $700 million per year. Australia's intervention in Solomon Islands is estimated to cost around $200 million per year … The combined expenditure on regional defence force interventions has averaged over half a billion dollars per year since 1999 (pp. 258-259)

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 highly 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.

As advanced as the Review's modelling is, it leaves out a great many important factors which have serious economic implications. It seems highly unlikely that the modelling has captured 65-85 per cent of the market costs of future climate change, as claimed.

Premise 4: The best way to a 450 ppm deal is through a 550 ppm deal

From environmental, economic and social perspectives, the lower 450 ppm target is clearly preferable to the higher 550 ppm target, something the Review emphasises repeatedly. But the Review recommends starting with the higher target:

> … Australia should now indicate its willingness to play its proportionate part in future, and if possible early, movement towards a more ambitious global goal than 550 ppm. As such, the details of the targets and trajectories that the Review is recommending will not be the best for all time. They are the best available to us now. (T&T, p. 3)

> The most important first step towards stabilisation at 450 ppm CO_2-e is to quickly put in place an effective international agreement directed at 550 ppm, to put in place the national and international carbon pricing and support for research, development and commercialisation of low-emissions technologies that can lower the costs of mitigation, and to begin the process of reduction of emissions. (T&T, p. 40)

> … the first best approach for Australia would be to pursue a comprehensive and cooperative global agreement targeting stabilisation of atmospheric concentrations at 550 ppm. (T&T, p. 45)

And even more emphatically:

> The only option for Australia at this time is to pursue global agreement to stabilise atmospheric greenhouse gas concentrations at 550 ppm. (T&T, p. 46)

The implication seems to be that planning for the 550 target will make switching to the 450 ppm target later more easy. It is not obvious why that should be the case. The deal being negotiated to cover the post-2012 period is likely to cover at least 10-15 years. The nature of that deal and the policies that are enacted to enforce it will send strong signals to governments and firms that will guide investment decisions. Many of those decisions will involve capital equipment and large plants that will have intended lives of several decades.

An agreement on a 550 ppm target will result in many long-term, relatively high-emissions investments which would be uneconomic under a 450 ppm target and, conversely, the discouragement of many low-emissions investments that would be viable under the more stringent target. Different decisions need to be made in the next two decades to have much chance of reaching the 450 ppm target later.

The developed countries will need to reengineer their energy and transport systems and the developing countries will need to build the next stages of their economies far more energy efficiently than we did. It would seem far preferable and more economically efficient to have a very clear policy signal on the target we are aiming for, and to plan investment decisions in accordance with that target. That target has to be *effective* in preventing dangerous climate change as far as possible.

Adopting an initial 550 ppm plan with an unspecified *ad hoc* plan B to switch to 450 ppm at some later point would seem to be a recipe for uncertainty, costly investment mistakes and legal recriminations over the next two decades. Nick Stern recently emphasised the importance of clear long-term policy signals:

> [S]tarting now in a strong way and with clear signals will allow more time for planned choices, discovery of options, and exploration of the renewal periods and timings for equipment. This is the measured, lower-cost approach. Going more slowly and then moving in haste when and if the science is confirmed still more strongly, is likely to be the expensive option. (Stern, 2008, p. 9)

Scientists are already emphatic that stabilisation at 550 ppm, even if it could be achieved, is not low enough to avoid dangerous climate change. As this becomes more widely appreciated among investors and planners over the next decade, the expectation is likely to grow that tougher targets will be required. Several consequences could follow:

- First, there would be large sunk costs from investments in plant and equipment optimised for a 550 target which could lead to resistance to having to quickly ratchet down emissions caps in carbon markets towards a stronger target.
- Second, a later unanticipated switch of targets could give grounds for legal compensation against governments who knew that stronger targets would be required but who led investors to believe that the 550 ppm trajectory would be adequate.
- Third, starting with a signal for a 550 ppm target may well eliminate the remaining opportunity to rein in dangerous climate change because of the delay in introducing the stronger targets that are actually needed to deal with the problem.

The Review emphasised how important the window of time is in dealing with this challenge (T&T, p. 8)

> Time is an essential element in any resolution of the policy problem.
>
> But the science, and the realities of emissions growth in the absence of mitigation, shows that there is not enough time. The world is rapidly approaching points at which high risks of dangerous climate change are no longer avoidable. … we would delude ourselves if we thought that scientific uncertainties were cause for delay. Such an approach would eliminate attractive lower-cost options, and diminish the chance of avoiding dangerous climate change.
>
> In such circumstances, the only way through the constraints is to make a start on domestic and international action, along paths that may now be feasible, but which in themselves do not lead quickly to ideal outcomes. Early action, even if incomplete and inadequate, on a large enough scale, can buy time, and begin building the foundations for effective collective action.

The Review is right to emphasise the urgency of the problem and the dangers of delay. But it gives a misleading impression by implying that the 'ambitious' 450 ppm target should be considered an 'ideal' to aim for. Ideal outcomes are not on the table. The ideal would be more like 400 ppm CO_2-eq. Instead we are discussing 'minimum tolerable' outcomes. The discussion of Premises 1 and 3 above concluded that the 550 ppm target has such serious implications that it should not even be considered 'tolerable'.

The Review also asserted that 550 ppm could be a strong enough target to prevent dangerous climate change (T&T, p. 9):

> The first step, built around immediately moving onto a path of global emissions designed to stabilise concentrations of greenhouse gases at no higher than at 550 ppm, is large and far-reaching enough to keep open the possibility of avoiding high risks of dangerous climate change.

There are two problems with this assessment: Firstly, as discussed under Premises 1 and 3, the 550 ppm trajectory almost certainly does not allow us to avoid high risks of dangerous climate change. If that is the case, global tensions are likely to be exacerbated as damage from climate change escalates. An equitable global deal would probably be far more difficult to achieve in the context of heightened global tension, particularly if regional conflicts are beginning to emerge.

The second problem is that 'keeping open the possibility of avoiding dangerous climate change' is hardly a bold or comforting goal. Have we really reached the point where we can't imagine doing better? If this was a war with similar projections for damage to Australia, would we plan our response merely to keep open the possibility of success? An earlier generation of Australians was prepared to make incredible sacrifices to *maximise* the chance of success (Walker, 1944). They were not content merely to keep open a small window of possibility and hope for the best. Are we not their equals?

The difference this time is not in the scale of the threat we face, but in the fact that this time the threat is not as immediately obvious and there is a time lag between our failure to act decisively and the devastating consequences. That means we require strong political leadership and a clear bipartisan articulation of the scale of the threat we are facing. In my experience, people are quite prepared to 'do their bit' once they understand the scale of the threat – but no-one wants to be a sucker, making sacrifices while others free-ride. That again suggests the need for strong political leadership to solve the co-ordination problem, and that co-ordination through careful regulation and strong market incentives is likely to be far more effective and politically saleable than voluntary measures.

Finally, a 450 ppm deal would imply strong obligations on the part of developed countries to provide funding and technology transfer to developing countries, to help them to adapt to climate change and to develop far more energy-efficiently. The main challenge to achieving an ambitious deal on targets may not lie then with developing countries, but with the reluctance of the developed countries to countenance the funding that would be required to help developing countries reduce their emissions from their 'business as usual' projections.

Premise 5: Australia can do relatively little to influence the international negotiations

This is more of an implicit than a stated premise, and in places the Review is clear that the world is watching our response:

> Australia matters. What we do matters. When we do it matters. It would be really silly to take action with costs to ourselves meant to assist the emergence of a good international agreement, but to do it too late to have a chance of avoiding high risks of dangerous climate change. What we do now, in time to influence the global mitigation regime from the end of the Kyoto period, is of high importance. What we do later runs the risk of being inconsequential in avoiding dangerous climate change. (T&T, p. 23)
>
> The Europeans, Americans, Chinese, Indonesian and Japanese, among others, are all watching Australia with acute interest to see how we handle the problems of our trade-exposed, emissions intensive industries. If we get this wrong, it will give every country on earth another excuse to also get it wrong (T&T, p. 43).

But elsewhere the Review seems to reflect the view that Australia cannot do much at all to influence the negotiations, with statements such as the following:

> There are large risks to the Australian economy, and to Australian values manifested outside market processes, if the concentrations of carbon dioxide equivalent in the atmosphere reach 550 ppm and remain there. The analysis suggests that a global objective of 450 ppm, with discussion of transition to 400 ppm once the 450 ppm goal is being approached with confidence, would better suit Australian interests. However, the Review has reluctantly concluded that international agreement on a global goal of 450 ppm is not possible at this time. While the Review's modelling of the time path to a 450 ppm objective, with overshooting, is closely consistent with the G8 goal of 50 per cent reduction of global emissions by 2050, the awful arithmetic of developing country emissions in the Platinum Age … makes it unlikely that this goal can be agreed in current circumstances. Achieving the objective of 450ppm would require tighter constraints on emissions than now seem feasible in the period to 2020. If international developments change the conditions that led to this judgment, Australia should encourage acceptance of more ambitious global objectives. (T&T, p. 3)

If there are large risks to Australia from remaining at 550 ppm, and 450 ppm or 400 ppm would be far more in our interests, shouldn't the Australian government be doing all it can to try to achieve those goals and to "change the conditions that led to this judgement"? The Australian government should be articulating as strongly as possible the dangers of targets greater than 450 ppm, and seeking to build a coalition of support for the more ambitious targets and a feasible transition to even 400 ppm. It will involve some peaking in greenhouse gas concentrations, but the scale of the threat and the potential to cross dangerous climatic thresholds suggests that we should be exerting all our efforts to explain to both domestic and international audiences why ambitious targets are essential.

Australia's negotiating position will affect the dynamics of the negotiations – particularly in the context of having just undertaken such a major review of the issues. The Garnaut Review is a major contribution to the global policy debate on climate change. If Australia, with the highest CO_2-intensity for electricity of any country in the OECD (DR, p. 205), is seen to have carefully weighed the evidence and comes out strongly advocating ambitious targets, that will send a very strong signal of just how serious climate change is. Conversely, advocating the weaker 550 ppm target as our *starting* position is not only at odds with Australia's best interests (T&T, p. 3), but it is likely to be interpreted by others as being the target that Australia has concluded is in its own *best* interests. Others may then seek targets in their own (perceived) best interests. Consensus that 550 ppm might be the best we can do could become a self-fulfilling prophecy.

The Review has been careful to argue that a 450 ppm target would be better, and has only reluctantly recommended the 550 ppm target because of its assessment of the state of negotiations. It is likely however that this carefully nuanced view will be completely forgotten if targets for 550 ppm become Australia's position. What will be remembered is that 'Garnaut recommended 550 ppm' – the reasons won't matter. For example, on 6-7 September the *Weekend Australian* led with the headline '**Garnaut pushes low-key target'**, with Paul Kelly declaring (p. 1) "Professor Garnaut recommended Australia set a low initial greenhouse gas reduction target of between 5 and 10 per cent by 2020."

Instead of starting by pushing for a 550 ppm deal, Australia could play a pivotal role in changing the dynamics of the debates and could make a lasting contribution to history by strongly and clearly articulating the scale of the threat we are facing and why ambitious emissions reductions targets are essential. If we fail, we fail. But at least we would not have failed because we didn't try.

Conclusion

This paper has discussed five of the explicit and implicit premises in the Review's *Draft Report* and *Targets and Trajectories Supplementary Draft Report* which led to the recommendation of the 550 ppm targets for Australia:

1. A 550 ppm CO_2-eq stabilisation is feasible
2. A global agreement is more likely if the rich countries choose targets in line with 550 ppm stabilisation
3. The modelling captures 65-85 per cent of market impacts
4. The best way to a 450 ppm deal is through a 550 ppm deal
5. Australia can do relatively little to influence the international negotiations

All of these premises are probably individually incorrect. For the recommendation on the 550 ppm target to be preferred, they all need to hold. In my view the joint probability of them all being correct is close to zero and so the strategy of Australia pushing for a 550 ppm goal should be emphatically rejected in favour of the 450 ppm goal.

One last issue should be raised. The Review documents contain very little discussion of ethics and justice in the context of choosing targets for Australia. Ethical issues are discussed in the context of discounting (DR, pp. 42-44) and income distribution effects (DR, pp. 469-479). Ethics is also a clear driver of the recommendation for convergence to equal per capita emissions (T&T, pp. 15-16) and it is noted that ethical judgements are required to define 'dangerous' climate change (DR, p. 76). Justice is not mentioned explicitly apart from a passing reference to Rawls (DR, p. 7). There may be other references I missed and I do not wish to imply that the Review staff were not aware of the ethical implications of their recommendations. Nevertheless there are some striking statements. For example:

> The focus of Australian policy making is on maximising the welfare - or utility - of Australians. (DR, p. 34)

This is surely a far too narrow lens. Australian policy making must also focus on preserving the ecological and resource base of our country – we are its stewards, not its owners to do as we please. At the very least we should also eliminate as far as possible any adverse external effects on others resulting from our utility-maximising activities. We clearly have not done that with our emissions. Ethics is also not mentioned at all in T&T Section 8 (pp. 29-40) on 'Is mitigation worth the cost for Australia?'

> Is it worth paying less than 1 per cent of GNP through the 21st century for the insurance and nonmarket impacts, and these and market benefits beyond 2200, of the 450 strategy? This is a matter of judgment. … Given the benefits after 2200 of stronger mitigation, and the greater risks of catastrophic consequences to the natural environment under the 550 strategy, the Review judges that it is worth paying less than 1 per cent of GNP as a premium for the 450 strategy. (T&T, p. 39)

I would argue however that this is not just a matter of judgement based on a net cost-benefit analysis for Australia – it is also a matter of ethics and justice. Nick Stern emphasised strongly 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:

> 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 (Stern, 2008, 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.
> (Stern, 2008, 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. (Stern, 2008, 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]. (Stern, 2008, 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. (Stern, 2008, p. 19)

… 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. (Stern, 2008, p. 23)

The rich countries largely caused this problem. We have crowded the 'ecological space' to such an extent that developing countries must now be constrained in how much they can emit. For a global deal to be achieved, the developing countries want to see some awareness by the rich countries of their historical responsibilities for the problem, the justice dimensions of climate change policy and a commitment by the rich countries to taking on the strongest possible emission reduction targets.

Children too, have no say in these matters. But as they grow up, wanting to have families of their own, they will learn about the decisions made by those in power at the beginning of the 21st century. As Lester Brown warns (2008, p. 266), if we squander this opportunity by adopting targets which fail to rein in climate change, we risk not only climatic devastation, but the searing sadness of our children, whose future we frittered away:

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?"

Given the extremely serious consequences of the 550 ppm trajectory for developing countries' agriculture, water availability, coastal livelihoods and political stability, and for our children and future generations, I do not believe it is either effective or ethical to give up on the 450 ppm or 400 ppm targets. In saying this I do not suggest that Professor Garnaut or the Review team have given up on them either – only that they appear to have come reluctantly to the view that the best way to achieve the more ambitious targets is by first cutting a deal on a 550 ppm trajectory.

Advocating a 550 ppm CO_2-eq target is in my view a strategic mistake which, despite the Review's carefully nuanced arguments, has had the effect of signaling that 550 ppm is somehow adequate to meet the scale of the threat we are facing. As the Review has clearly shown, it is not. The 'ambitious' 450 ppm target should be the absolute maximum that is considered tolerable as a first step, and the Australian government should do all it can to articulate to the Australian people and to the international community the scale of the threat we are facing, and to work energetically towards securing an international agreement for the more ambitious targets.

References

Anthoff, D., Nicholls, R.J., Tol, R.S.J. and Vafeidis, A.T., (2006) "Global and Regional Exposure to Large Rises in Sea-Level: A Sensitivity Analysis", Working Paper 96, Norwich, Tyndall Centre for Climate Change Research, pp. [http://www.tyndall.ac.uk/publications/working_papers/twp96.pdf]

Arnone, J.A., III, *et al.* (2008) "Prolonged Suppression of Ecosystem Carbon Dioxide Uptake after an Anomalously Warm Year", *Nature,* Vol. 455, No. 7211, 18 September, pp. 383-386.

Baldocchi, D., (2005) "The Carbon Cycle Under Stress", *Nature,* Vol. 437, No. 7058, 22 September, pp. 483-484.

Bamber, J.L., Alley, R.B. and Joughin, I., (2007) "Rapid Response of Modern Day Ice Sheets to External Forcing", *Earth and Planetary Science Letters,* Vol. 257, No. 1-2, 15 May, pp. 1-13

Brown, L.R., (2008) *Plan B 3.0: Mobilizing to Save Civilization,* W.W. Norton for the Earth Policy Institute, New York & London, xiv + 398 pp.

Ciais, P., *et al.* (2005) "Europe-Wide Reduction in Primary Productivity Caused by the Heat and Drought in 2003", *Nature,* Vol. 437, No. 7058, 22 September, pp. 529-533.

Consultative Group on International Agricultural Research Inter-Center Working Group on Climate Change (2002), *The Challenge of Climate Change: Research to overcome its impact on food security, poverty, and natural resource degradation in the developing world*, [www.cgiar.org].

Cruz, R.V., Harasawa, H., Lal, M., Wu, S., Anokhin, Y., Punsalmaa, B., Honda, Y., Jafari, M., Li, C. and Huu Ninh, N., (2007) "Asia", In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E.; Cambridge University Press, Cambridge & New York, pp. 469-506.

DeCanio, S.J., (2003) *Economic Models of Climate Change: A Critique,* Palgrave Macmillan, New York & Houndmills, Basingstoke, UK, xiii + 203 pp.

Friedlingstein, P., et al. (2006) "Climate-Carbon Cycle Feedback Analysis: Results from the C^{4}MIP Model Intercomparison", *Journal of Climate,* Vol. 19, No. 14, July, pp. 3337-3353.

Greenblat, E. and Craig, N., (2008) "Coastal strategy all at sea over climate", *The Age,* Melbourne, Saturday 13 September, pp. B1 & B4.

Howat, I.M., Smith, B.E., Joughin, I. and Scambos, T.A., (2008) "Rates of Southeast Greenland Ice Volume Loss from Combined ICESat and ASTER Observations", *Geophysical Research Letters,* Vol. 35, L17505, 9 September, 5 pp.

IPCC, (2007a) "Summary for Policymakers", In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Solomon, S., Qin , D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L.; Cambridge University Press, Cambridge & New York, pp. 1-17.

IPCC, (2007b) "Summary for Policymakers", In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E.; Cambridge University Press, Cambridge & New York, pp. 7-22.

IPCC, (2007c) *Climate Change 2007: Synthesis Report: Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.,* Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.); IPCC, Geneva, 104 pp.

Kelly, P., (2008) "Garnaut pushes low-key target", *The Weekend Australian*, 6-7 September, pp. 1 & 8.

Klare, M.T., (2001) *Resource Wars: The New Landscape of Global Conflict,* Henry Holt, New York, xiii + 289 pp.

Kobashi, T., Severinghaus, J.P. and Barnola, J.-M., (2008) "4 ± 1.5 °C Abrupt Warming 11,270 Yr Ago Identified from Trapped Air in Greenland Ice", *Earth and Planetary Science Letters,* Vol. 268, No. 3-4, 30 April, pp. 397-407.

Luetz, J., (2008) Planet Prepare: Preparing Coastal Communities in Asia for Future Catastrophes, World Vision Asia-Pacific Regional Office, Bangkok, 123 pp.

Michael, J.A., (2007) "Episodic Flooding and the Cost of Sea-level Rise", *Ecological Economics,* Vol. 63, No. 1, 15 June, pp. 149-159.

Millar, R., (2008) "Coastal strategy all at sea as fears rise over compo claims", *The Age,* Melbourne, Saturday 13 September, p. 8.

Pfeffer, W.T., Harper, J.T. and O'Neel, S., (2008) "Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise", Science, Vol. 321, No. 5894, 5 September, pp. 1340-1343.

Phipps, S.J., (2006) "The CSIRO Mk3L Climate System Model", Technical Report 3, Hobart, Antarctic Climate & Ecosystems Cooperative Research Centre.

Qiu, J., (2008) "The Third Pole", *Nature,* Vol. 454, No. 7203, 24 July, pp. 393-396.

Schuur, E.A.G., *et al.* (2008) "Vulnerability of Permafrost Carbon to Climate Change: Implications for the Global Carbon Cycle", *BioScience,* Vol. 58, No. 8, September, pp. 701-714.

Sitch, S., *et al.,* (2008) "Evaluation of the Terrestrial Carbon Cycle, Future Plant Geography and Climate-Carbon Cycle Feedbacks Using Five Dynamic Global Vegetation Models (DGVMs)", *Global Change Biology,* Vol. 14, No. 9, September, pp. 2015-2039.

Steffensen, J.P., *et al.* (2008) "High-Resolution Greenland Ice Core Data Show Abrupt Climate Change Happens in Few Years", *Science,* Vol. 321, No. 5889, 1 August, pp. 680-684.

Stern, N.H., (2008) "The Economics of Climate Change", *American Economic Review,* Vol. 98, No. 2, May, pp. 1-37.

Walker, E.R., (1944) "War-Time Economic Controls", *Quarterly Journal of Economics,* Vol. 58, No. 4, August, pp. 503-520.

WHO, (2002) The World Health Report 2002: Reducing Risks, Promoting Healthy Life, World Health Organization, Geneva, 248 pp.

Wigley, T.M.L., (2003) *MAGICC/SCENGEN 4.1: Technical Manual,* National Center for Atmospheric Research, Colorado.