Submission to the

Garnaut Climate Change Review

World Vision Australia

April 2008

Contents

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1. Introduction

Climate change is fundamentally a development problem and a human rights 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 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 may constitute 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 about the rights of today's children and their future families to inherit a world at least as stable and habitable as the world we inherited.

WVA believes that emissions reduction targets for Australia must be strong and based on sound science. To have a reasonable chance of keeping global warming to 2°C or less above pre-industrial levels, binding agreements must be made to ensure that greenhouse gases are stabilised below 450 ppm CO_2- equivalent. According to the IPCC, that means that the Kyoto Protocol's Annex 1 countries (including Australia) must reduce their annual greenhouse gas emissions to 25-40% below 1990 levels by 2020, and to 80-95% below 1990 levels by 2050.[1] As a stable and very prosperous democracy WVA believes Australia should aim for the upper ends of those ranges.

Australia should seek to ensure that a new agreement is concluded by the end of 2009 at the Conference of Parties (COP) in Copenhagen to allow time for the agreement to be ratified by enough countries to come into force by the start of 2013. As part of the new agreement, the rich countries must commit to ensuring that sufficient resources are made available to assist developing countries in building sustainable, low-carbon economies, and in supporting 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.

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[1] Gupta *et al.*, (2007), p. 776

WVA has already contributed to two other submissions, namely those of the *Make Poverty History* campaign, and the *Climate Action Network Australia*. We endorse those submissions and in the interests of brevity, we will not seek to repeat material substantially from those submissions. Instead we will confine our remarks to a number of more specific issues.

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. For example, applying a specific amount of heat to a saucepan of water will gradually raise the temperature in a predictable way. There won't be any sudden jumps in temperature unless the heat input suddenly increases. But with nonlinear systems, slow, gradual causes can result in sudden and quite radical effects – for example, at close to 100°C the water in our saucepan will start to boil. At that point the water is undergoing a nonlinear phase change from its liquid to its gaseous state. This example also shows that the same system can behave in a linear manner for some parameter values and in a nonlinear manner for values lying beyond a certain threshold.

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.

This distinction between linear and nonlinear systems is critical in the context of climate change. 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 apparently stable state to another.[2] 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."[3] The emergence from the last ice age for example, was characterised by dramatic oscillations, or 'flickering' between cold and warm periods.[4]

We know, for example, from annual bands in ice cores from Greenland, as well as other evidence, that the so-called Younger Dryas period, which began abruptly about 12,800 years ago, interrupted the gradual thawing from the last ice age, sending temperatures plummeting again in the Northern hemisphere. Overall it made the world drier, windier and dustier.[5] It ended even more suddenly than it had begun, around 11,600 years ago when temperatures

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[2] On nonlinear climate change, see Alley (2004); Buchanan (2007); Pearce (2007); Hansen (2004), and Lenton *et al.* (2008).
[3] Hansen *et al.* (2007), p. 1925. See also Glickson (2008).
[4] Taylor *et al.* (1993).
[5] Pearce (2007), p. 149.

rose some 8°C within 10 years.[6] The abrupt climatic shifts of the Younger Dryas period are by no means unique, as two 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]

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.[9] This corresponds to what would occur if the Greenland Ice Sheet were to melt. But more extreme levels have also occurred in the past. Sea levels were around 73 metres higher some 35 million years ago when CO_2 levels were around 1250 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.[10]

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: if the climate sensitivity to a doubling of CO_2 turns out to be greater than 3°C, if ice sheet dynamics mean the ice sheets are less stable than we had previously thought, or if carbon-cycle feedbacks 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 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. [11]

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[6] National Research Council (2002), p. 27. See also: Pearce (2007), pp. 149-150; Alley (2000).
[7] National Research Council (2002), p. 153.
[8] Alley (2004), p. 64.
[9] Overpeck *et al.* (2006), p. 1747.
[10] Alley *et al.* (2005), p. 456.
[11] IPCC (2007), p. 14.

In view of the uncertainty surrounding the complex nonlinearity of the climate system, WVA suggests that statements such as the following are unhelpful:

> As this discussion relates to *Australia's* emissions reduction trajectory only, it will not affect the environmental outcome. However, the trajectory of global emissions reductions may affect the environmental outcome.[12]
>
> Because Australian action alone will be of little consequence to climate change impacts, there seems no case for adjusting budgets and trajectories for new information and developments of an economic or scientific kind.[13]

Such statements reinforce the view 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 quite misleading to assert definitively 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 cannot 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.

Recommendations:

1. That the Garnaut Review strongly emphasises 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. That the Garnaut Review avoids making statements that give the misleading impression that Australia's emissions may not have serious climatic repercussions.

3. 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 our overall recommendation is to urge those undertaking the modelling for the Garnaut Review, if they have not already done so, to read Stephen DeCanio's 2003 book *Economic Models of Climate Change: A Critique*.

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 and so for the

[12] Garnaut Climate Change Review (2008b), p. 23, footnote 1.
[13] Garnaut Climate Change Review (2008b), p. 26.

modelling undertaken by the Garnaut Review to be taken seriously as a useful guide to policy, it should take into account the issues summarized by DeCanio. 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.

3.1 The economic modelling framework

Computable General Equilibrium (CGE) models are the standard work-horses for much economic policy analysis and as such, we expect that they will be used by the Garnaut Review for its 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.[14] DeCanio's *Critique*, mentioned above, discusses 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.[15]

- 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.[16]

- 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.[17]

- 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.[18]

[14] For some key books, papers and quotes see: http://www-personal.buseco.monash.edu.au/~BParris/BPEconomicTheory.html
[15] See Kirman (1992)
[16] See Kehoe (1985, 1998), Saari (1995, 1996), Ackerman (2002).
[17] See Radner (1968), Greenwald & Stiglitz (1986), Stiglitz (2002).
[18] See Dillard (1988), Minsky (1982), Schumpeter (1934).

- 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.[19]

- The expectations-formation processes modelled within CGE models are usually very primitive, relying on a long-discredited 'rational expectations' approach.[20] 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.[21]

- 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.[22]

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.[23] 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

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[19] See Fisher (1983, 1987, 1989, 2003), Kehoe (1987), Hallegatte *et al.* (2007).
[20] See Arrow (1987), Lewis (1985), Akerlof & Yellen (1985)
[21] 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).
[22] See Hahn (1982), p. 3, Hart (1975), p. 442, Arrow (1987), p. 72-73.
[23] 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

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.

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, they are still relatively unknown in Australia – particularly among economists. The CSIRO has undertaken some very good agent-based modelling work[24] and this should be applauded, but overall, ABMs have yet to be implemented at the scale required for the problems confronting the Garnaut Review. 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.[25]

A useful service that the Garnaut Review 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.

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[24] http://www.csiro.au/science/CABM.html
[25] Boulanger & Bréchet (2005), p. 349.

3.2 Low discount rates *are* appropriate

Sir Nicholas Stern's 2006 report for the British government on *The Economics of Climate Change* was both lauded and condemned by economists. 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.[26] 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.[27]

Eric Neumayer (1999, 2007) 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. 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 and which is also under threat from a second source to be discussed in Section 4.

3.3 Baseline projections should reflect the reality of impending climate change

WVA is greatly concerned that the 'baseline' projections for GDP growth that are used to provide a benchmark against which to compare the net costs of mitigating climate change, frequently 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.[28] To project a 'base case' for GDP growth out to 2050 based on past experience and 'business as usual projections', as if climate change was not a problem is pure fantasy and constitutes a woeful basis for comparing the costs and benefits of mitigation measures. It is like deciding whether

[26] See for example, Nordhaus (2007).
[27] 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.
[28] See Hall & Behl (2006).

or not to hose our house down based purely on the cost of the water, neglecting the fact that our house is now on fire. Allowing it to burn is also likely to be costly.

A baseline projection that assumes we do nothing to mitigate climate change, and in effect allows climate change to run its course, will seriously underestimate the cumulative losses to GDP from drought, floods, heatwaves, fires, extreme weather events and higher insurance premiums by 2050. By doing nothing, we would be running the serious risk, and indeed likelihood, of our economies taking a far bigger hit in the future from the effects of climate change and more frequent extreme weather events than the 'business as usual' baseline projections suggest.

3.4 Economic models need to integrate financial and insurance market effects

As mentioned briefly in Section 3.1, many CGE models are simply 'real' models in which money, credit markets, financial markets and insurance play no real role. WVA views this deficiency as so serious that we elaborate on it here. 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.*[29] [Emphasis added]

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 revalued 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. To our knowledge these effects are not captured well in the standard non-monetary economic models usually used to assess the potential costs of climate change.

3.5 Foregone GDP growth does not simplistically equate to 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

[29] Michael (2007), p. 149.

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.[30]

3.6 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*.[31] 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.

3.7 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.*[32] [Emphasis added]

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.[33] The poor are likely to suffer most from climate change, just as they have suffered most from the terrible droughts and famines induced by severe El Niños in the past.[34]

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

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[30] See Easterlin (2003), Layard (2005 & 2006) and Frey & Stutzer (2002) on 'happiness', Hamilton & Denniss (2005) on 'affluenza'.
[31] Roundtable, (2006), p. 19.
[32] Dasgupta *et al.* (2007), p. 2.
[33] For more on the security implications and likely conflicts resulting from climate change, see Dupont & Pearman (2006), WBGU (2007) and the Council of the European Union, (2008).
[34] See Davis (2001).

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. But let us not forget that human history will likely continue beyond 2100, with warming continuing and risking substantial melting from the Greenland and West Antarctic ice sheets. In a world with sea levels several metres higher than today, 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.

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.

Recommendations:

3. That the Garnaut Review notes the many problems inherent in computable general equilibrium models that have been identified in the economics literature and suggests options for placing integrated climate policy modelling on a firmer footing.

4. That the Garnaut Review uses low discount rates that do not unfairly place the burdens of adjustment on future generations.

5. That all baseline economic scenarios produced for the Garnaut Review used to estimate the costs of mitigation incorporate the likely economic impacts of unfettered climate change.

6. That the economic models used for the Garnaut Review incorporate financial, credit and insurance markets.

7. That the Garnaut Review does not simplistically equate foregone GDP growth with a loss of wellbeing.

8. That the Garnaut Review emphasises the role that sound government policies can play in reducing the uncertainty that poisons economies and delays much-needed investment decisions.

9. That the Garnaut Review gives due consideration to the likelihood of extremely costly security implications if climate change is allowed to continue unfettered.

10. That the Garnaut Review emphasises that this issue doesn't end in 2100. We have serious ethical obligations to our children and to future generations.

4. Energy futures and projections of global oil production

In our view, it is not possible to evaluate Australia's likely economic trajectories over the next two decades, and its capacities to respond to climate change, without taking a position on the likely trajectory of oil prices. Positions are often implicit, buried in assumptions about future economic growth, assuming that past decades will be a reliable enough guide to the future. Taking a more explicit position on the issue requires confronting the controversy over 'peak oil'. The phrase 'peak oil' does not refer to "running out of oil". It refers to a peak in the *rate* of global oil production - which everyone agrees is inevitable at some point. The main areas of disagreement concern how soon this will happen, with estimates ranging from now to around 2040, and what will happen after the peak. Some believe we will see a protracted, undulating plateau, followed by a gentle decline, others believe that the peak will be followed by a quite sharp decline in oil production, leading to all manner of calamities.

4.1 Factors to consider

There are a number of factors that should be borne in mind in evaluating this issue:

1. Oil is the lifeblood of our economies, providing 94% of transport fuel globally, according to the International Energy Agency (IEA).[35] Oil is also the primary feedstock for the petrochemical industry and oil and gas play major roles in most of the world's agriculture, with nitrogen fertilizer produced from natural gas, pesticides produced from oil, and with oil running farm machinery and fuelling transport. As we have witnessed over the past year, oil price rises contribute to food price rises, both directly due to rising farm input and transportation costs, and indirectly through increased competition for land from biofuels.

The usual assumption that economic growth will continue uninterrupted into the future therefore relies heavily on the implicit assumption of continuing cheap energy supplies – and particularly cheap oil supplies. This link is important because the justification for the discounting used in economic policy models is that people in the future will be richer than we are. But if that assumption is incorrect, it changes our economic analysis of how we should respond to climate change (which on its own is also likely to make future generations poorer). If in fact we are living near the end of an economic Golden Age, gilded by cheap oil, it suggests we should be using it more wisely and making more of a sacrifice than the high discount rates embedded in some economic models suggest we should.

2. Most economic models simply presume that relatively low oil prices will continue indefinitely, but there are good reasons for questioning that assumption, as will be discussed below. But even if prices were stable, Australia has already lost its relative self-sufficiency in oil, and the need to import an increasing proportion of our requirements will have severe implications for Australia's balance of payments in the near future. The Australian Petroleum Exploration and Production Association claimed in February 2008 for example, that:

> Australia's crude oil and condensate production is declining from nearly 100 percent of Australia's needs in 2000 to just over 60% today and, without major new discoveries, an

[35] IEA (2007), p. 80.

> anticipated 32% by 2017… This translates into a decline in the petroleum and petroleum products (excluding LNG) trade balance from a surplus of $0.9 billion in 2000, to a deficit of $13.7 billion today and projected at $28 billion in 2017.[36]

3. The fact that there may be some people advocating a 'peak oil' perspective who seem to gravitate all too willingly to apocalyptic scenarios, does not mean the issue should not be taken seriously. There are also many serious and sober agencies, researchers, companies and commentators who are deeply concerned about this issue.

4. A great deal hinges on the definitions of oil 'reserves' used.[37] 'Proven' reserves (also called 1P or P90 reserves) are reserves meeting a very strict reporting definition of the US Securities & Exchange Commission - essentially reserves which are known with greater than 90% probability and are ready to be pumped out of the ground. 'Proven and probable' reserves (also called 2P or P50 reserves) are the assessments oil companies themselves tend to use, based on their assessments of what a field is likely to yield. Much of the growth in reserves is due to the upgrading of 2P reserves to 1P.

5. Reserves data are poor. It's often not clear whether 1P or 2P is being referred to. Many countries hold their true reserve situations as closely-guarded state secrets. Some reserve inflation looks very suspiciously political, such as the dramatic increases in many OPEC countries' reserves in the mid-1980s when production quotas came to be tied to the size of reserves.[38]

6. In 2000 the US Geological Survey (USGS) published its comprehensive assessment of oil reserves and future prospects. An evaluation five years later found that, in the period assessed from 1995-2003, additions to reserves from upward revisions to reserve estimates in existing fields had roughly kept pace with expectations. But for new oil discoveries, only 41% of the oil that the USGS expected to have been discovered, was in fact discovered.[39] The IEA expects global oil demand in 2008 to average 87.2 million barrels per day (mb/d)[40] – which is 31.8 billion barrels per year. Even large recent finds such as the Tupi field in the Santos Basin off Brazil, which may hold anywhere from 5-30 billion barrels, represents between 2 months' and one years' global supply. It is not insignificant, but in general, we are simply not finding enough new 'supergiant' fields to replace those in decline and to keep up with new demand. Moreover, the key to this issue is not the total volume of reserves, but the maximum sustainable rate at which the oil can be extracted and whether that is enough to meet demand without constraining demand through large price increases.

7. The problem then is not simply one of uncertain supply, but also soaring demand. The IEA projects global demand to grow from 84.7 mb/d in 2006 to 116.6 mb/d by 2030 in its reference scenario (or to 102.3 mb/d in its 'Alternative Policy Scenario' which assumes implementation of those policies currently being considered by governments, or to 120 mb/d under its 'High Growth Scenario'). Demand for oil from developing countries is

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[36] APPEA (2008).
[37] See: Bentley *et al.* (2007).
[38] Campbell & Laherrère (1998).
[39] Klett *et al.* (2005).
[40] IEA (2008) *Oil Market Report*, April: http://omrpublic.iea.org/

projected to rise from 28.8 mb/d in 2006 to 53.3 mb/d in 2030, an increase of 24.5 mb/d, including increases of 9.4 mb/d to China and 3.9 mb/d to India alone, almost all of which is expected to come from increased imports for those two countries.[41] But even these demand projections may be optimistic. A recent review of the IEA's demand forecasts for China based on the experiences of other countries at similar levels of GDP per capita, suggests that demand may be some 12.2 mb/d higher for China by 2030 than the IEA is expecting. In other words, China's demand for oil could be closer to 28.7 mb/d by 2030 rather than 16.5 mb/d.[42] But even a daily requirement of 16.5 mb/d is 94% of the 17.5 mb/d that the IEA hopes that Saudi Arabia will be able to produce by 2030.[43]

Writing in the journal *Science*, Richard Kerr summarized the scale of the challenge to meet increasing demand between 2005 and 2030: "The volume of oil required will be 35% greater than what was produced in the previous 25 years; that's more oil than consumed throughout human history up to 2005. And the easiest oil to extract has by now been produced."[44]

8. The scale of this challenge is leading many to doubt whether it can be met. The investment required is enormous. According to the IEA, around US$22 trillion of new investment (in 2006 US dollars) is needed to meet rapidly growing energy demand by 2030, including US$9.6 trillion in the oil and gas sectors alone.[45] The IEA even gave a stark warning in its latest *World Energy Outlook*:

> Although new oil-production capacity additions from greenfield projects are expected to increase over the next five years, it is very uncertain whether they will be sufficient to compensate for the decline in output at existing fields and keep pace with the projected increase in demand. *A supply-side crunch in the period to 2015, involving an abrupt escalation in oil prices cannot be ruled out.*[46] [Emphasis added]

9. Many economists appear to have an unduly optimistic view of these challenges that seems to arise more from faith that somehow the magic of the market will solve any supply bottlenecks. But when a sober assessment of the details of demand projections and supply constraints is undertaken, the picture is less rosy. There is a global shortage of oil rigs and skilled personnel and rig costs have increased dramatically over recent years.[47]

> [T]he cost to hire or purchase a drilling rig is rocketing. Between 2002 and 2006, the cost of purchasing a new deepwater, semi-submersible rig almost doubled to $500m, and the daily rate to hire an offshore rig increased by 135-430 per cent, depending on location and drilling depth. Day rates for the technologically advanced fifth and sixth-generation rigs, built in the past 10 years, increased to more than $450,000 a day in 2006 from less than $120,000 a day at the start of 2002. The global cost of a semi-submersible rig, which drills in water depths of 2,001-5,000 feet, increased by 250 per

[41] IEA (2007), pp. 74, 80, 101, 110.
[42] Nel & Cooper (2008).
[43] IEA (2007), p. 82.
[44] Kerr (2007).
[45] IEA (2007), pp. 42, 94-95.
[46] IEA (2007), p. 43.
[47] Simmons (2007)

> cent over the same period. Although the variety of rigs used to drill in a range of environments across the world makes it impossible to have a single measure of the increase in rig prices, the sharp upward trend over the past five years is indisputable.[48]

The IEA expects that between 2006-2030, non-OPEC oil production will rise by only around 6.2 mb/d (a 13% increase), with conventional oil production peaking and most of that increase coming from non-conventional sources such as Canadian tar sands. The vast majority of the increased production is expected to come from OPEC countries (+24.8 mb/d, a 69% increase to 60.6 mb/d), and most of that would come from the Middle East (+20.9 mb/d, an 87% increase to 45.0 mb/d). Assuming these production figures can be met, OPEC's share of world oil production would increase from 42% in 2006 to 52% in 2030.[49]

Sadad Al-Huseini was until March 2004 the head of exploration and production at Saudi Aramco, the state-owned oil monopoly which accounts for 97% of Saudi Arabia's crude oil production. In an October 2007 interview, he gave a much more sober assessment than the IEA's projections of the likelihood of OPEC ever producing 60 mb/d:

> What we've seen is that although the price of oil has almost quadrupled - or more - in the last few years, the supply has not. The non-OPEC, non-former Soviet Union countries - and that includes countries like Mexico, North Sea, and others - have, in fact, gone down, even though the prices have increased four-fold or five-fold. We're also seeing that OPEC and non-OPEC former Soviet Union are levelling off. So, the normal economic theory is not working in this case, and that's because of course there's - there are ceilings in the industry that don't allow the normal equation to work.... There's no question that there are giant fields left in the world, and there are major reserves left in the world, but they are all maturing oil fields - large fields, but maturing. The additional discoveries that are happening are very complex fields - smaller, less durable, less sustainable. The demand on resources, both human and equipment, is increasing to the point where their isn't any additional resource - human or mechanical. ... The evidence is that in spite of the increases - very large increases - in oil prices over the last four years, we haven't been able to match that with increasing capacity. So, essentially, we are on a plateau. ...
>
> I don't have a concern about Saudi Arabia's production. I think the confusion is that many of these international organizations have assumed that Saudi Arabia will double - or more - its capacity; in other words, produce 20 to 20-plus million barrels a day. That's the unrealistic aspect of these forecasts. But, as far as Saudi Arabia sustaining its capacity, it's doing very well, and can sustain its capacity. The problem is nobody else seems to be doing anything, whether in the Gulf region or internationally - whether it's Russia or Mexico or any of the others - so it's a bit of an unfair burden to assume that Saudi Arabia will pull everybody's chestnuts out of the fire. ...
>
> Some of those assumptions, for example, assume that OPEC will go from about 30 million barrels a day - which is what it produces now - to well over 45 or 47 million barrels a day. ... Staying at 30 million barrels a day is not a small feat - that's a lot of oil - that's half of the exported (sold) oil in the markets today, and to stay there requires a sustained investment program which is quite massive, and a lot of resources. I think

[48] Nield (2008).
[49] IEA (2007) p, 82.

> that's realistic - staying at 30. But going to some of these numbers - 47, 48, 60 million barrels a day - I think that's quite unrealistic. ...
>
> I think, perhaps, they're just not looking realistically at prices because the equation has three factors: supply, demand, and price. If you assume that you have a endless supply to meet demand, then price would stay reasonably low. If you assume supply is constrained - which is what I'm saying - and has a ceiling, then the only way to balance the equation is to assume that prices will increase significantly, and I think that's a more prudent and realistic outlook.[50]

Supply lines are also highly concentrated and vulnerable to disruption, which can lead to dramatic spikes in oil prices. In 2006, 13.4 mb/d, (about 16%) of the world's oil passed through the Strait of Hormuz between Iran and Oman. By 2030, the best case according to the IEA, is that 26.9% of the world's daily oil supplies will pass through that Strait (with 30.5% the worst case).[51]

10. The higher concentration of production in OPEC and the higher proportion of oil passing through the Persian Gulf, suggest both higher prices and more volatile prices in future – even if there is enough supply to meet demand. Higher prices on their own might be manageable if the price outlook was high but stable. But increased volatility makes planning production investments difficult and makes it more likely that price uncertainty will stifle some projects. Rising oil prices certainly make some formerly unprofitable fields economic - but we are finding fewer and fewer large, supergiant fields, and the fixed costs of developing multiple small fields are much higher than developing a few supergiant fields.

In summary, the IEA's Chief Economist, Fatih Birol, confessed in *Time*, on 5th November 2007: "I am sorry to say this, but we are headed toward really bad days … Lots of targets have been set but very little has been done."[52]

4.2 Australian government inquiries

There have been two government inquiries into the issue in Australia: one by the Australian Senate and a second by the Queensland Government Oil Vulnerability Task Force. The Australian Senate Inquiry Report released in February 2007, concluded:

> The essence of the peak oil problem is risk management. Australian governments need better information from which to decide a prudent response to the risk. … In the committee's view the possibility of a peak in conventional oil production before 2030 should be a matter of concern.[53]

It also recommended: "that Geoscience Australia and ABARE reassess both the official estimates of future oil supply and the 'early peak' arguments and report to the Government

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50 Strahan & Al-Huseini (2007).
51 IEA (2007) p. 170.
52 Walt, V., (2007) "Oil Prices: It Gets Worse", *Time,* 7 November, [http://www.time.com/time/business/article/0,8599,1681362,00.html].
53 Commonwealth of Australia (2007), pp. 54-55.

on the probabilities and risks involved."[54] The Queensland Government's Oil Vulnerability Taskforce Report, from April 2007 was more forthright:

> The Taskforce concludes that the overwhelming evidence is that world oil production will peak within the next 10 years. … The Taskforce also notes that the world oil market is becoming increasingly supplied from politically and/or socially unstable areas, such as from many OPEC and Middle East nations. This means that, regardless of the global peak oil issue, the risks of supply disruptions are rising. … the Taskforce recommends that a prudent risk mitigation approach requires a mix of initiatives such as reduction in consumption of liquid fossil fuels, encouraging the development and use of alternative fuels, technologies and strategies, and preparation for demographic and regional changes, as Queenslanders change travel, work and living habits in response to rising fuel prices.[55]

4.3 Expert testimonies

Oil company executives have also expressed grave doubts about our abilities to continue to access cheap oil. Christophe de Margerie, Head of Exploration for French oil company Total, declared in April 2006: "Numbers like 120 million barrels per day will never be reached, never."[56] And in January this year, Jeroen van der Veer, CEO of Shell, sent an email to all Shell staff which included the statement: "Shell estimates that after 2015 supplies of easy-to-access oil and gas will no longer keep up with demand."[57] In February this year John B. Hess, Chairman and CEO of the oil company Hess Corporation told the Cambridge Energy Research Associates' conference in Houston:

> Given the long lead times of at leat 5-10 years from discovery to production, an oil crisis is coming and sooner than most people think. Unfortunately, we are behaving in ways that suggest we do not know there is a serious problem.[58]

Similarly, Fournier and Westerfelt for the US Army Corps of Engineers warned:

> The doubling of oil prices from 2003-2005 is not an anomaly, but a picture of the future. Oil production is approaching its peak; low growth in availability can be expected for the next 5 to 10 years. As worldwide petroleum production peaks, geopolitics and market economics will cause even more significant price increases and security risks.[59]

One of the key problems is that the entire spatial geography of our settlements and the spatial structure of our economies and the supply chain networks which keep us alive all presume cheap oil. Our sprawling cities with poor public transport, particularly in the outer suburbs, presume cheap oil. Our economy currently relies on millions of people and millions of tonnes of freight moving vast distances each day. Any rapid and permanent escalation in oil prices could have severe economic and social consequences. The so-called Hirsch Report

[54] Commonwealth of Australia (2007), pp. xii.
[55] McNamara (2007), pp. 4-5.
[56] Mortished (2006).
[57] Mortished (2008). A copy of the email can be found at: http://royaldutchshellplc.com/2008/01/24/email-correspondence-with-shell-on-22-january-2008-concerning-another-leaked-shell-internal-communication/
[58] Fletcher (2008), p. 27.
[59] Fournier & Westerfelt (2005), p. vii.

for the US Department of Energy contained a stark warning that we cannot meet this challenge by waiting until it is upon us. It can only be met by serious planning more than a decade in advance:

> The world has never faced a problem like this. Without massive mitigation more than a decade before the fact, the problem will be pervasive and will not be temporary. Previous energy transitions (wood to coal and coal to oil) were gradual and evolutionary; oil peaking will be abrupt and revolutionary.[60]

4.4 Conclusions on oil and its relation to the challenge of climate change

To conclude this section we emphasise two points:

- We cannot plan Australia's climate change response adequately over the next two to three decades without taking the possibility of a significant oil supply crunch into account. Our views on this possibility affect our perceptions of Australia's (and the world's) likely economic health and our assumptions about what discount rates are appropriate for economic analysis.

- The urgency of both climate change mitigation and the need to plan more than a decade in advance for any severe and potentially permanent oil supply shock, suggest a common policy response, namely to place the Australian economy on a 'war footing': We need urgent action on energy efficiency at all levels, particularly in road transport and in the expansion of public transport infrastructure. But energy efficiency measures are needed in all sectors. While improvements in public transport will help reduce emissions and our vulnerability to an oil supply shock, the most preferred replacement for petrol-driven cars could well be plug-in electric hybrids. This suggests a significant expansion in demand for electricity in Australia – which must be met from sources which do not increase emissions.

Recommendations:

11. That the Garnaut Review recognises that projections for oil supply, demand and prices have significant implications for Australia's capacities to respond to climate change, for Australia's future economic growth and therefore also for the appropriate discount rates chosen for economic modelling.

12. That the Garnaut Review takes seriously the evidence presented to the two Australian government inquiries, and further evidence available since then, and comes to a view on this issue.

13. That the Garnaut Review recommends that Australia be placed on a 'war-footing' with regards to energy efficiency, energy R&D, expansion of public transport infrastructure and expansion of renewable fuels.

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[60] Hirsch *et al.* (2005), p. 64.

5. 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.

Recommendation:

14. That the Garnaut Review recommends that the Government seeks to discover and takes seriously into account the perspectives of children and youth on this issue. The Australia 2020 Youth Summit is a good example of the kind of event that could be repeated with a specific focus on climate change.

6. Conclusions and summary of recommendations

This submission has canvassed a number of specific issues. We emphasise again however that this submission does not stand alone, but rather it is complementary to the Make Poverty History (MPH) and Climate Action Network Australia (CANA) submissions, which WVA helped to develop and which we endorse. Most of the issues raised in this submission have been of a fairly technical nature. They are not simply esoteric considerations however. They 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.

Recommendations

1. That the Garnaut Review strongly emphasises 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. That the Garnaut Review avoids making statements that give the misleading impression that Australia's emissions may not have serious climatic repercussions.

3. That the Garnaut Review notes the many problems inherent in computable general equilibrium models that have been identified in the economics literature and suggests options for placing integrated climate policy modelling on a firmer footing.

4. That the Garnaut Review uses low discount rates that do not unfairly place the burdens of adjustment on future generations.

5. That all baseline economic scenarios produced for the Garnaut Review used to estimate the costs of mitigation incorporate the likely economic impacts of unfettered climate change.

6. That the economic models used for the Garnaut Review incorporate financial, credit and insurance markets.

7. That the Garnaut Review does not simplistically equate foregone GDP growth with a loss of wellbeing.

8. That the Garnaut Review emphasises the role that governments can play in reducing the uncertainty that poisons economies and delays much-needed investment decisions.

9. That the Garnaut Review gives due consideration to the likelihood of extremely costly security implications if climate change is allowed to continue unfettered.

10. That the Garnaut Review emphasises that this issue doesn't end in 2100. We have serious ethical obligations to our children and to future generations.

11. That the Garnaut Review recognises that projections for oil supply, demand and prices have significant implications for Australia's capacities to respond to climate change, for Australia's future economic growth and therefore also for the appropriate discount rates chosen for economic modelling.

12. That the Garnaut Review takes seriously the evidence presented to the two Australian government inquiries, and further evidence available since then, and comes to a view on this issue.

13. That the Garnaut Review recommends that Australia be placed on a 'war-footing' with regards to energy efficiency, energy R&D, expansion of public transport infrastructure and expansion of renewable fuels.

14. That the Garnaut Review recommends that the Government seeks to discover and takes seriously into account the perspectives of children and youth on this issue. The Australia 2020 Youth Summit is a good example of the kind of event that could be repeated with a specific focus on climate change.

7. References

Ackerman, F., (2002) "Still Dead after All These Years: Interpreting the Failure of General Equilibrium Theory", *Journal of Economic Methodology*, Vol. 9, No. 2, June, pp. 119-139.

Akerlof, G.A. and Yellen, J., (1985) "Can Small Deviations from Rationality Make Significant Differences to Economic Equilibria?" *American Economic Review,* Vol. 75, No. 4, September, pp. 708-720.

Alley, R.B., (2000) "The Younger Dryas Cold Interval as Viewed from Central Greenland", *Quaternary Science Reviews,* Vol. 19, No. 1-5, January, pp. 213-226.

Alley, R.B., (2004) "Abrupt Climate Change", *Scientific American,* Vol. 291, No. 5, November, pp. 62-69.

Alley, R.B., Clark, P.U., Huybrechts, P. and Joughin, I., (2005) "Ice-Sheet and Sea-Level Changes", *Science,* Vol. 310, No. 5747, 21 October, pp. 456–460.

APPEA, (2008) "Report Holds Key to Tackling Petroleum Deficit", Canberra & Perth, Australian Petroleum Production & Exploration Association, 22 February, 1 pp. [http://www.appea.com.au/content/pdfs_docs_xls/NewsMedia/APPEAMediaReleases/220208_report_holds_key_to_tackling_petroleum_deficit.pdf]

Arrow, K.J., (1987) "Economic Theory and the Hypothesis of Rationality", In *The New Palgrave: A Dictionary of Economics* ed. Eatwell, J., Milgate, M. and Newman, P.; MacMillan Press, London; Stockton Press, New York & Maruzen Company, Tokyo, Vol. 2 pp. 69-75. Reprinted from *Journal of Business*, 1986, Vol. 59, No. 4, Pt. 2.

Bentley, R.W., Mannan, S.A. and Wheeler, S.J., (2007) "Assessing the Date of the Global Oil Peak: The Need to Use 2P Reserves", *Energy Policy,* Vol. 35, No. 12, December, pp. 6364-6382.

Boulanger, P.-M. and Bréchet, T., (2005) "Models for Policy-Making in Sustainable Development: The State of the Art and Perspectives for Research", Ecological Economics, Vol. 55, No. 3, 15 November, pp. 337-350; p. 349.

Buchanan, M., (2007) "Less Reticence on Nonlinear Climate Change", *Nature Physics,* Vol. 3, May, pp. 291.

Campbell, C.J. and Laherrère, J.H., (1998) "The End of Cheap Oil", *Scientific American,* Vol. 278, No. 3, March, pp. 78-83.

Cartier, M., (2004) "An Agent-Based Model of Innovation Emergence in Organizations: Renault and Ford Through the Lens of Evolutionism", *Computational & Mathematical Organization Theory*, Vol. 10, No. 2, pp. 147-153.

Commonwealth of Australia, (2007) "Australia's Future Oil Supply and Alternative Transport Fuels: Final Report", Senate Standing Committee on Rural and Regional Affairs and Transport, Canberra, February, xxii + 196 pp. [http://www.aph.gov.au/senate/committee/rrat_ctte/oil_supply/index.htm]

Council of the European Union, (2008) "Climate Change and International Security: Paper from the High Representative and the European Commission to the European Council", S113/08, Brussels, 14 March, 11 pp. [http://www.consilium.europa.eu/ueDocs/cms_Data/docs/pressdata/en/reports/99387.pdf]

Dasgupta, S., Laplante, B., Meisner, C., Wheeler, D. and Yan, J., (2007) "The Impact of Sea Level Rise on Developing Countries: A Comparative Analysis", Policy Research Working Paper No. 4136, Washington DC, World Bank, February, 51 pp.

Davis, M., (2001) *Late Victorian Holocausts: El Niño Famines and the Making of the Third World,* Verso, London & New York, x + 463 pp.

Dawid, H., (2006) "Agent-Based Models of Innovation and Technological Change", In *Handbook of Computational Economics, Volume 2: Agent-Based Computational Economics* ed. Tesfatsion, L. and Judd, K.L.; North-Holland, Amsterdam, pp. 1235-1272.

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

Demsetz, H., (1997) "The Firm in Economic Theory: A Quiet Revolution", *American Economic Review*, Vol. 87, No. 2, May, pp. 426-429.

Dew, N., Read, S., Sarasvathy, S.D. and Wiltbank, R., (2008) "Outlines of a Behavioral Theory of the Entrepreneurial Firm", *Journal of Economic Behavior & Organization*, Vol. 66, No. 1, April, pp. 37-59.

Dillard, D., (1988) "The Barter Illusion in Classical and Neoclassical Economics", *Eastern Economic Journal,* Vol. 14, No. 4, October-December, pp. 299-318.

Dosi, G., (1988) "Sources, Procedures and Microeconomic Effects of Innovation", *Journal of Economic Literature*, Vol. 36, No. 3, September, pp. 1120-1171.

Dosi, G., (2002) "Review: Technology, Learning, and Innovation: Experiences of Newly Industrializing Economies", *Journal of Economic Literature*, Vol. 40, No. 1, March, pp. 202-203.

DuPont, A. and Pearman, G., (2006) "Heating Up the Planet: Climate Change and Security", Lowy Institute Paper 12, Sydney, Lowy Institute for International Policy, 143 pp. [http://www.lowyinstitute.org/Publication.asp?pid=391]

Easterlin, R.A., (2003) "Explaining Happiness", *Proceedings of the National Academy of Sciences of the United States of America,* Vol. 100, No. 19, 16 September, pp. 11176-11183.

Edenhofer, O., Lessman, K., Kemfert, C., Grubb, M. and Köhler, J., (2006) "Induced Technological Change: Exploring its Implications for the Economics of Atmospheric Stabilization: Synthesis Report from the Innovation Modeling Comparison Project", *The Energy Journal Special Issue, Endogenous Technological Change and the Economics of Atmospheric Stabilization,* pp. 57-108.

Fagiolo, G. and Dosi, G., (2003) "Exploitation, Exploration and Innovation in a Model of Endogenous Growth with Locally Interacting Agents", *Structural Change and Economic Dynamics*, Vol. 14, No. 3, September, pp. 237-273.

Fisher, F.M., (1983) *Disequilibrium Foundations of Equilibrium Economics,* Cambridge University Press, Cambridge & New York, xi + 236 pp.

Fisher, F.M., (1987) "Adjustment Processes and Stability", In *The New Palgrave: A Dictionary of Economics* ed. Eatwell, J., Milgate, M. and Newman, P.; MacMillan Press, London; Stockton Press, New York & Maruzen Company, Tokyo, Vol. 1, pp. 26-29.

Fisher, F.M., (1989) "Stability Analysis in Micro and Macro Theory: An Interview", In *Joan Robinson and Modern Economic Theory* ed. Feiwel, G.R.; New York University Press, New York, pp. 311-322; p. 320.

Fisher, F.M., (2003) "Disequilibrium and Stability", In *General Equilibrium: Problems and Prospects* ed. Petri, F. and Hahn, F.; Routledge, London & New York, pp. 74-94;

Fletcher, S., (2008) "CERA: Action Needed Now on Demand, Supply Fronts to Avoid Crisis, Hess Says", *Oil & Gas Journal,* Vol. 106, No. 8, 25 February, pp. 27-29.

Fournier, D.F. and Westervelt, E.T., (2005) "Energy Trends and Their Implications for U.S. Army Installations", ERDC/CERL TR-05-21, U.S. Army Corps of Engineers, Engineer Research and Development Center, September, xix + 65 pp.
[http://www.cecer.army.mil/techreports/Westervelt_EnergyTrends/Westervelt_EnergyTrendsTR.pdf]

Frey, B.S. and Stutzer, A., (2002) "What Can Economists Learn from Happiness Research?" *Journal of Economic Literature,* Vol. 40, No. 2, June, pp. 402-435.

Garnaut Climate Change Review, (2008a) "Interim Report to the Commonwealth, State and Territory Governments of Australia", February, 63 pp.
[http://www.garnautreview.org.au/CA25734E0016A131/pages/reports-and-papers]

Garnaut Climate Change Review, (2008b) "Emissions Trading Scheme Discussion Paper", March, 89 pp.
[http://www.garnautreview.org.au/CA25734E0016A131/pages/reports-and-papers]

Gilbert, N., Ahrweiler, P. and Pyka, A., (2007) "Learning in Innovation Networks: Some Simulation Experiments", *Physica A*, Vol. 378, No. 1, 1 May, pp. 100-109.

Glickson, A.Y., (2008) "Milestones in the Evolution of the Atmosphere with Reference to Climate Change", *Australian Journal of Earth Sciences,* Vol. 55, No. 2, pp. 125-139.

Greenwald, B.C. and Stiglitz, J.E., (1986) "Externalities in Economies with Imperfect Information and Incomplete Markets", *Quarterly Journal of Economics,* Vol. 101, No. 2, May, pp. 229-264.

Gupta, S., Tirpak, D.A., Burger, N., Gupta, J., Höhne, N., Boncheva, A.I., Kanoan, G.M., Kolstad, C., Kruger, J.A., Michaelowa, A., Murase, S., Pershing, J., Saijo, T. and Sari, A., (2007) "Policies, Instruments and Co-operative Arrangements", In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. and Meyer, L.A.; Cambridge University Press, Cambridge & New York, pp. 745-807.
[http://www.ipcc.ch/ipccreports/ar4-wg3.htm]

Hahn, F.H., (1982) "Reflections on the Invisible Hand", *Lloyds Bank Review,* No. 144, April, pp. 1-21.

Hall, D.C. and Behl, R.J., (2006) "Integrating Economic Analysis and the Science of Climate Instability", *Ecological Economics,* Vol. 57, No. 3, 25 May, pp. 442-465.

Hallegatte, S., Hourcade, J.-C. and Dumas, P., (2007) "Why Economic Dynamics Matter in Assessing Climate Change Damages: Illustration on Extreme Events", *Ecological Economics,* Vol. 62, No. 2, April, pp. 330-340.

Hamilton, C. and Denniss, R., (2005) *Affluenza: When Too Much is Never Enough,* Allen & Unwin, Crows Nest, NSW, ix + 224 pp.

Hansen, J.E., (2004) "Defusing the Global Warming Time Bomb", *Scientific American,* Vol. 290, No. 3, March, pp. 68-79.

Hansen, J.E., Sato, M., Kharecha, P., Russell, G., Lea, D.W. and Siddall, M., (2007) "Climate Change and Trace Gases", *Philosophical Transactions of the Royal Society A,* Vol. 365, No. 1865, 15 July, pp. 1925-1954.

Hart, O., (1975) "On the Optimality of Equilibrium then the Market Structure is Incomplete", *Journal of Economic Theory,* Vol. 11, No. 3, December, pp. 418-443.

Hirsch, R.L., Bezdek, R. and Wendling, R., (2005) "Peaking of World Oil Production: Impacts, Mitigation & Risk Management", Office of Systems, Analyses and Planning at the National Energy Technology Laboratory of the U.S. Department of Energy, February, 91 pp.
[http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf]

IEA, (2007) *World Energy Outlook 2007: China and India Insights,* International Energy Agency, Paris, 663 pp.

IPCC, (2007) "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. [http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_SPM.pdf]

Kehoe, T.J., (1985) "Multiplicity of Equilibria and Comparative Statics", *Quarterly Journal of Economics,* Vol. 100, No. 1, February, pp. 119-147.

Kehoe, T.J., (1987) "Comparative Statics", In *The New Palgrave: A Dictionary of Economics* ed. Eatwell, J., Milgate, M. and Newman, P.; MacMillan Press, London; Stockton Press, New York & Maruzen Company, Tokyo, Vol. 1 pp. 517-521.

Kehoe, T.J., (1998) "Uniqueness and Stability", In *Elements of General Equilibrium Analysis* ed. Kirman, A.P.; Blackwell Publishers, Oxford, pp. 38-87.

Kerr, R.A., (2007) "Even Oil Optimists Expect Energy Demand to Outstrip Supply", *Science,* Vol. 317, No. 5837, 27 July, pp. 437.

Kirman, A.P., (1992) "Whom or What Does the Representative Individual Represent?" *Journal of Economic Perspectives,* Vol. 6, No. 2, Spring, pp. 117-136.

Klett, T.R., Gautier, D.L. and Ahlbrandt, T.S., (2005) "An Evaluation of the U.S. Geological Survey World Petroleum Assessment 2000", *AAPG Bulletin*, Vol. 89, No. 8, 1 August, pp. 1033-1042.

Layard, R., (2005) *Happiness: Lessons from a New Science,* Penguin Press, New York & London, ix + 310 pp.

Layard, R., (2006) "Happiness and Public Policy: A Challenge to the Profession", *Economic Journal,* Vol. 116, No. 510, March, pp. C24-C33.

Lenton, T.M., Held, H., Kriegler, E., Hall, J.W., Lucht, W., Rahmstorf, S. and Schellnhuber, H.J., (2008) "Tipping Elements in the Earth's Climate System", *Proceedings of the National Academy of Science of the United States of Amercia,* Vol. 105, No. 6, 12 February, pp. 1786-1793.

Lewis, A.A., (1985) "On Effectively Computable Realizations of Choice Functions", *Mathematical Social Science,* Vol. 10, No. 1, August, pp. 43-80.

Lundvall, B.-A., Johnson, B., Andersen, E.S. and Dalum, B., (2002) "National Systems of Production, Innovation and Competence Building", *Research Policy*, Vol. 31, No. 2, February, pp. 213-231.

McNamara, A., (2007) "Queensland's Vulnerability to Rising Oil Prices: Taskforce Report", Brisbane, Queensland Oil Vulnerability Taskforce, Queensland Government, April, 158 pp. [http://www.epa.qld.gov.au/publications/?id=2190]

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

Minsky, H.P., (1982) *Can "It" Happen Again? Essays on Instability and Finance,* ME Sharpe, New York, xxiv + 301 pp.

Mortished, C., (2006) "World 'Cannot Meet Oil Demand'", *The Times,* London, 8 April, [http://business.timesonline.co.uk/tol/business/industry_sectors/natural_resources/article703204.ece].

Mortished, C., (2008) "Shell Chief Fears Oil Shortage in Seven Years", *The Times,* London, 25 January, [http://business.timesonline.co.uk/tol/business/economics/wef/article3248484.ece].

National Research Council, (2002) *Abrupt Climate Change: Inevitable Surprises,* by the Committee on Abrupt Climate Change, Ocean Studies Board, Polar Research Board, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, National Research Council, Chaired by Richard B. Alley; National Academy Press, Washington DC, xii + 230 pp.

Nel, W.P. and Cooper, C.J., (2008) "A Critical Review of IEA's Oil Demand Forecast for China", *Energy Policy,* Vol. 36, No. 3, March, pp. 1096-1106.

Nelson, R.R., (1994a) "The Role of Firm Differences in an Evolutionary Theory of Technical Advance", In *Evolutionary and Neo-Schumpeterian Approaches to Economics* ed. Magnusson, L.; Kluwer Academic Publishers, Boston, Dordrecht & London, pp. 231-242.

Nelson, R.R., (1994b) "What has been the Matter with Neoclassical Growth Theory?" In *The Economics of Growth and Technical Change: Technologies, Nations, Agents* ed. Silverberg, G. and Soete, L.; Edward Elgar, Cheltenham, UK & Northampton, MA, pp. 290-324.

Nelson, R.R. and Nelson, K., (2002) "Technology, Institutions, and Innovation Systems", *Research Policy*, Vol. 31, No. 2, February, pp. 265-272.

Neumayer, E., (1999) "Global Warming: Discounting is not the Issue, but Substitutability is", *Energy Policy,* Vol. 27, No. 1, January, pp. 33-43.

Neumayer, E., (2007) "A Missed Opportunity: The Stern Review on Climate Change Fails to Tackle the Issue of Non-Substitutable Loss of Natural Capital", *Global Environmental Change,* Vol. 17, No. 3-4, August - October, pp. 297-301.

Nield, R., (2008) "Rig Prices Soar as Oil Hits New Highs", *Middle East Business Intelligence,* 1 February, 3 pp. [http://www.meed.com/algeria/features/2008/02/rig_prices_soar_as_oil_hits_new_highs.html].

Nordhaus, W., (2007) "Critical Assumptions in the Stern Review on Climate Change", *Science,* Vol. 317, No. 5835, 13 July, pp. 201-202.

Overpeck, J.T., Otto-Bliesner, B.L., Miller, G.H., Muhs, D.R., Alley, R.B. and Kiehl, J.T., (2006) "Paleoclimatic Evidence for Future Ice-Sheet Instability and Rapid Sea-Level Rise", *Science,* Vol. 311, No. 5768, 24 March, pp. 1747-1750.

Pearce, F., (2007) *With Speed and Violence: Why Scientists Fear Tipping Points in Climate Change,* Beacon Press, Boston, xxvi + 278 pp.

Radner, R., (1968) "Competitive Equilibrium Under Uncertainty", *Econometrica,* Vol. 36, No. 1, January, pp. 31-58.

Radner, R., (1996) "Bounded Rationality, Indeterminacy, and the Theory of the Firm", *Economic Journal*, Vol. 106, No. 438, September, pp. 1360-1373.

Roundtable, (2006) "The Business Case for Early Action", Australian Business Roundtable on Climate Change, April, 25 pp. [www.businessroundtable.com.au]

Saari, D.G., (1995) "Mathematical Complexity of Simple Economics", *Notices of the American Mathematical Society,* Vol. 42, No. 2, February, pp. 222-230. [http://www.ams.org/notices/199502/saari.pdf].

Saari, D.G., (1996) "The Ease of Generating Chaotic Behavior in Economics", *Chaos, Solitons & Fractals,* Vol. 7, No. 12, December, pp. 2267-2278.

Schumpeter, J.A., (1934) *The Theory of Economic Development: An Enquiry into Profits, Capital, Credit, Interest and the Business Cycle,* Transaction Publishers reprint, 1983, New Brunswick NJ & London; originally published by Harvard University Press, trans. from the 2nd German edition of 1926 by Redvers Opie, lxiv + 255 pp.

Simmons, M.R., (2007) "For Lack of a Nail, the War was Lost: Overview of Global Oil Service and Contract Drilling Industry", Presentation to the 2007 Oil & Money Conference, London, Simmons & Co. International, 31 October, 23 pp. [http://www.simmonsco-intl.com/files/Oil%20&%20Money2007.pdf]

Stern, N.H., (2006) *The Economics of Climate Change: The Stern Review,* Cambridge University Press, Cambridge, xix + 692 pp.

Stern, N.H. and Taylor, C., (2007) "Climate Change: Risk, Ethics, and the Stern Review", *Science,* Vol. 317, No. 5835, 13 July, pp. 203-204.

Stiglitz, J.E., (2002) "Information and the Change in the Paradigm in Economics", *American Economic Review,* Vol. 92, No. 3, June, pp. 460-501.

Strahan, D. and Al-Huseini, S., (2007) "Interview with Sadad Al-Huseini, former Head of Exploration & Production for Saudi Aramco", 29 October, pp. [Interview: http://www.davidstrahan.com/blog/?p=67 Transcript: http://globalpublicmedia.com/transcripts/2851]

Taylor, K.C., Lamorey, G.W., Doyle, G.A., Alley, R.B., Grootes, P.M., Mayewski, P.A., White, J.W.C. and Barlow, L.K., (1993) "The 'Flickering Switch' of Late Pleistocene Climate Change", *Nature,* Vol. 361, No. 6411, 4 February, pp. 432-436.

Teitelbaum, D. and Dowlatabadi, H., (2000) "A Computational Model of Technological Innovation at the Firm Level", *Computational & Mathematical Organization Theory*, Vol. 6, No. 3, pp. 227-247.

Tesfatsion, L., (2002) "Agent-Based Computational Economics: Growing Economies From the Bottom Up", *Artificial Life*, Vol. 8, No. 1, Winter, pp. 55-82.

Tesfatsion, L., (2003) "Agent-Based Computational Economics: Modeling Economies as Complex Adaptive Systems", *Information Sciences*, February, Vol. 149 263-269 pp.

Tesfatsion, L., (2007) "Agents Come to Bits: Towards a Constructive Comprehensive Taxonomy of Economic Entities", *Journal of Economic Behavior and Organization*, Vol. 63, No. 2, June, pp. 333-346.

Tesfatsion, L. and Judd, K.L. (Eds.), (2006) *Handbook of Computational Economics, Vol. 2: Agent-Based Computational Economics*, North-Holland, Amsterdam, Boston & London, xxx + pp. 829-1660 pp.

Voinov, A. and Farley, J., (2007) "Reconciling Sustainability, Systems Theory and Discounting", *Ecological Economics,* Vol. 63, No. 1, June, pp. 104-113.

Walt, V., (2007) "Oil Prices: It Gets Worse", *Time,* 7 November, [http://www.time.com/time/business/article/0,8599,1681362,00.html].

WBGU, (2007) "World in Transition – Climate Change as a Security Risk: Summary for Policy Makers", Berlin, German Advisory Council on Global Change, 13 pp. [http://www.wbgu.de/wbgu_jg2007_kurz_engl.pdf]