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1 December 2007

Professor Ross Garnaut
Garnaut Climate Change Review
Level 2, 1 Treasury Place
Melbourne 3002 VIC

By email only to: contactus@garnautreview.org.au

Dear Professor Garnaut,

Re: Stabilisation targets for the Garnaut Climate Change Review

I believe that your current review of the impacts of climate change on the Australian economy for the purpose of recommending medium to long-term policies and policy frameworks to improve the prospects for sustainable prosperity is an immensely important opportunity to re-set the compass on Australia's climate change policy.

I note that the website for the review states that you will, from time to time, request submissions from relevant stakeholders and the public on particular topics of interest but that a member of the public can lodge a submission at any time on a topic relevant to the scope of the review and all submissions will be considered.[1]

I have read the terms of reference of the review and wish to make a general submission on the stabilisation targets that should be considered for climate policy. I note that the terms of reference have not identified a stabilisation target for global temperature rises that Australia should base its policy response upon. However, consistent with the *Stern Review*,[2] I understand that the stabilisation target broadly envisaged is to allow a rise in mean global temperatures of 2-3°C above pre-industrial temperatures. I understand this is the case from the fourth "core factor" identified in the terms of reference, namely that:[3]

> The weight of scientific opinion that developed countries need to reduce their greenhouse gas emissions by 60 percent by 2050 against 2000 emission levels, if global greenhouse gas concentrations in the atmosphere are to be stabilised to between 450 and 550ppm by mid century.

The major point I wish to raise for your consideration is that your review, and Australian climate policy generally, should use protection of the Great Barrier Reef (GBR) as the yardstick to measure "dangerous climate change" and, conversely, acceptable climate change. This has significant implications for the stabilisation targets we should set based on the currently available science. Based on the "best guess" of the Intergovernmental Panel on Climate Change (IPCC), stabilising atmospheric greenhouse gases and aerosols at 450-550 parts per million (ppm) carbon dioxide equivalents (CO_2-eq) will lead to a rise in mean global temperature of 2-3°C. Stabilisation at these levels appears to be far too

[1] http://www.garnautreview.org.au/CA25734E0016A131/pages/submissions (viewed 1 December 2007).
[2] Stern N, *The Stern Review on the Economics of Climate Change* (Cambridge University Press, Cambridge, 2007).
[3] Available at http://www.garnautreview.org.au/ (viewed 1 December 2007).

high to protect the GBR from severe damage and, hence, constitutes "dangerous climate change".

If we wish to protect the GBR, we should aim to stabilise mean global temperature rises no higher than 1°C by stabilising atmospheric greenhouse gases and aerosols at 350 ppm CO_2-eq. Any stabilisation and emission reductions targets above a mean global temperature rise of 1°C, such as a target of a 60% reduction in Australia's emissions by 2050 and stabilisation at 3°C, whether based on pragmatism or otherwise, should come with a frank admission that they are unlikely to protect the GBR from severe damage.

I will explain the background and basis to my submission before concluding with my recommendations for designing effective climate change policies in your review.

Effective policy

Given the scale and complexity of climate change, responding to it effectively presents an enormous challenge for government and society. I recognise that the Australian and State governments' policies cannot afford to move too far in front of public opinion or public acceptance. Policies are unlikely to be effective in the long-term unless they are generally efficient, cost-effective, equitable, politically acceptable, and "optimal".[4] Short term success at a cost that leads to long-term failure (perhaps by leading to a change of government and reversal of unacceptable policies) is not truly *effective*.

While the Australian and State governments are constrained in responding to climate change by what is politically acceptable, I believe it is important to recognise that a 60% reduction in greenhouse gas emissions by 2050, even if achieved globally, will not be effective in protecting the GBR from severe degradation. There is obviously no question that protecting the GBR is a major policy objective of the Australian and State governments or that the GBR has immense social, economic and environmental value to Australia. The GBR can also be used as a "flagship ecosystem" to garner public support for very strong action that will, thereby, protect other ecosystems, the economy, and society from climate change.

Economic impacts of climate change severely degrading the GBR

It is inherently difficult to place an economic value on natural assets such as the GBR, particularly when loss of natural assets is non-substitutable. The importance of this issue was highlighted in a recent report prepared for the Great Barrier Reef Marine Park Authority (GBRMPA) by Access Economics which calculated that the GBR contributes $6.9 billion annually to the Australian economy or gross domestic profit (based on 2005-2006 figures).[5] This comprises $6 billion from the tourism industry, $544 million from recreational activity and $251 million from commercial fishing. It generates about 66,000 jobs, mostly in the tourism industry, and brings over 1.8 million visitors to the reef each year. Access Economics found it was unable to calculate the likely economic cost of climate change due to impacts on the GBR. A major difficulty for calculating this cost was stated to be the potential for substitution if less well managed reefs around the world are damaged more quickly by climate change than the GBR thereby leading to increasing

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[4] See generally, Gunningham N and Grabosky P, *Smart Regulation: Designing Environmental Policy* (Oxford University Press, Melbourne, 1998), pp 26-27.

[5] Access Economics Pty Ltd, *Measuring the Economic & Financial Value of the Great Barrier Reef Marine Park 2005-06* (GBRMPA, Townsville, February 2007), available at http://www.gbrmpa.gov.au/corp_site/info_services/publications/research_publications/rp087/access_economics_report_0607 (viewed 7 October 2007).

tourism to the GBR and for tourist operators in the GBR to substitute other activities as corals become damaged.

Eric Neumayer argues that many impacts of climate change involve non-substitutable loss of natural capital.[6] This argument appears a cogent one when considering the impacts of climate change to the GBR and I support this view over the one expressed by Access Economics. In my view the GBR should be viewed as a non-substitutable natural asset, loss of which cannot be replaced by, effectively, people putting their money into the Australian economy by doing other things as corals around the globe and in the GBR become increasingly degraded due to climate change.

I note, in passing, that my principal criticism of the *Stern Review* is it appears to "write-off" coral reefs by recommending stabilisation targets that the authors believe will lead to loss of coral reefs. Page 94 of the *Stern Review* notes the impacts on coral reefs of different rises in global temperatures as follows:

- **1°C warming.** … Coral reef bleaching will become much more frequent, with slow recovery, particularly in the southern Indian Ocean, Great Barrier Reef and the Caribbean. …
- **2°C warming.** … Coral reefs are expected to bleach annually in many areas, with most never recovering, affecting tens of millions of people that rely on coral reefs for their livelihood or food supply.
- **3°C warming.** …[No specific comment on coral bleaching].

While the *Stern Review* indicates "coral reef ecosystems [will be] extensively and eventually irreversibly damaged" by temperature change relative to pre-industrial levels of 0.5-2°C,[7] for what is clearly reasons of pragmatism and feasibility, the review recommends the stabilisation goal should lie within the range of 450-550 ppm CO_2-eq,[8] thereby accepting a likely warming of 2-3°C and loss of coral reefs, including the GBR.

In my view, policy objectives that write-off the GBR are not an acceptable for Australia. At a minimum, if we choose to set policy objectives that the science is saying will destroy the GBR because of pragmatism and feasibility we should be perfectly frank about publicly acknowledging this point.

Setting climate change targets to protect the GBR

I noted in an article published in the *Environmental and Planning and Law Journal*, a copy of which I have attached to this submission,[9] that policy targets of stabilising atmospheric greenhouse gases and aerosols at 450–550 ppm CO_2-eq to limit increases in mean global temperatures to 2–3°C over pre-industrial levels are likely to be too high to avoid severe impacts of coral bleaching to the GBR. I noted in that article that stabilising greenhouse gases and aerosols around year 2000 levels, giving a net effect of around 370 ppm CO_2-eq, and allowing a rise in mean global temperature of 1°C, appear to be the highest targets that should be set if the GBR is to be protected from serious degradation. However, that article was written prior to the full texts of the IPCC Fourth Assessment Report (AR4) being released, which indicate that based on the IPCC's best guess of climate sensitivity, stabilisation at 350 ppm CO_2-eq is likely to lead to an equilibrium

[6] Neumayer E, "A missed opportunity: The Stern Review on Climate Change fails to tackle the issue of non-substitutable loss of natural capital" (2007) 17 (Nos 3-4) *Global Environmental Change* 297.
[7] Stern, n 2, Figure 13.4, p 330.
[8] Stern, n 2, p 338.
[9] McGrath C, "Setting climate change targets to protect the Great Barrier Reef" (2007) 24 EPLJ 182.

temperature rise of 1°C, therefore the target I specified in my article should be updated with the later IPCC views.

In support of these points I note the scientific evidence of the likely impacts of climate change on coral reefs globally. There is now compelling evidence and strong consensus of scientific opinion that coral reefs globally, including the GBR, are one of the most vulnerable ecosystems[10] to climate change and are endangered by the expected climate change in coming decades.[11] The IPCC AR4 stated there is a very high confidence that, "significant loss of biodiversity is projected to occur by 2020 in some ecologically-rich sites including the Great Barrier Reef and Queensland Wet Tropics."[12] It found, when considering the impacts of climate change on coastal systems, there is very high confidence that:[13]

> Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1 to 3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals.

Ove Hoegh-Guldberg and his colleagues recently concluded:[14]

> The vulnerability of coral and the reefs they build to climate change was bought into sharp focus after 1998, when an estimated 16 percent of the world's coral communities died. Analysing the literature since that time reveals that rapidly rising sea temperatures and increasing levels of acidity in the ocean remain the major threat to coral reefs. Successive studies of the potential impacts of thermal stress on coral reefs have supported the notion that coral dominated reefs are likely to largely disappear with a 2°C rise in sea temperature over the next 100 years. This, coupled with the additional vulnerability of coral reefs to high levels of acidification once the atmosphere reaches 500 parts per million [CO_2-only], suggests that coral dominated reefs will be rare or non-existent in the near future.

The IPCC's best estimates of the stabilisation levels for greenhouse gases believed to be required to avoid temperature rises into the range of 1 to 3°C are shown in Table 1.

Table 1: IPCC estimates of mean global temperature rises for different concentrations of atmospheric greenhouse gases in carbon dioxide equivalents[15]

Equivalent CO_2	Best guess
350	1.0
450	2.1
550	2.9
650	3.6
750	4.3
1,000	5.5
1,200	6.3

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[10] Noting the first criterion of Art 2 of the UNFCCC states that avoiding dangerous climate change requires allowing "ecosystems to adapt naturally to climate change".
[11] See IPCC, *Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. Working Group II Contribution to the IPCC Fourth Assessment Report* (Cambridge University Press, UK, 2007), pp 320-321, 330, 509, 527, and 850-855, and the references cited therein.
[12] IPCC, n 11, p 509. "Very high confidence" was defined as at least a 9 out of 10 chance of being correct.
[13] IPCC, "Summary for policy-makers", in IPCC, n 11, p 12. See also IPCC, n 11, p 330.
[14] Hoegh-Guldberg O, Anthony K, Berkelmans R, Dove S, Fabricus K, Lough J, Marshall P, van Oppen MJH, Negri A and Willis B, "Vulnerability of reef-building corals on the Great Barrier Reef to climate change", Ch 10 in Johnson JE and Marshall PA (eds), *Climate Change and the Great Barrier Reef: A Vulnerability Assessment* (GBRMPA, Townsville, 2007), p 295 (citations omitted), available at http://www.gbrmpa.gov.au/corp_site/info_services/publications/misc_pub/climate_change_vulnerability_assessment/climate_change_vulnerability_assessment (viewed 7 October 2007).
[15] IPCC, *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC* (Cambridge University Press, Cambridge, 2007), Table 10.8, p 826.

Atmospheric concentrations of greenhouse gases and aerosols have already passed 350 ppm CO_2-eq making stabilisation at that level extremely difficult if not impossible in practice particularly in the context of current global growth and energy use patterns. Atmospheric carbon dioxide reached 379 ppm in 2005 and was increasing by around 2 ppm per year.[16] Including the effect of other greenhouse gases such as methane, the total concentration of atmospheric greenhouse gases was around 455 ppm CO_2-eq (range: 433–477 ppm CO_2-eq) in 2005.[17] However, the cooling effects of aerosols and landuse changes reduce radiative forcing so that the net forcing of human activities was in the range of 311 to 435 ppm CO_2-eq, with a central estimate of about 375 ppm CO_2-eq for 2005.[18]

Compounding the difficulty of stabilising greenhouse gases and aerosols around 350 ppm CO_2-eq to attempt to keep global temperature rises beneath 1°C are the facts that even if emissions are dramatically reduced natural processes in the Carbon Cycle will be slow to remove the current levels of the major anthropogenic greenhouse gas, carbon dioxide (CO_2), from the atmosphere. Following perturbation of the natural Carbon Cycle about 50% of an increase in atmospheric CO_2 will be removed within 30 years, a further 30% will be removed within a few centuries and the remaining 20% may remain in the atmosphere for many thousands of years.[19]

While difficult or impossible to achieve in practice, stabilising greenhouse gases and aerosols around 350 ppm CO_2-eq, and allowing a rise in mean global temperature of 1°C, appear to be the highest targets that should be set if the GBR is to be protected from serious degradation. Stabilising greenhouse gases and aerosols at 450–550 ppm CO_2-eq, to limit increases in mean global temperatures to 2–3°C over pre-industrial levels, are likely to be too high to avoid severe impacts of coral bleaching to the GBR.

The IPCC AR4 did not model emission reduction regimes to stabilise global mean temperature rises beneath 2°C. The six stabilisation regimes presented by the IPCC AR4 are shown in Table 2.

Table 2: Extract of stabilisation scenarios from IPCC WGIII report[20]

	Concentration of greenhouse gases (ppm CO_2-eq)	Global mean temperature increase (°C)	Percentage change in global CO_2 emissions 2000-2050
I	445 – 490	2.0 – 2.4	-85 to -50
II	490 – 535	2.4 – 2.8	-60 to -30
III	535 – 590	2.8 – 3.2	-30 to +5
IV	590 – 710	3.2 – 4.0	+10 to +60
V	710 – 855	4.0 – 4.9	+25 to +85
VI	855 – 1130	4.9 – 6.1	+90 to +140

When the conclusions of the IPCC are synthesised, it becomes clear that reductions of greenhouse emissions of 60% by 2050, such as proposed by the new Australian Government[21] and State governments,[22] are not likely to prevent serious damage to the

[16] IPCC, n 15, p 137.
[17] IPCC, *Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the IPCC* (Cambridge University Press, UK, 2007), p 102.
[18] IPCC, n 17, p 102.
[19] IPCC, n 15, Ch 7, p 514.
[20] IPCC, n 17, Table 3.5, p 198.
[21] Based on the climate change policy stated by the new Australian Prime Minister, Kevin Rudd, in May 2007, available at http://www.alp.org.au/media/0507/speloo300.php (viewed 25 November 2007).

GBR. A 60% reduction in global emissions by 2050 is likely to lead to a mean global temperature rise around 2.4°C, which is likely to severely degrade the GBR. If a developed country such as Australia achieves a reduction in emissions of 60% by 2050 it is unlikely that global emissions will meet this target. The new Australian Government does not have an express stabilisation target for global temperature rises but the emissions reductions target of 60% by 2050 appears to be based on stabilising global temperature rises at 3°C.[23]

I am not able to say what emission reductions are required to protect the GBR but extrapolating from the IPCC figures in Table 2 it appears reductions in emissions alone will be insufficient and we need to become a net sink to reduce even the existing levels of greenhouse gases in the atmosphere. I do not know whether this is technically possible[24] but, as a policy analyst, I believe policy-makers should set targets primarily based on what we want to achieve and shape policies consistently with those objectives so that governments, industry and technical experts are at least aiming in the right direction. To give a more tangible example of this: if we need to cross a river that is 1km wide it would be foolish to ask our engineers to build a bridge that is only 500m long. Setting policy targets that we believe will not protect the GBR will virtually ensure that the GBR is not protected. We need to do better.

Conclusion

I recognise that the Australian and State governments cannot move too far ahead of public opinion in setting climate change policy. I also recognise that Australia cannot solve the problem of climate change alone but must be part of an international solution. However, I suggest that a frank admission that the policies we are setting are not likely to protect the GBR from severe degradation is likely to encourage greater public support for stronger action. The GBR can be used as a "flagship ecosystem" to garner public support for very strong early action.

I, therefore, recommend that your review should explicitly recognise that a 60% reduction in greenhouse emissions by 2050 is not likely to protect the GBR from severe impacts and call for public submissions on what policies that are more likely to be effective are acceptable to protect the GBR. Australians have a huge stake in implementing policies that are likely to be effective in protecting the GBR from severe degradation from climate change. I believe that many Australians will support the Australian and State governments taking a leading role in promoting an effective national and international response to climate change.

I suggest that this course is preferable to quietly ignoring the scientific evidence that policies aiming for a 60% reduction in greenhouse emissions by 2050 are not likely to be effective in protecting the GBR. Simply ignoring the impacts scientists believe will occur to the GBR is not a satisfactory or even tenable policy option. Choosing not to listen to weather forecasts does not stop it raining.

[22] E.g., Queensland Government, *ClimateSmart 2050: Queensland's Climate Change Strategy* (Queensland Government Department of Premier and Cabinet, Brisbane, 2007), p 1. Available at http://www.thepremier.qld.gov.au/news/initiatives/climate/index.shtm (viewed 25 June 2007).

[23] See Spratt D, "Is Labor's climate policy 'backed by the science'?" (Carbon Equity, Melbourne, 2007), available at http://www.carbonequity.info/docs/alppolicy.html (viewed 14 November 2007).

[24] For example, by widespread use of geosequestration of CO_2 emissions from biofuels acting as a "pump" to draw in atmospheric CO_2 and remove it from the atmosphere faster than natural processes will achieve.

Recommendations

Based on the matters set out above, to balance the reality of climate change with what is perceived to be "political acceptable" in deciding climate change policies, I recommend that that the policy objectives and context for your review should:

1. Use protection of the Great Barrier Reef as the yardstick to measure "dangerous climate change" and, conversely, acceptable climate change.

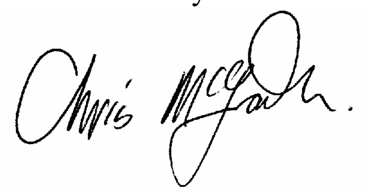
2. Aim to stabilise mean global temperature rises no higher than 1°C by stabilising atmospheric greenhouse gases and aerosols at 350 ppm CO_2-eq. Stabilising at 450-550 ppm CO_2-eq and allowing a rise in mean global temperature of 2-3°C appears to be far too high to protect the GBR from severe damage and, hence, constitutes "dangerous climate change".

3. Any stabilisation and emission reductions targets above a mean global temperature rise of 1°C, such as a target of a 60% reduction in Australia's emissions by 2050 and stabilisation at 3°C, whether based on pragmatism or otherwise, should come with a frank admission that they are unlikely to protect the GBR from severe damage.

Finally, I note that over the past six months I have presented a series of hour long seminars on "setting climate change targets to protect the GBR" to a variety of groups around Queensland as part of The Climate Project initiated by Al Gore.[25] I would be very happy to present this seminar for you or any members of your review should I be requested to.

Please contact me if you have any questions about these matters.

Yours faithfully



Chris McGrath

[25] See http://www.acfonline.org.au/default.asp?section_id=193 (viewed 1 December 2007).

Setting climate change targets to protect the Great Barrier Reef

Chris McGrath*

This article examines what targets should be set to avoid severe impacts to the Great Barrier Reef from climate change. Policy targets of stabilising atmospheric greenhouse gases and aerosols at 450-550 parts per million carbon dioxide equivalents, to limit increases in mean global temperatures to 2-3°C over pre-industrial levels, are likely to be too high to avoid severe impacts of coral bleaching on the Great Barrier Reef. Stabilising greenhouse gases and aerosols around year 2000 levels, giving a net effect of around 370 parts per million carbon dioxide equivalents, and allowing a rise in mean global temperatures of 1°C, appear to be the highest targets that should be set if the Great Barrier Reef is to be protected from serious degradation. Current policies are far from achieving or even setting these objectives and, consequently, severe impacts to the Great Barrier Reef are likely in coming decades.

INTRODUCTION

Climate change is expected to have severe impacts on many parts of the ecosystem in coming decades, but few parts of the ecosystem appear as vulnerable to these impacts as coral reefs. This article summarises: key parts of the current state of knowledge of climate change; how climate change is a major threat to Australia's Great Barrier Reef (GBR); the current policies of the Australian government in relation to climate change; and what targets should be set if the policy objective is to avoid severe impacts on the GBR.

GREENHOUSE GAS CONCENTRATIONS AND CLIMATE CHANGE

Global temperatures, and hence the Earth's climate, are closely linked with the concentration of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere.[1] Increasing concentrations of greenhouse gases trap greater heat in the atmosphere, causing a warming effect. For at least 650,000 years prior to the Industrial Revolution, the concentration of carbon dioxide in the atmosphere varied between 180 and 300 parts per million (ppm).[2] Since the Industrial Revolution, globally averaged concentrations of carbon dioxide, the major greenhouse gas after water vapour, have increased dramatically beyond the upper threshold of natural fluctuation for the past 650,000 years. The increase is primarily due to anthropogenic emissions of greenhouse gases from the combustion of fossil fuels, agriculture and land-use changes.

The Intergovernmental Panel on Climate Change (IPCC), the world's leading scientific body on climate change, is due to present its Fourth Assessment Report in late 2007. At the time of writing it had released two summaries for policymakers of parts of the coming report. These summaries precede release of the detailed report in late 2007 and are from two of the three IPCC working groups.

* BSc, LLB (Hons), LLM (Environmental Law), Barrister. The law and facts are stated at 27 April 2007. Thanks to Niki Durrant, Marita Muller, Fred Cheever, Andrew Macintosh, and Charlotte Gill for their comments on drafts of this article. This article is based upon research undertaken with the assistance of an APA Scholarship for a PhD thesis at the Queensland University of Technology, available at http://www.envlaw.com.au/phd.pdf (viewed 21 April 2007).

[1] See generally, Pittock AB, *Climate Change: Turning Up the Heat* (CSIRO Publishing, 2005) and Houghton J, *Global Warming: The Complete Briefing* (3rd ed, Cambridge University Press, 2004).

[2] Petit JR, Jouzel J, Raynaud D, Barkov NI, Barnola JM, Basile I, Bender M, Chappellaz J, Davis M, Dalaygue G, Delmotte M, Kotlyakov VM, Legrand M, Lipenkov VY, Lorius C, Peplin L, Ritz C, Saltzman E, and Stievenard M, "Climate and Atmosphere History of the Past 420,000 Years From the Vostok Ice Core, Antarctica" (1999) 399 *Nature* 429; and Siegenthaler U, Stocker TF, Monnin E, Luthi D, Schwander J, Stauffer DR, Barnola JM, Fisher H\, Masson-Delmotte V and Jouzel J, "Stable Carbon Cycle – Climate Relationship During the Late Pleistocene" (2005) 310 *Science* 1313.

Working Group I addresses the physical science basis for climate change. Working Group II addresses climate change impacts, adaptation and vulnerability. Working Group III addresses mitigation of climate change. Only Working Groups I and II had released summary reports at the time of writing.

The IPCC released a summary of the report from Working Group I dealing with the physical science basis of climate change on 2 February 2007.[3] It concluded that mean global surface temperatures have increased by 0.74 ± 0.18 degrees Celsius (°C) in the past 100 years. Globally averaged carbon dioxide concentrations in the atmosphere reached 379 ppm in 2005 and are increasing by 2 ppm per year. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected leading to a total increase of approximately 1°C by 2100 over pre-industrial temperatures.[4] It also concluded that most of the observed increase in globally averaged temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. "Very likely" was defined in the report as greater than 90% probability. Doubling pre-industrial atmospheric concentrations of carbon dioxide to 550 ppm is likely to result in increased mean surface temperatures in the range of 2 to 4.5°C with a best estimate of about 3°C. "Likely" was defined in the report as greater than 66% probability.

To understand the implications of the IPCC's latest findings, it is important to clarify some of the terminology and concepts inherent in the IPCC's references to concentrations of carbon dioxide that are likely to result in rises in global temperatures. These concepts provide the basic intellectual toolkit for the discussion later in this article of the targets for stabilising atmospheric greenhouse gases that need to be set to protect the GBR.

An initial concept to understand is "radiative forcing".[5] In simple terms, radiative forcing is the heating or cooling effect of different components in the atmosphere contributing to climate change. In more technical terms, radiative forcing values compare current-day effects of a climate change mechanism in relation to pre-industrial conditions defined at 1750 and expressed in watts per square metre (Wm^{-2}). Radiative forcing values can be positive or negative depending on whether a component contributing to climate change has a heating or cooling effect. At the present time, carbon dioxide accounts for the majority of the heating effect of anthropogenic greenhouse gases. Aerosols are tiny particles of dust and liquid in the atmosphere that cause a cooling effect. While the cooling effect of aerosols is an area of considerable scientific uncertainty, at present it is believed to approximately cancel the heating effect of greenhouse gases other than carbon dioxide.[6]

The concept of radiative forcing forms the foundation for the concept of Global Warming Potentials (GWPs). This is a relative measure and is defined as the time integrated commitment to climate forcing from the instantaneous release of 1 kg of a trace gas expressed relative to that of 1 kg of carbon dioxide as a reference gas.[7] This concept allows the warming effect of different greenhouse gases over time to be compared using carbon dioxide as a standard unit for reference. For example, the GWP over 100 years for methane (CH_4) is 21. The GWP over 100 years of sulphur hexafluoride (SF_6), a gas used in electrical systems, is 23,900.[8] These figures make it clear that releasing a tonne of methane or sulphur hexafluoride, eg has a greater impact on climate change than releasing a tonne of carbon dioxide. This is a fundamental point when accounting for net or aggregate greenhouse gas emissions and the effect of different greenhouse gas concentrations in the atmosphere.

[3] Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: The Physical Science Basis – Summary for Policymakers – Contribution of Working Group I to the Fourth Assessment Report of the IPCC* (IPCC, 2007). Available at http://www.ipcc.ch/SPM2feb07.pdf (viewed 7 April 2007).

[4] Intergovernmental Panel on Climate Change, n 3, p 12 and Figure SPM-5 on p 14.

[5] See generally, Houghton, n 1, Ch 3; and Fuglestvedt JS, Berntsen TK, Godal O, Sausen R, Shine KP, and Skodvin T, "Metrics of climate change: assessing radiative forcing and emission indices" (2003) 58 *Climatic Change* 267 at 273.

[6] Intergovernmental Panel on Climate Change, n 3, Figure SPM-2, p 4.

[7] See Houghton, n 1, p 52; and Fuglestvedt et al, n 5, p 276.

[8] See Fuglestvedt et al, n 5, p 277.

Based on the GWP of different greenhouse gases, for ease of comparison and modelling greenhouse gases emissions and atmospheric concentrations are commonly measured in a standard unit known as “carbon dioxide equivalents” (CO_2-e). This term is defined and used in slightly different ways in the context of *emissions* and *atmospheric concentrations* of greenhouse gases. The unifying theme for the different uses is that, like the concept of GWP, they allow the effect of different greenhouse gases to be compared using carbon dioxide as a standard unit for reference. It may be noted also that some authors and inventories refer to “carbon equivalents” when discussing quantities or atmospheric concentrations of greenhouse gases. Figures for “carbon equivalents” can be converted to “carbon dioxide equivalents” by multiplying by 44/12 to take account of the different molecular weights. However, the IPCC guidelines use “carbon dioxide equivalents”[9] and this term will be used here.

When referring to greenhouse gas emissions, “carbon dioxide equivalent” refers to the amount of carbon dioxide that would give the same warming effect as the effect of the greenhouse gas or greenhouse gases being emitted. It is normally used when attributing aggregate emissions from a particular source over a specified timeframe. It is used in this way at national and international levels to account for greenhouse emissions and reductions over time. Article 3 of the *Kyoto Protocol to the United Nations Framework Convention on Climate Change 1997* (the Kyoto Protocol) states targets for emissions reductions in terms of “aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A.”[10] Using this approach, Australia’s net greenhouse gas emissions across all sectors in 2004 totalled 564.7 million tonnes of carbon dioxide equivalent.[11] The expected carbon dioxide equivalent emissions from burning different fuels can also be calculated using a standard methodology.[12]

When referring to atmospheric concentrations of greenhouse gases, “carbon dioxide equivalent” refers to the concentration of carbon dioxide that would give the same warming effect as the collective effect of all of the greenhouse gases in the atmosphere. Put in a more technical way, this means the atmospheric concentration of carbon dioxide that gives a radiative forcing equal to the sum of the forcings from all of the individual greenhouse gas in the atmosphere. John Houghton explains that when converting from carbon dioxide only concentrations to carbon dioxide equivalent concentrations, the amount that needs to be added varies with different concentrations of greenhouse gases as the relationship between radiative forcing and concentration is non-linear.[13] For example, setting stabilisation targets of atmospheric carbon dioxide at 450 or 550 ppm would become about 520 or 640 ppm carbon dioxide equivalents, respectively, due to the additional warming effect of other greenhouse gases.[14] The *Stern Review* uses the term in this manner, noting that atmospheric greenhouse gas concentrations are already around 430 ppm carbon dioxide equivalents compared with 380 ppm carbon dioxide only.[15] These approaches exclude the cooling effect of aerosols.

However, the use of this term is not uniform when discussing stabilisation targets as some authors define carbon dioxide equivalent concentrations as the net forcing of all anthropogenic radiative

[9] Intergovernmental Panel on Climate Change (IPCC), *2006 Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006), available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm (viewed 27 April 2007).

[10] Done at Kyoto on 11 December 1997. Entry into force generally on 16 February 2005. Not yet in force for Australia. Available at http://unfccc.int/resource/docs/convkp/kpeng.pdf (viewed 27 April 2007). Annex A lists six gases: carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); and sulphur hexafluoride (SF_6).

[11] Australian Greenhouse Office, *National Greenhouse Gas Inventory 2004* (Australian Greenhouse Office, 2006), p 1, available at http://www.greenhouse.gov.au/inventory/2004/pubs/inventory2004.pdf (viewed 27 April 2007).

[12] See the Australian Greenhouse Office, *AGO Factors and Methods Workbook* (Australian Greenhouse Office, 2006), p 39, available at http://www.greenhouse.gov.au/workbook/pubs/workbook2006.pdf (viewed 27 April 2007).

[13] Houghton, n 1, pp 124, 259-260, and 267.

[14] Houghton, n 1, p 259.

[15] Stern N, *The Stern Review on the Economics of Climate Change* (Cambridge University Press, 2007), pp 5, 221-225, and 334.

forcing agents including greenhouse gases, tropospheric ozone, and aerosols but not natural forcings.[16] The inclusion of aerosols alters the meaning considerably. As noted earlier, the IPCC's latest report indicates that the current radiative forcing of non-carbon dioxide greenhouse gases and aerosols effectively cancel each other,[17] so that the net effect of all radiative forcing components is currently roughly equal to the effect of carbon dioxide alone, which was around 370 ppm in 2000 and currently around 380 ppm. However, this offsetting effect is unlikely to remain in the future as improved pollution controls are expected to significantly reduce the cooling effect of aerosols over the course of coming decades.[18]

Despite the uncertainty associated with the effect of aerosols and their likely diminishing effect in the future, the critical issue for setting stabilisation targets is the effect of all radiative forcing components on global temperatures. Consequently, in this article references to "carbon dioxide equivalents" will refer to the effect of all radiative forcing components, including aerosols.

The levels of reduction in anthropogenic greenhouse gas emissions that are required to stabilise global temperatures at less than a mean 2–3°C rise are uncertain, but probably require stabilisation of greenhouse gas concentrations and aerosols at 450–550 ppm carbon dioxide equivalents.[19] This will require reductions in greenhouse gas emissions of 60–80% by 2100 with further reductions after 2100.[20] There is, however, an ongoing, vigorous debate about these matters in the context of the uncertainty and risks involved. For example, some scientists consider that only stabilisation levels at 400 ppm carbon dioxide equivalence (350 ppm carbon dioxide-only) can limit the probability of exceeding 2°C to reasonable levels.[21] These matters have very serious implications for coral reefs.

CLIMATE CHANGE IS A MAJOR THREAT TO THE GREAT BARRIER REEF

Climate change is accepted as a major threat to coral reefs worldwide, including the GBR.[22] It is expected to affect coral reefs mainly through changes of three variables: increases in sea surface temperature causing coral bleaching; decreases in calcification rates, slowing coral growth due to changing seawater chemistry; and increases in sea level.[23] The most immediate threat is coral bleaching. It occurs when water temperatures exceed normal extremes causing corals to expel their

[16] Hare B and Meinshausen M, "How much warming are we committed to and how much can be avoided?" (2006) 75 *Climatic Change* 111 at 120, 122 and 125. Similarly, see Intergovernmental Panel on Climate Change, n 3, p 12.

[17] Intergovernmental Panel on Climate Change, n 3, Figure SPM-2, p 4; Hare and Meinshausen, n 16, pp 115, 122, 125, 136 and 138.

[18] For a detailed analysis of the future effects of different greenhouse gases and aerosols, see Meinshausen M, Hare B, Wigley TML, van Vuuren D, den Elsen MGJ, and Swart R, "Multi-gas emissions pathways to meet climate targets" (2006) 75 *Climatic Change* 151.

[19] Pittock, n 1, pp 152-155; Houghton, n 1, pp 257-261; Scientific Expert Group on Climate Change, *Confronting Climate Change: Avoiding the Unmanageable and Managing the Unavoidable* (United Nations Foundation and Sigma Xi, 2007), pp 44-45, available at http://www.unfoundation.org/SEG (viewed 26 April 2007).

[20] Pittock, n 1, pp 152-155; Houghton, n 1, pp 257-261.

[21] Hare and Meinshausen, n 16, p 137.

[22] Hoegh-Guldberg O, "Coral Bleaching, Climate Change and the Future of the World's Coral Reefs" (1999) 50 (8) *Marine and Freshwater Research* 839; Hughes TP, Baird AH, Bellwood DR, Card M, Connolly SR, Folke C, Grosberg R, Hoegh-Guldberg O, Jackson JBC, Kleypas J, Lough JM, Marshall P, Nystrom M, Palumbi SR, Pandolfi JM, Rosen B, Roughgarden J, "Climate Change, Human Impacts, and the Resilience of Coral Reefs" (2003) 301 *Science* 929; Done T, Whetton P, Jones R, Berkelmans R, Lough J, Skirving W and Wooldridge S, *Global Climate Change and Coral Bleaching on the Great Barrier Reef* (Queensland Government Department of Natural Resources and Mines, 2003); Hoegh-Guldberg O and Hoegh-Guldberg H, *The Implications of Climate Change for Australia's Great Barrier Reef* (WWF Australia, 2004); Wilkinson C (ed), *Status of the Coral Reefs of the World* (Australian Institute of Marine Science, 2004), Vol 1, pp 7-8; Grimsditch GD and Salm RV, *Coral Reef Resilience and Resistance to Bleaching* (IUCN, 2005); Hoegh-Guldberg O, "Low Coral Cover in a High-CO2 World" (2005) 110 J Geophys Res C09S06; Donner SD, Skirving WJ, Little CM, Oppenheimer M, Hoegh-Guldberg O, "Global Assessment of Coral Bleaching and Required Rates of Adaptation Under Climate Change" (2005) 11 *Global Change Biology* 2251; and Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: Climate Change Impacts, Adaptatation and Vulnerability – Working Group II Contribution to the IPCC Fourth Assessment Report* (IPCC, 2007), pp 9 and 11, available at http://www.ipcc.ch/SPM6avr07.pdf (viewed 7 April 2007).

[23] Reviewed in Hoegh-Guldberg and Hoegh-Guldberg, n 22.

symbiotic algae, known as zooxanthellae, and turn a brilliant white colour.[24] The term "coral bleaching" is used to describe this phenomenon because the normally colourful corals appear to have been bleached white. Corals may recover from mild coral bleaching events but severe events can cause widespread death of corals.[25]

Coral reefs dominate coastal tropical environments between latitudes 25 degrees south and 25 degrees north and roughly coincide with water temperatures between 18°C and 30°C.[26] Corals appear to be living only 1–2°C below their upper thermal limit at which bleaching occurs and an additional 1°C in maximum sea temperatures results in mortality.[27]

Coral bleaching in 1998 effectively destroyed 16% of the coral reefs of the world, with losses in the Indian Ocean of almost 50%.[28] These impacts are unprecedented in the evolutionary history of the GBR or globally. The mass mortality of Caribbean reef corals dramatically altered reef community structures in a manner that has been unprecedented for at least the past 95,000 years.[29]

Reviews of the pressure of climate change on the health of the GBR conclude that its waters are already warming, and are predicted to continue to do so, resulting in increased levels of coral bleaching over coming decades.[30] There have been two major coral bleaching events on the GBR, one in 1998 and the other in 2002. Ray Berkelmans and his colleagues found that spatial patterns of bleaching were similar in both years and that short periods of high water-temperature are highly stressful to corals and result in highly predictable bleaching patterns.[31] They found in 1998, 42% of reefs were bleached to some extent with 18% strongly bleached. In 2002, 54% of reefs were bleached to some extent with 18% strongly bleached. There was a close correlation between coral bleaching and maximum sea surface temperature. Modelling the relationship between the bleaching events and maximum sea surface temperature:[32]

> … indicates that a 1°C increase [in maximum sea surface temperature over a three-day period] would increase the bleaching occurrence of reefs from 50% (approximate occurrence in 1998 and 2002) to 82%, while a 2°C increase would increase the occurrence to 97% and a 3°C increase to 100%. These results suggest that coral reefs are profoundly sensitive to even modest increases in temperature and, in the absence of acclimatization/adaptation, are likely to suffer large declines under mid-range International Panel for Climate Change predictions by 2050.

Ove Hoegh-Guldberg found the size of a thermal anomaly and the time that corals are exposed to it in Degree Heating Weeks or Months can give a fairly accurate projection of the outcome of the exposure of corals to stress.[33] Using the IPCC "business as usual" scenario for future greenhouse emissions, he found:[34]

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[24] Several other factors, such as changes in salinity and some toxins, also cause coral bleaching but are not relevant to the present discussion. See Hoegh-Guldberg and Hoegh-Guldberg, n 22, pp 33-34.

[25] Hoegh-Guldberg and Hoegh-Guldberg, n 22, pp 33-34.

[26] Hoegh-Guldberg (1999), n 22, at 841.

[27] Lough J, Berkelmans R, van Oppen M, Wooldridge S, Steinberg C, "The Great Barrier Reef and Climate Change" (2006) 19 *Bull. Aust. Meteorological and Oceanographic Soc.* 53 at 54.

[28] Wilkinson, n 22, p 22.

[29] Pandolfi JM and Jackson JBC, "Ecological Persistence Interrupted in Caribbean Coral Reefs" (2006) 9(7) *Ecology Letters* 818.

[30] See the reviews listed in n 22. For a review of impacts on the Australian marine ecosystem generally, see Hobday AJ, Okey TA, Poloczanska ES, Kunz TJ, and Richardson AJ (eds), *Impacts of Climate Change on Australian Marine Life* (Australian Greenhouse Office, 2006), available at http://www.greenhouse.gov.au/impacts/publications/marinelife.html (viewed 27 April 2007).

[31] Berkelmans R, De'ath G, Kininmonth S and Skirving WJ, "A Comparison of the 1998 and 2002 Coral Bleaching Events on the GBR: Spatial Correlation, Patterns and Predictions" (2004) 23 (1) *Coral Reefs* 74.

[32] Berkelmans et al, n 31, pp 74 and 82; see also Done et al, n 22.

[33] Hoegh-Guldberg (1999), n 22; Hoegh-Guldberg and Hoegh-Guldberg, n 22, p 62.

[34] Hoegh-Guldberg and Hoegh-Guldberg, n 22, p 66.

> If the projected increases in sea temperature follow the trajectory suggested by the [IPCC], reefs should soon start to decline in terms of coral cover and appearance. With a doubling of CO_2, thermal stress levels will soon reach the levels seen at isolated yet catastrophically affected sites in 1998. When these conditions arrive on reefs on the Great Barrier Reef more than three times per decade, coral cover should have declined to near zero. These dates are on average around 2030–2040 for southern, central and northern sectors of the Great Barrier Reef.

Hoegh-Guldberg noted that a key observation regarding heat stress in reef-building corals is that not all corals are equally sensitive to temperature.[35] However, he concluded that, while there is some variability in the impact of climate change according to latitude and proximity to the Queensland coast, the differences are small and delays in response to warming due to these factors are, at most, a couple of decades.[36]

The IPCC has also concluded that climate change is a major threat to coral reefs worldwide, including the GBR. It released a summary of the report from Working Group II, dealing with climate change impacts, adaption and vulnerability, from its coming Fourth Assessment Report on 6 April 2007.[37] In relation to Australia and New Zealand specifically, the IPCC found there is a very high confidence that, "significant loss of biodiversity is projected to occur by 2020 in some ecologically-rich sites including the Great Barrier Reef and Queensland Wet Tropics."[38] It defined "very high confidence" as at least a 9 out of 10 chance of being correct. It found, when considering the impacts of climate change on coastal systems, there is very high confidence that:[39]

> Corals are vulnerable to thermal stress and have low adaptive capacity. Increases in sea surface temperature of about 1 to 3°C are projected to result in more frequent coral bleaching events and widespread mortality, unless there is thermal adaptation or acclimatisation by corals.

In relation to the potential for thermal adaptation and acclimatisation noted by the IPCC, there is evidence that adult corals, at least in some circumstances, are capable of limited acclimatisation or adaptation to increased water temperatures.[40] However, there is not a strong case for adaptation playing a role in modifying the thermal tolerances of the reef-building corals to keep pace with the expected rate of water temperature increase due to climate change.[41] The widespread coral bleaching events in 1998 and 2002 suggest that adaptation by corals will not avoid, at least, severe short to medium-term impacts of rising sea temperatures.

While improvements to coastal management may help reduce these impacts, based on current knowledge it is expected that the ecology of the GBR will change dramatically over the next few decades due to climate change. This indicates that climate change represents the most severe threat to the GBR in the immediate to medium-term future.[42]

CURRENT AUSTRALIAN POLICY RESPONSE TO CLIMATE CHANGE

The response to global warming has involved the international community, the Commonwealth government and other levels of government in Australia. The principal international treaty for collective action to address climate change is the *United Nations Framework Convention on Climate*

[35] Hoegh-Guldberg (1999), n 22; Hoegh-Guldberg and Hoegh-Guldberg, n 22, p 37.

[36] Hoegh-Guldberg and Hoegh-Guldberg, n 22, p 72.

[37] Intergovernmental Panel on Climate Change, n 22.

[38] Intergovernmental Panel on Climate Change, n 22, p 11.

[39] Intergovernmental Panel on Climate Change, n 22, p 9.

[40] See Baker AC, "Flexibility and Specificity in Coral-algal Symbiosis: Diversity, Ecology, and Biogeography of Symbiodinium" (2003) 34 Annu Rev Ecol Syst 661; Berkelmans R and van Oppen MJH, "The Role of Zooxanthellae in the Thermal Tolerance of Corals: A 'Nugget of Hope' for Coral Reefs in an Era of Climate Change" (2006) 273 Proc R Soc Lond B 2305.

[41] Hoegh-Guldberg and Hoegh-Guldberg, n 22, pp 42-49; Hoegh-Guldberg (2005), n 22.

[42] Miller I and Sweatman H, *Status of Coral Reefs in Australia and PNG in 2004* in Wilkinson, n 22, Vol 2, Ch 11, p 327.

Change 1992 (UNFCCC).[43] It seems to be often forgotten that Australia has signed and ratified this Convention and is bound by it. It is probably forgotten because of the controversy over Australia's conduct[44] in negotiating the Kyoto Protocol and the fact that Australia subsequently refused to ratify the Protocol. The Kyoto Protocol provides, amongst other things, binding quantitative targets for the reduction of greenhouse gas emissions by developed countries. Like Australia, the United States of America signed the Kyoto Protocol but refused to ratify it and, therefore, is not bound by it.

Australia negotiated a target of a 108% increase in its greenhouse gas emissions over 1990 levels during 2008–2012 under the Kyoto Protocol but, because it has not ratified the Protocol, it is not bound to achieve this target. Nevertheless, principally through reductions in the rates of land clearing, Australia is expected to almost achieve this target. Australia's greenhouse gas emissions are projected to reach 603 million tonnes of carbon dioxide equivalents annually during 2008–2012, which is 109% of 1990 levels.[45]

To address climate change issues outside the binding targets in the Kyoto Protocol, in 2005 Australia entered into the Asia-Pacific Partnership on Clean Development and Climate (AP6) with China, India, Japan, South Korea and the United States.[46] The AP6 focuses on a non-binding agreement for expanding investment and trade in cleaner energy technologies, goods and services. It sets no binding targets for reductions of greenhouse gases.

The policy response of the Australian government to climate change is almost entirely based upon non-legislative and non-regulatory mechanisms loosely coordinated under the 1998 National Greenhouse Strategy, with the aim of meeting Australia's Kyoto target. There is a plethora of funding programs, including:[47]

- **Greenhouse Challenge Plus**: a $36.6 million voluntary scheme whereby the Australian government signs an agreement with a participating organisation that provides a framework for undertaking and reporting on actions to abate greenhouse emissions.
- **Greenhouse Gas Abatement Programme** (GGAP): a $243.7 million funding program, commenced in 2000, to support activities that are likely to result in substantial emissions reductions or substantial sink enhancement, particularly in the period 2008-2012. The GGAP aims to reduce emissions equivalent to 27.5 million tonnes of carbon dioxide during this period. An example of a GGAP project is $15.47 million funding to the German Creek colliery, in central Queensland, to install and operate equipment to burn methane contained in waste coal mine gas to produce electricity to achieve a projected abatement of 2.4 mega tonnes of carbon dioxide equivalent.
- **Low Emissions Technology Demonstration Fund**: a $523 million fund, over 15 years, that supports the commercial demonstration of technologies that have the potential to deliver large-scale greenhouse gas emission reductions in the energy sector, such as "clean coal" initiatives. An example of a grant under the fund is a $60 million grant for the Gorgon CO_2 Injection Project. This project involves separating and capturing the carbon dioxide from the natural gas produced from the Gorgon fields off Western Australia. The carbon dioxide will be injected deep underground into a saline aquifer. When fully operational the project is expected to capture up to 3 million tonnes of carbon dioxide a year.
- **Renewable Remote Power Generation Programme**: a $205.9 million fund, commenced in 2000, providing rebates for the use of renewable energy generation in remote parts of Australia to replace diesel generators.

[43] Done at New York on 9 May 1992. Entry into force for Australia and generally, 21 March 1994. 31 ILM 849; ATS 1994 No 2. Available at http://unfccc.int/resource/docs/convkp/conveng.pdf (viewed 27 April 2007).

[44] See Cusack V, "Perceived costs versus benefits of meeting the Kyoto target for greenhouse gas emission reduction: the Australian perspective" (1999) 16 EPLJ 53.

[45] Australian Greenhouse Office, *Tracking to the Kyoto Target: Australia's Greenhouse Emissions Trends 1990 to 2008–2012 and 2020* (AGO, 2006), available at http://www.greenhouse.gov.au/projections/pubs/tracking2006.pdf (viewed 27 April 2007).

[46] See http://www.asiapacificpartnership.org and http://www.ap6.gov.au (viewed 27 April 2007).

[47] Described at http://www.greenhouse.gov.au/ago/funding/index.html and in media releases since 2000 available at http://www.environment.gov.au/minister/env/2007/index.html (viewed 27 April 2007).

- **Solar Cities**: a $75.3 million program designed to trial and demonstrate how solar power, smart meters, energy efficiency and new approaches to electricity pricing can combine to provide a sustainable energy future in urban locations throughout Australia. Adelaide, Townsville, Blacktown and Alice Springs were the first four solar cities to be announced.
- **Australian Climate Change Science Programme**: a research funding program, renewed in 2004, providing $30.7 million over four years to improve understanding of the causes, nature, timing and consequences of climate change.
- **Global Initiative on Forests and Climate**: a $200 million fund to support projects in developing countries, particularly in South-East Asia and the Pacific, to improve forest management and, thereby, reduce greenhouse gas emissions from deforestation.

In addition to entirely voluntary, non-legislative programs, the Australian government has a limited regulatory framework for greenhouse gas emissions. The UNFCCC is nominally incorporated into Australian domestic law. It is annexed, in whole, in Sch 3E of the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (Cth). That Act, however, focuses on ozone depleting substances and not on greenhouse gas emissions contributing to climate change.

There are two pieces of Commonwealth legislation of note in relation to greenhouse issues. The *Renewable Energy (Electricity) Act 2000* (Cth) aims to reduce greenhouse gas emissions by imposing a Mandatory Renewable Energy Target (MRET). This requires electricity providers to source 2% of their energy from renewable sources by requiring an additional 9,500 gigawatt hours (GWh) of electricity to be sourced from renewables by 2010.[48] The scheme was reviewed in 2004 and recommendations were made by the review panel to extend the scheme with a new target of 20,000 GWh between 2010 and 2020.[49] However, the Australian government decided not to increase or extend the MRET target for 2010.[50] In addition to the MRET, the *Energy Efficiency Opportunities Act 2006* (Cth) requires large energy-using businesses[51] to undertake and report publicly an assessment of their energy efficiency opportunities, one of the objects of which is to reduce greenhouse emissions.

The centrepiece of the Australian government's environmental laws, the *Environment Protection and Biodiversity Conservation Act 1999* (Cth), is largely silent on greenhouse gas emissions and climate change. Section 520(3)(k) of the Act allows the Governor-General to make regulations to give effect to the UNFCCC but no regulations have been made for that purpose. A decision of the Federal Court indicates that greenhouse gas emissions are effectively not regulated under the Act as even projects involving extremely large emissions of greenhouse gases, such as major coal mines, are not considered by the Australian government to have a significant impact on the matters protected by the Act in the context of total global greenhouse emissions.[52]

Another emerging policy response, at least on the horizon at a federal level, is the possibility of a national greenhouse emissions trading scheme linked to an international emissions trading scheme. In December 2006, the Australian Prime Minister, John Howard, established a Task Group on Emissions Trading made up of representatives from the business community and the public service to advise on the design of a global emissions trading scheme. The Task Group "is currently examining the nature and design of a workable global emissions trading system in which Australia would be able to participate and the additional steps that might be taken, in Australia, consistent with the goal of

[48] A tax penalty is imposed for failing to achieve this target by the *Renewable Energy (Electricity) (Charge) Act 2000* (Cth).

[49] Mandatory Renewable Energy Target (MRET) Review Panel, *Renewable Opportunities: A Review of the Operation of the Renewable Energy (Electricity) Act 2000* (Australian Greenhouse Office, 2003), available at http://www.mretreview.gov.au/report/pubs/mret-review.pdf (viewed 26 November 2006).

[50] Energy Task Force, *Securing Australia's Energy Future* (Australian Government, 2004), p 147, available at http://www.dpmc.gov.au/publications/energy_future/docs/energy.pdf (viewed 18 March 2007).

[51] The threshold for reporting is use of more than 0.5 petajoules in a financial year.

[52] *Wildlife Preservation Society of Queensland Proserpine/Whitsunday Branch Inc v Minister for the Environment and Heritage* [2006] FCA 736 (Dowsett J). See http://www.envlaw.com.au/whitsunday.html (viewed 27 April 2007).

establishing such a system" and is to report to the Prime Minister by 31 May 2007.[53] State and Territory governments have also established a separate National Emissions Trading Taskforce.[54] It seems plausible that a national emissions trading scheme will be announced before, or shortly after, the Australian federal election in late 2007.

In addition to these laws, programs and policies of the Australian government, various State and Territory laws, programs and policies seek to address climate change. The New South Wales Greenhouse Gas Abatement Scheme is a leading example of this.[55] An important legislative contribution made by the Queensland government is to end broad-scale land clearing for agricultural development by 2006. In early 2004 the Queensland government passed the *Vegetation Management and Other Legislation Amendment Act 2004* (Qld), with a stated objective of reducing greenhouse emissions.[56] This aims to reduce greenhouse gas emissions due to vegetation clearing by 20-25 megatonnes per year by 2008.[57] This major change in the law has been a key to Australia almost meeting its targets under the Kyoto Protocol for the 2008-2012 commitment period. However, rises in energy use and transportation emissions mean that Australia will need to find further means of reducing emissions to meet any similar or more stringent targets that are set after the 2008-2012 period dealt with by the Kyoto Protocol.

SETTING TARGETS FOR GREENHOUSE POLICIES

A major deficiency in the current response of the Australian government to climate change is a refusal to set binding, quantitative targets for unacceptable levels of climate change. By not setting targets it is difficult to gauge the effectiveness of the response or to take corrective action if it does not appear to be achieving suitable outcomes. As Stephen Dovers points out, setting measurable policy goals is essential for evaluating the success of a policy.[58] Setting ambitious targets can also be used as a means of "technology forcing" by signalling to industry what standards must be met in the future, even if they are currently not achievable. This approach was first developed in the United States and has been extensively used there for pollution reduction. There is ample evidence that market forces such as higher prices or stringent environmental policies induce technological change.[59]

The question that the failure to set targets for greenhouse gas reductions raises, then, is what targets should be set? The objective of the UNFCCC, stated in Art 2, is:

> stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

The objective of the UNFCCC is commonly referred to as avoiding "dangerous climate change". It is synonymous with the overall objective of the environmental legal system, "sustainable development", in relation to protecting the atmospheric processes on which life depends. The objective of the UNFCCC is a useful starting point but it is a qualitative target only, as is "sustainable development". The quantitative targets set for some countries under the Kyoto Protocol, such as Australia's target of a 108% increase in greenhouse gas emissions over 1990 levels during 2008-2012,

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[53] See http://www.greenhouse.gov.au/emissionstrading (viewed 3 April 2007).

[54] See http://www.emissionstrading.net.au (viewed 3 April 2007).

[55] Noting the criticisms of Kearney T, "Market-based Policies for Demand Side Energy Efficiency: A Comparison of the New South Wales Greenhouse Gas Abatement Scheme and the United Kingdom's Energy Efficiency Commitment" (2006) 23 EPLJ 113.

[56] Section 3(1)(g) of the amended *Vegetation Management Act 1999* (Qld). See McGrath C, "End of Broadscale Clearing in Queensland" (2007) 24 EPLJ 5.

[57] See Queensland government, *State Policy for Vegetation Management* (May 2004). Available at http://www.nrm.qld.gov.au/vegetation/legislation (viewed 10 March 2007).

[58] Dovers S, *Environment and Sustainability Policy: Creation, Implementation, Evaluation* (The Federation Press, 2005), pp 101-102.

[59] Popp D, "R&D subsidies and climate change: is there a 'free lunch'?" (2006) 77 *Climatic Change* 311 at 311.

are relative targets that do not define the levels of unacceptable climate change. Recent, ambitious targets for reducing greenhouse emissions by the European Union,[60] the United Kingdom,[61] the State of California,[62] and the State of South Australia,[63] are also relative targets that do not define the levels of unacceptable climate change. One must turn to climate change science to establish a scientifically valid, quantitative target to determine the effectiveness of the response to avoiding dangerous climate change or achieving sustainable development, measured in terms of an environmental indicator or suite of environmental indicators.

The topic of target setting for climate change policy has generated a large amount of literature, particularly since 2001, of which the work of Michael Oppenheimer is particularly outstanding.[64] The most widely adopted interpretation and target for avoiding dangerous climate change is that of the European Union: "to limit global warming to no more than 2°C above the temperature in pre-industrial times."[65] The target of "no more than 2°C" is a quantitative, and measurable, target.

The reference period for climate change is important to consider when setting targets. For instance, in an article published in 2005, Jan Corfee-Morlot and her colleagues discussed global mean temperature increases of 1-4°C "compared with 1990 levels".[66] Global mean temperatures had risen by approximately 0.6°C by 1990. A reference period of pre-industrial temperatures accounting for this 0.6°C rise is used here. Consequently, consistent with the approach of the European Union, references to 1-3°C temperature rises here are compared with pre-industrial levels.

The levels of reduction in anthropogenic greenhouse gas emissions that are required to stabilise global temperatures at less than a mean 2-3°C rise are uncertain but probably require stabilisation of greenhouse gas concentrations and aerosols at 450-550 ppm of carbon dioxide equivalents, which will require reductions in greenhouse gas emissions of 60-80% by 2100 with further reductions after 2100.[67] Limiting the total increase in mean global temperature to approximately 1°C by 2100 would require stabilisation of atmospheric greenhouse gases and aerosols at their existing levels. This is because a rise of 0.1°C per decade in global mean temperature is expected on top of the existing 0.74°C rise observed in the past 100 years even if greenhouse gases and aerosols were held at year 2000 levels.[68] Barrie Pittock provides a clear explanation of what is needed to mitigate the impacts of climate change and the uncertainty associated with setting any target of atmospheric greenhouse gases:[69]

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[60] The European Commission set a target of reducing the European Union's greenhouse gas emissions by 20% by 2020 (compared to 1990 levels) and by 30% if the international community make similar commitments. See http://ec.europa.eu/environment/climat/pdf/future_action/com_2007_2_en.pdf (viewed 21 April 2007).

[61] The United Kingdom's *Draft Climate Change Bill 2007* proposes to impose statutory obligations on the United Kingdom government to reduce carbon dioxide emissions by 26-32% by 2020 (compared to 1990 levels) and by 60% by 2050. See http://www.official-documents.gov.uk/document/cm70/7040/7040.pdf (viewed 21 April 2007).

[62] California's *Global Warming Solutions Act 2006* aims to reduce California's emissions to 1990 levels by 2020, a reduction of 25%. The Act is available at http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.pdf (viewed 21 April 2007).

[63] The *Climate Change and Greenhouse Emissions Reduction Bill 2006* (SA) sets a target to reduce, by 31 December 2050, greenhouse gas emissions within South Australia by at least 60% to an amount that is equal to or less than 40% of 1990 levels. See http://www.climatechange.sa.gov.au (viewed 24 March 2007).

[64] A recent, comprehensive summary is Oppenheimer M and Petsonk A, "Article 2 of the UNFCCC: Historical Origins, Recent Interpretations" (2005) 73 *Climate Change* 195.

[65] There have been repeated European Union resolutions to this effect. A recent one is the European Union Environment Council Conclusion at its 2785th meeting, Brussels, 20 February 2007, available at http://europa-eu-un.org/articles/fr/article_6790_fr.htm (viewed 7 March 2007).

[66] Corfee-Morlot J, Smith J, Agrawala S, and Franck T, "Long-term Goals and Post-2012 Commitments: Where Do We Go From Here With Climate Policy?" (2005) 5(3) *Climate Policy* 251.

[67] Pittock, n 1, pp 152-155; Houghton, n 1, pp 257-261; Scientific Expert Group on Climate Change, n 19, pp 44-45.

[68] Intergovernmental Panel on Climate Change, n 3, p 12 and Figure SPM-5 on p 14; Hare and Meinshausen, n 16, pp 124-125.

[69] Pittock, n 1, pp 152-155. See also Houghton, n 1, pp 257-261.

> The percentage reduction needed in greenhouse gas emissions to avoid dangerous changes to the Earth's climate is large, around 60-80% by 2100, but uncertain. Stabilising the Earth's climate requires total emissions at some time in the future to be less than or equal to the total removal of greenhouse gases from the combined atmosphere – shallow oceans – land – soil biota system. Removal can occur by natural processes or it can be artificially accelerated …
>
> The precise reduction in emissions needed depends on what is the upper limit to concentrations of greenhouse gases that will avoid dangerous climate change, taking account of possible abrupt and irreversible changes in the climate system as well as gradual climate change …
>
> Despite [uncertainties], there seems to be wide agreement … that global average warmings of around 2 or 3(C may be considered "dangerous" in terms of the UNFCCC. Such a level of warming is likely to lead to mass coral bleaching and the death of many coral reefs, and to the flooding of many low-lying islands and coasts …
>
> It would seem then that *if* it is possible to achieve an initial stabilisation of equivalent greenhouse gas concentration of 450 ppm, and reduce this further after 2100, we may well avoid dangerous global climate impacts, but it is not certain.

The critical need to stabilise global mean temperatures at less than 2-3°C is clear from the work of Berkelmans, Hoegh-Guldberg, and other coral reef scientists noted earlier. These studies indicate that a doubling of atmospheric carbon dioxide equivalent concentrations to 550 ppm, allowing a probable rise of 3°C in mean global temperature, is far too high a target to set if the policy objective is to avoid severe damage to the GBR. A rise of 2°C based on stabilising greenhouse gas concentrations and aerosols at 450 ppm carbon dioxide equivalents also appears too high; however, it may be impossible to avoid exceeding this target because the global atmospheric concentrations of carbon dioxide is already 379 ppm and is rising by around 2 ppm each year.

Detlef van Vuuren and his colleagues recently suggested that, technically, stabilising greenhouse concentrations at 650 ppm, 550 ppm, 450 ppm and, under specific assumptions, 400 ppm carbon dioxide equivalents is feasible from median IPCC baseline scenarios on the basis of known technologies.[70] They suggested that creating the right socio-economic and political conditions for mitigation is more important than any of the technical constraints.

Given the difficulties in the negotiations of the Kyoto Protocol, targets of stabilising atmospheric greenhouse gases at 450 ppm carbon dioxide equivalents, with a likely warming of around 2°C, appear to be the lowest targets that are politically possible to achieve. They are not targets that are desirable to set if the objective is to avoid severe damage to the GBR and other coral reefs around the world, but they are still likely to be far better than a target of 550 ppm with a warming of around 3°C.

Setting targets, such as stabilising global greenhouse gas concentrations at no greater than 450 ppm carbon dioxide equivalents, is an essential step to normal policy setting and evaluation of effectiveness.[71] It is a principal criticism of the policy response of the Australian government that no targets have been set for stabilising atmospheric greenhouse gas concentrations and global temperatures. Even though these targets must be achieved by global collaboration and cannot be achieved by Australia in isolation, the Australian government should play an active role in negotiating and implementing these targets if it considers protecting the GBR an important policy objective. At the present time the policies of the Australian government are inconsistent with protecting the GBR from the severe impacts of climate change. Simply ignoring the impacts scientists believe will occur to the GBR is not a satisfactory or even tenable policy option. Choosing not to listen to weather forecasts does not stop it raining.

FOCUS ON VOLUNTARY POLICY MEASURES AND RESEARCH

Another criticism of the policy response of the Australian government is that the response is virtually entirely based on voluntary policy instruments and research. There appears to be no back-up plan if

[70] van Vuuren DP, den Elzen MGJ, Lucas PL, Eickhout B, Strengers BJ, van Ruijven B, Wonink S, and van Houdt R, "Stabilizing Greenhouse Gas Concentrations at Low Levels: an Assessment of Reduction Strategies and Costs" (2007) 81 *Climate Change* 119 at 152.

[71] See generally in relation to environmental policy, Dovers, n 58.

the government's policies, such as the AP6 program and technological development, fail to produce alternative energy sources and sufficient reductions in emissions.[72]

Stephen Dovers criticises the adoption of a myopic approach to environmental policy which focuses on one category of policy instrument to respond to complex environmental problems such as climate change. He suggests:[73]

> Debates about policy instruments commonly recognise just a few general categories, notably regulation, education, and market-based approaches, but also increasingly self-regulation and community-based programs. Just as commonly, the general superiority of one or other category is advocated over others by different policy actors, with the classic argument being between the merits of regulation versus market mechanisms. Some policy actors advocate one kind of instrument as suitable for many or even all problems. This puts the means before the ends and narrows the scope of policy options. This is, however, to be expected, remembering that political ideology or disciplinary leaning play a strong role in determining what policy options will be favoured.

Dovers' criticism, that advocates of market-based mechanisms in environmental policy are often ideologically-driven, is telling. He recommends a wider, richer approach to environmental policy-making:[74]

> It is common now to hear the statement that "regulation doesn't work" … Opponents of regulation see an unwieldy administrative rationality and a wrongful belief that people only respond to imposed rules. These opponents include "woolly social scientists" who hold a communicative rationality that instructs cooperative and educational instruments, and "hard-nosed economists" who champion price signals in a free market as the prime way to influence rational, utility-maximising individuals … [These] positions are all both partially true and singularly inadequate, as all instruments are available [and necessary].

Dovers' critique of the recurrent debate about regulation versus market mechanisms is particularly relevant to the debate over climate change policies. The Australian government's policies are currently largely based on voluntary measures and research subsidies. The Prime Minister's Task Group on Emissions Trading, which is due to report by 31 May 2007, seems likely to recommend a national greenhouse emissions trading scheme,[75] which is a market-based mechanism though necessarily supported by regulation to create the market. Yet the Australian government currently refuses to set binding emission targets or to directly regulate greenhouse gas emissions even from large-scale sources. Dovers delivers a strong, intellectual blow to such narrow approaches to environmental policy.

The conundrum that the Australian government faces is that, from a policy perspective, merely relying on voluntary measures and research without a regulatory safety net is a huge risk. Forecasting the future is inherently difficult because of the significant uncertainties involved. No one knows for sure what future technological breakthroughs will occur or when.[76] Needless to say, the stakes are extremely high in this gamble. Taking a risk assessment approach, the high likelihood and severe consequences of global warming suggest that the failure to address it in a comprehensive and effective manner is a serious policy failure in terms of achieving sustainable development.

The principal justification given by the Australian government for its refusal to set binding targets for greenhouse gas reductions or impose constraints on the emission of greenhouse gases is to avoid damage to the economy.[77] This argument loses a great deal of weight when the economic impacts of

[72] Parker C, "The Greenhouse Challenge: Trivial Pursuit?" (1999) 16 EPLJ 63 at p 64, made the same comment about the lack of targets or sanctions in the Australian Greenhouse Challenge.

[73] Dovers, n 58, pp 106-107.

[74] Dovers, n 58, pp 124-125.

[75] See http://www.greenhouse.gov.au/emissionstrading (viewed 3 April 2007).

[76] See particularly the work of Rump P, *State of the Environment Reporting: Source Book of Methods and Approaches* (United Nations Environmental Program, Division of Environment Information and Assessment, 1996), pp 93-104.

[77] Many of the arguments advanced by the Australian government for the greenhouse policies it has adopted are set out in the majority report in the Senate Environment, Communications, Information Technology and the Arts Legislation Committee,

allowing climate change to proceed are considered.[78] It is inherently difficult to place an economic value on natural assets such as the GBR. One way to gauge the economic value of the GBR is to consider the economic value of industries associated with it. Tourism is one of the major industries in the GBR catchment, and highly dependent on a healthy reef being maintained. Hoegh-Guldberg and Hoegh-Guldberg have suggested that total tourism expenditure in the GBR region is forecast to grow from $4.2 billion in 2001 to $4.9 billion in 2010 and $6.4 billion in 2020.[79] Similarly, the Productivity Commission estimated that in 1998-1999 the gross production value of tourism associated with the GBR was $4.269 billion and the industry employed 47,660 people.[80] These analyses highlight the serious impacts to the Australian and Queensland economies if the GBR is severely degraded due to climate change.

EFFECTIVENESS OF CURRENT POLICY MEASURES

Evaluating the likely effectiveness of current policy measures for climate change requires them to be assessed in terms of the likelihood that they will achieve the objective of sustainable development. This is because, in a legal context, "effectiveness" can be seen as a measure of how successful law is in solving the problem it was designed to address.[81] In terms of climate change, this means the response is likely to avoid "dangerous climate change" under the UNFCCC. The pressure-state-response method of State of the Environment Reporting provides the best available conceptual framework for evaluating the effectiveness of environmental policy and is used here.[82] The pressures, conditions and responses relevant to the impacts of climate change on the GBR are set out above.

Based on the likely impacts on the GBR, targets of holding the rise of global temperatures beneath 2-3°C by stabilising greenhouse gas concentrations and aerosols between 450-550 ppm carbon dioxide equivalents appear too high. Stabilising greenhouse gases and aerosols around year 2000 levels, having a net effect of 370 ppm carbon dioxide equivalents, and allowing a rise in mean global temperature of 1°C appear to be the highest targets that should be set if the GBR is to be protected from serious degradation

Whether a target of 370 ppm, 450 ppm, or 550 ppm carbon dioxide equivalent concentrations in the atmosphere is set, to determine the effectiveness of the legal system and overall response, the question becomes whether any of these can be achieved in practice. It appears unlikely that even the 550 ppm target will be achieved under the current legal and policy framework.

Even if the United States and Australia ratified the Kyoto Protocol, and all countries achieved their emissions targets (something that appears completely unrealistic at this point in time), the Protocol would reduce global emissions of greenhouse gases by only a small fraction of the emissions that would be likely to occur without the Protocol being in force.[83] There are three main reasons for this. First, the Protocol sets binding targets only for developed countries,[84] and excludes developing countries with large emissions such as India and China. Second, it sets binding targets only for a short period (2008-2012). Third, the targets set – a net reduction of emissions from developed countries of around 5% – are themselves small. Tom Wigley modelled reductions in global temperatures assuming

Report on the Kyoto Protocol Ratification Bill 2003 [No. 2] (Australian Senate Printing Unit, March 2004). Available at http://www.aph.gov.au/Senate/committee/ecita_ctte/completed_inquiries/2002-04/kyoto/report/report.pdf (viewed 21 April 2007).

[78] See Stern, n 15; van Vuuren et al, n 70; and the series of articles in (2007) 8(1) *World Economics*.

[79] Hoegh-Guldberg and Hoegh-Guldberg, n 22, p 169.

[80] Productivity Commission, *Industries, Land Use and Water Quality in the Great Barrier Reef Catchment Research Report* (Productivity Commission, 2003), p 73, available at http://www.pc.gov.au/study/gbr/finalreport/gbr.pdf (viewed 7 April 2007).

[81] Zaelke D, Kaniaru D, and Kruzíkova E (eds), *Making Law Work – Environmental Compliance & Sustainable Development* (Cameron May Ltd International Law Publishers, 2005), p 22.

[82] See generally, in relation to this methodology, Rump, n 76.

[83] This is unless the Kyoto Protocol is seen as a "stepping-stone" to an effective international regime. It remains to be seen whether this will occur.

[84] Listed in Annex I to the UNFCCC. Their targets are set out in Annex B to the Kyoto Protocol.

no further emissions reductions are achieved after 2010 than specified under the Kyoto Protocol and found the reduction in temperature by 2100 would only be 4% lower than under a "business as usual" scenario.[85] Therefore, even under a best-case scenario, with perfect compliance by all signatories including the United States and Australia, the Kyoto Protocol would achieve only small reductions in greenhouse emissions and expected climate change.

Turning to consider the recently signed AP6, although it is not possible to calculate for certain what reduction in emissions the AP6 is likely to achieve over "business as usual", it is logically small or negligible. As there are no binding targets, and objectives are based on being cost-effective and maintaining economic growth, it is logical to assume that any reductions under the AP6 achieved by the development of new technology are very likely to have occurred under a "business as usual" approach without the AP6 being in place. Modelling prepared for the Australian government that suggests a more optimistic view of the benefits of the AP6 is difficult to accept as more than positive wishing.[86]

In 2003, Rosemary Lyster reviewed the legal framework for the Australian energy sector. Her analysis was prior to the AP6 and limited to the greenhouse emissions from the stationary energy sector, but her overall conclusions still appear applicable generally for Australia's regulation of greenhouse emissions. After reviewing Australia's policies and regulatory framework for greenhouse emissions she concluded:[87]

> There have been various initiatives at both the Federal and State government levels to combat the greenhouse gas emissions associated with the stationary energy sector. The question remains, however, whether or not these have been effective, and what more needs to be done before Australia has a sustainable energy policy and law framework. The overall conclusion will be that to date the efforts to control greenhouse emissions … are not sufficient. The largely voluntary measures resorted to by Australian governments have not delivered effective greenhouse emissions reductions. To be effective, mechanisms must be written into statute and be enforceable.

Lyster's conclusions in relation to the failure of voluntary measures to reduce greenhouse emissions reflects the findings of Neil Gunningham and Darren Sinclair's research into the ability of voluntary policy mechanisms to effectively control non-point source river pollution. Based on their analysis of non-point source pollution in the Swan-Canning river catchment in Western Australia they concluded:[88]

> There is little evidence to suggest that various forms of exhortation, *when used in isolation*, have the capacity to deliver tangible environmental improvements when applied to matters of non-point source pollution. Indeed, there is a substantial body of evidence … which suggests quite the contrary. Unless landholders have a self-interest in engaging in the desired environmental improvements, then information, education and voluntarism alone will usually be unable to overcome the costs barriers (and sometimes conservatism) that often inhibit change. For these reasons such measures should *not* be used as "stand alone" approaches to reducing non-point source agricultural pollution in the Swan-Canning river catchment. This is an important conclusion, yet one which policymakers have been most reluctant to hear notwithstanding a growing, and now almost overwhelming, body of evidence to support it.

Gunningham and Sinclair's conclusions appear highly relevant to greenhouse gas emissions, even though these emissions occur from both point sources and non-point sources. Their conclusions cast considerable doubt on the ability of the current greenhouse policies of the Australian government, based almost entirely on voluntarism for reducing greenhouse gas emissions, to provide an effective

[85] Wigley TML, "The Kyoto Protocol: CO_2, CH_4 and Climate Implications" (1998) 25(13) *Geophys Res Letters* 2285 at 2287. Note: Wigley assumed a climate sensitivity of 2.5°C for doubling CO_2 concentrations, which is roughly consistent with the latest IPCC projection of 3°C for doubling CO_2 concentrations.

[86] The modelling is published in Fisher BS, Ford M, Jakeman G, Gurney A, Penm J, Matysek A and Gunasekera D, *Technological Development and Economic Growth* (Australian Bureau of Agricultural and Resource Economics, 2006), available at http://www.abareconomics.com/publications_html/climate/climate_06/06_climate.pdf (viewed 20 March 2007).

[87] Lyster R, "The Implications of Electricity Restructuring For A Sustainable Energy Framework: What's Law Got To Do With It?" (2003) 20 EPLJ 359 at 367.

[88] Gunningham N and Sinclair D, "Non-point Pollution, Voluntarism and Policy Failure: Lessons From The Swan-Canning" (2004) 21 EPLJ 93 at 103.

policy response to global warming. David Popp's work suggests a similar conclusion regarding the Australian government's reliance on research subsidies as a substitute for more restrictive emissions reductions policies such as a carbon tax or direct regulation.[89]

Jaqueline Peel made similar criticisms of the largely voluntary approach to regulating greenhouse gas emissions in a recent review of the Australian policy response to climate change:[90]

> Although it has become unfashionable to say it, strong regulatory action by governments ("command-and-control") remains one of the most effective ways to bring about behavioural change for the benefit of the environment, particularly where such change has high associated economic costs. This would certainly appear to be the case in the climate change context, where the nature of the problem at issue is such that it will require fundamental changes in the way we produce and use energy, transport goods, manufacture and dispose of products, and utilise our natural resources. This is not to say that a single regulatory approach will suffice in order to manage the greenhouse issue – indeed, it seems probable that the breadth and integrative nature of the climate change challenge will necessitate a multi-faceted regulatory approach. Nonetheless, … government still plays a vital role in setting mandatory targets for GHG emissions reduction and harnessing the necessary resources to ensure effective monitoring and a credible enforcement effort.

Rory Sullivan also expressed similar views when evaluating the effectiveness of Australia's greenhouse policies, including entering into the AP6. He noted, in 2006 when he wrote his article, that Australia was expected to meet its Kyoto target, but commented that:[91]

> looking beyond the Kyoto Protocol to the broader goals of climate change policy, a different picture emerges. There is a general consensus that stabilising atmospheric greenhouse gas emissions at an acceptable level would require a 60-80% reduction in greenhouse gas emissions over the period 1990 to 2050 (equivalent to reductions of between 1 and 1.5% per annum over this 60 year period). From these statistics, it is clear that the [policies of the Australian government] did not have anything like the necessary effect on reducing greenhouse gas emissions.

Lyster, Gunningham and Sinclair, Popp, Peel, and Sullivan's analyses are supported by the facts of the current increases in levels of greenhouse gases in the atmosphere and the likelihood that the levels of these gases expected to cause "dangerous climate change" are likely to be exceeded in the near future. These facts and analyses strongly suggest that the current policies of the Australian government, as part of a global response to climate change, are not likely to be effective in preventing climate change from causing very serious damage to the GBR. This indicates the environmental legal system protecting the GBR is not being effective in relation to climate change. The failure to comprehensively and effectively reduce the pressure of greenhouse gas emissions appears likely to have unsustainable impacts on the GBR that will severely degrade its condition.

CONCLUSION

The current international and Australian environmental legal systems are not likely to be effective in preventing climate change from causing very serious damage to the GBR. Based on what we know at this point in time, particularly current greenhouse gas emissions and current policies, the impacts of climate change appear likely to cause severe impacts to the GBR. Atmospheric concentrations of carbon dioxide in 2005 were 379 ppm and rising by 2 ppm per year. Limiting the total increase in mean global temperature to approximately 1°C by 2100 would require stabilisation of atmospheric greenhouse gases and aerosols close to their existing levels. Increasing atmospheric greenhouse gases and aerosols to 450-550 ppm carbon dioxide equivalents is expected to result in a 2-3°C rise in mean surface temperatures. These increases are expected to severely degrade the GBR by 2030-2040. There are currently no international or national legal constraints to hold greenhouse gas concentrations beneath these thresholds and they appear likely to be exceeded, which indicates the environmental legal system protecting the GBR is not likely to be effective in relation to climate change.

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[89] Popp, n 59.

[90] Peel J, "The Role of Climate Change Litigation in Australia's Response to Global Warming" (2007) 24 EPLJ 90 at 103 (footnotes omitted).

[91] Sullivan R, "Greenhouse Challenge Plus: A New Departure or More of the Same?" (2006) 23 EPLJ 60 at 64 (footnote omitted). See also, Sullivan R, *Rethinking Voluntary Approaches in Environmental Policy* (Edward Elgar Publishing, 2005).

It can hardly be doubted that Australian policy should strive to protect the GBR from severe degradation and, consequently, the environmental legal system protecting the GBR should take strong and comprehensive measures to reduce greenhouse gas emissions. Such measures should include setting policy targets for stabilising atmospheric greenhouse gas concentrations and limiting increases in global temperatures. Policy targets of stabilising atmospheric greenhouse gases and aerosols at 450-550 ppm carbon dioxide equivalents to limit increases in mean global temperatures to 2-3°C are likely to be too high to avoid severe impacts of coral bleaching to the GBR. Stabilising greenhouse gases and aerosols around year 2000 levels, giving a net effect of around 370 ppm carbon dioxide equivalents, and allowing a rise in mean global temperature of 1°C, appear to be the highest targets that should be set if the GBR is to be protected from serious degradation. Even though these targets must be achieved by global collaboration and cannot be achieved by Australia in isolation, the Australian government should play an active role in negotiating and implementing these targets if it considers protecting the GBR an important policy objective. At the present time the policies of the Australian government are inconsistent with protecting the GBR from severe impacts from climate change. The likely consequences of such policies should be recognised. Simply ignoring the impacts scientists believe will occur to the GBR is not a satisfactory or even tenable policy option. Choosing not to listen to weather forecasts does not stop it raining.

