CHAPTER 2

THE POTENTIAL IMPACTS OF GLOBAL WARMING

> *The balance of evidence, from changes in global mean surface air temperature and from changes in geographical, seasonal and vertical patterns of atmospheric temperature, suggests a discernible human influence on global climate.*[1]

2.1 This chapter sets out the current state of knowledge about climate change and predictions of future climate change, including at a regional level. The chapter includes a discussion of scientific opinion on the potential for stabilising the global climate system, current areas of uncertainty in relation to the operations of the global climate system, and the predictive ability of climate change models. The chapter concludes with a discussion of the need for further research, particularly in relation to climate change in Australasia and its potential impact on Australia's environment, biodiversity and economy.

Introduction

2.2 The reality of human-induced ('anthropogenic') global warming is now widely accepted in the international community. The Australian Government's National Greenhouse Strategy (NGS) states that:

> The world's climate scientists have provided us with a clear message - that the balance of evidence suggests a discernible human influence on global climate. Scientists have further reported that climate is expected to change in the future as concentrations of greenhouse gases in the atmosphere increase, and that for many regions the effects are likely to be adverse. These findings… have been accepted and endorsed by Australia.[2]

2.3 Greenhouse gases (carbon dioxide CO_2, water vapour H_2O, methane CH_4, nitrous oxide N_2O, and ozone) are naturally present in the atmosphere and have the effect of trapping solar radiation, bringing the average temperature of the Earth to about 15°C. Since the 1950s, scientists have sought to establish whether human activities are changing the volume and composition of these gases in the atmosphere. By comparing contemporary measurements of atmospheric CO_2 with the analysis of

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1 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 2.4.

2 Australian Greenhouse Office, *The National Greenhouse Strategy: Strategic Framework for Advancing Australia's Greenhouse Response*, 1998, p 1.

air recovered from polar ice cores, it has been possible to establish that concentrations of the major greenhouse gases *are* increasing.[3]

2.4 A number of synthetic gases also impact on climate change, including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). Some of these gases have been used as substitutes for ozone depleting substances like CFCs and HCFCs in airconditioners and refrigeration, while SF_6 is used in aluminium, magnesium and semiconductor manufacture. While the quantities of emissions of these gases are currently comparatively low their global warming potency is thousands of times more than carbon dioxide[4] and their use is projected to grow.[5]

2.5 The IPCC cautions that 'stabilisation of the concentrations of very long-lived gases, such as SF_6 or perfluorocarbons, can only be achieved effectively by stopping emissions'.[6] The NGS (Measure 7.2) calls for the development of environmental management strategies for synthetic gases through coordinated action by all jurisdictions in consultation with industry. It states that, 'Governments will work with industry to develop environmental management strategies for each of the synthetic gases included in the Kyoto Protocol - HFCs, PFCs and SF_6. The Strategy for HFCs will address the use of HFCs in non-refillable containers'.[7]

2.6 A 1960s study by the Massachusetts Institute of Technology first documented concerns about climate change and, in the 1970s, the United Nations Secretary General made reference to the possibility of a 'catastrophic warming event' in his report on the environment. Scientific research and international action then began to gather pace with the 1979 World Climate Conference and the establishment of the Intergovernmental Panel on Climate Change (IPCC).[8]

2.7 The IPCC is an international group of over 300 independent scientists and experts that was established to provide the most authoritative assessments of the state of knowledge of global climate change. It was given a mandate to assess the state of existing knowledge about the world's climate system and climate change; the

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3 Dr Chris Mitchell, 'Greenhouse and the Science of uncertainty', *ABC Online*, http://www.abc.net.au/science/earth/climate/uncertain.htm, 1997.

4 The Global Warming Potentials (GWPs) are: HFC-23 11,700, HFC-134a 1,300, Perfluoromethane 6,500, Perfluoroethane 9,200, Perfluoropropane 7,000 and Sulphur Hexaflouride SF_6 23,900. Australian Greenhouse Office, *Synthetic Gas Use in Non-Montreal Protocol Industries*, April 2000, p 3.

5 IPCC Working Group 1, *Summary for Policymakers: The Science of Climate Change*, http://www.ipcc.ch/pub/sarsum1.htm (01/09/00).

6 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change*, clause 4.15.

7 Australian Greenhouse Office, *The National Greenhouse Strategy: Strategic Framework for Advancing Australia's Greenhouse Response*, 1998, p 85.

8 Michael Grubb, *The Kyoto Protocol: A Guide and Assessment*, The Royal Institute of International Affairs, London, 1999, pp 3-4.

environmental, economic, and social impacts of climate change; and the possible response strategies.

2.8 The First Assessment Report of the IPCC, published in 1990, laid the scientific and technical base for the negotiation of the United Nations Framework Convention on Climate Change (UNFCCC). Later work of the IPCC seeks to provide 'scientific, technical and socio-economic information' that will help policymakers interpret and respond to the basic objective of the UNFCCC, as described in Article 2:

> ... 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.[9]

2.9 The IPCC's reports are drafted by leading scientists, and subject to rigorous and exhaustive peer review. The reports provide 'state of the art reviews of the scientific literature in each of the specialised fields of climate science relevant to the determination future climate change'.[10] The draft reports are also reviewed by UNFCCC member governments, and approved at meetings of the IPCC where member governments, intergovernmental and non-governmental organisations are also present. For example, the process of drafting the Second Assessment Report, approved in December 1995, was as follows:

> Following a resolution of the Executive Council of the World Meteorological Organization (July 1992), the IPCC decided to include an examination of approaches to Article 2, the Objective of the UN Framework Convention on Climate Change (UNFCCC), in its work programme. It organized a workshop on the subject in October 1994 in Fortaleza, Brazil, at the invitation of the Government of Brazil. Thereafter, the IPCC Chairman assembled a team of lead authors… under his chairmanship to draft the Synthesis. The team produced the draft which was submitted for expert and government review and comment. The final draft Synthesis was approved line by line by the IPCC at its eleventh session (Rome, 11-15 December 1995), where representatives of 116 governments were present as well as 13 intergovernmental and 25 non-governmental organizations. It may be noted for information that all Member States of the World Meteorological Organization and of the United Nations are Members of the IPCC and can attend its sessions and those of its Working Groups.[11]

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9 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 1.4.

10 Commonwealth Bureau of Meteorology, Submission 207, p 2492.

11 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 1.1.

2.10 The IPCC assessment reports remain the most authoritative account of the state of greenhouse science and of the possible impacts of global climate change. The 1996 Second Assessment Report states that the IPCC's task 'is to provide a sound scientific basis that would enable policymakers to better interpret dangerous anthropogenic interference with the climate system'. The IPCC's reports seek to:

> Highlight what we know about the vulnerabilities of ecosystems and human communities to likely climate changes, especially in regard to agriculture and food production and to other factors such as water availability, health and the impact of sea-level rise which are important considerations for sustainable development.[12]

2.11 During its inquiry, the Committee heard evidence from a number of climate change scientists and organisations, both international and local. International witnesses included the Chairman of the IPCC, Dr Robert Watson; the Hadley Centre for Climate Change Prediction and Research (UK); and the Potsdam Institute for Climate Impacts Research (Germany).

2.12 Within Australia, the Committee heard scientists from the CSIRO Division of Atmospheric Research, the Commonwealth Bureau of Meteorology, Monash University, and the Antarctic Co-operative Research Centre at the University of Tasmania. The Committee also visited the CSIRO's Atmospheric Research Division in Melbourne.

The First and Second IPCC Assessment Reports

2.13 The IPCC has released two major assessments of the state of climate change research, in 1990 and 1995. A third is currently being drafted and reviewed, and is due to be released in 2001. The Committee was also able to hear evidence about some of the possible conclusions of the third assessment.[13]

2.14 The key finding of the First Assessment Report was that atmospheric levels of greenhouse gases were rising due to human activities and that, if they were to continue rising unchecked, global average temperature would rise at around 0.3°C per decade (3°C by 2100). This would represent the fastest sustained global rate of temperature change seen for the last ten thousand years. Within a century such warming could take the Earth to temperatures not experienced since the warm period before the last ice age, over one hundred thousand years ago.[14]

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12 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 1.6.

13 Commonwealth Bureau of Meteorology, Submission 207, p 2492.

14 Michael Grubb, *The Kyoto Protocol: A Guide and Assessment,* The Royal Institute of International Affairs, London, 1999, p 6.

2.15 The Second Assessment Report updated and refined the first assessment based on the growth of scientific research and evidence since 1990, along with improvements to climate change models. In particular, the Report described:

- anthropogenic interference with the climate system, both in terms of interference to the present day and possible consequences of future interference;
- sensitivity and adaptation of systems to climate change, including terrestrial and aquatic ecosystems, hydrology and water resources management, agriculture and forestry, human infrastructure, human health, and technology and policy options for adaptation;
- an analytical approach to the stabilization of atmospheric concentration of greenhouse gases;
- technology and policy options for mitigation;
- equity and social considerations; and
- sustainable paths of economic development, including the social, adaptation and mitigation costs of climate change.[15]

Human-induced climate change to the present day

2.16 The Second Assessment Report stated that atmospheric concentrations of greenhouse gases have grown significantly since pre-industrial times: carbon dioxide (CO_2) from about 280 to almost 360 parts per million by volume (ppmv[3]); methane (CH_4) from 700 to 1720 parts per billion by volume (ppbv); and nitrous oxide (N_2O) from about 275 to about 310 ppbv.[16]

2.17 The Report also stated that global mean surface temperature has risen by between 0.3°C and 0.6°C since the late 19th century, and that global sea levels have risen by between 10 and 25 cm over the past 100 years. Much of this rise, it said, ‘may be related to the global mean temperature’. These temperature and sea level changes, the Report concluded:

> … [are]unlikely to be entirely natural in origin. The balance of evidence, from changes in global mean surface air temperature and from changes in geographical, seasonal and vertical patterns of atmospheric temperature, suggests a discernible human influence on global climate. There are

15 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change.*

16 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 2.2.

> uncertainties in key factors, including the magnitude and patterns of long term natural variability.[17]

2.18 The rise in atmospheric concentrations of greenhouse gases, said the Report, 'can be attributed largely to human activities, mostly fossil fuel use, land use change and agriculture. Concentrations of other anthropogenic greenhouse gases have also increased. An increase of greenhouse gas concentrations leads on average to an additional warming of the atmosphere and the Earth's surface. Many greenhouse gases remain in the atmosphere - and affect climate - for a long time'.[18]

2.19 The Report also acknowledged that while there were high levels of certainty about global trends, it was more difficult to assess patterns of variability or changes at regional scales:

> There are inadequate data to determine whether consistent global changes in climate variability or weather extremes have occurred over the 20th century. On regional scales there is clear evidence of changes in some extremes and climate variability indicators. Some of these changes have been toward greater variability, some have been toward lower variability. However, to date it has not been possible to firmly establish a clear connection between these regional changes and human activities.[19]

2.20 The CSIRO also outlined a range of significant observed changes in climate over the past century. These included:

- the Atlantic, the Pacific and the Indian ocean basins now show warming over the past 20 years;
- the upper atmosphere (lower stratosphere) is showing a cooling trend, consistent with a 'greenhouse' signal;
- a widespread retreat of glaciers in the tropics and mid-latitude regions;
- a record published in 1998 of the recent temperature record in the context of the past 1000 years, shows that 20th century warming counters a millennial-scale cooling trend due to gradual changes in the Earth's orbit;
- precipitation (measured over land) has increased about 1 per cent since the beginning of the 20th century, which is considered statistically significant;

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17 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 2.4.

18 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change, clause 2.2.*

19 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 2.5.

- consistent with the increase in precipitation is an increase in cloud cover and a decrease in the difference between day and night temperatures;
- heavy extreme precipitation has generally increased in areas where average precipitation has risen;
- the pressure at high altitude observations is increasing consistent with surface warming; and
- the temperature profiles down bore-holes in the earth's crust indicate recent global warming.[20]

Possible consequences of future interference

2.21 The IPCC's Second Assessment Report refined previous models and developed six global warming scenarios (IS92a-f), with projections based on an assumption of little or no abatement action. The models differ according to a graded range of assumptions about population and economic growth, land-use, technological change, energy availability and fuel use. They predict emissions increases between 1990 and 2100. The scenarios predict that by 2100 CO_2 emissions would range from approximately six billion tonnes (similar to present levels) assuming low population and economic growth, to as much as 36 billion tonnes.[21]

2.22 A summary of the assumptions used by the IPCC in developing these models is listed below:

Table 2.1

THE 1992 IPCC SCENARIOS - SUMMARY OF ASSUMPTIONS[22]			
Scenario	**Population**	**Economic Growth**	**Energy Supplies**
IS92a,b	World Bank 1991 11.3 billion by 2100	1990-2025: 2.9% 1990-2100: 2.3%	12,000 EJ conventional oil 13,000 EJ natural gas Solar costs fall to $0.075/kWh 191 EJ of biofuels available at $70/barrel
IS92c	UN MediumLow Case 6.4 billion by 2100	1990-2025: 2.0% 1990-2100: 1.2%	8,000 EJ conventional oil Nuclear costs decline by 0.4% annually

20 CSIRO, Submission 206, p 2463.

21 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 2.6.

22 Source: IPCC Working Group 11, *Summary for Policymakers: Scientific Technical Analyses of Impacts, Adaptations and Mitigation of Climate Change*, section 1.

IS92d	UN MediumLow Case 6.4 billion by 2100	1990-2025: 2.7% 1990-2100: 2.0%	Oil and gas same as IS92c Solar costs fall to $0.065/kWh 272 EJ of biofuels available at $50/barrel
IS92e	World Bank 1991 11.3 billion by 2100	1990-2025: 3.5% 1990-2100: 3.0%	18,400 EJ conventional oil Gas same as IS92a,b Phase out nuclear by 2075
IS92f	UN MediumHigh Case 17.6 billion by 2100	1990-2025: 2.9% 1990-2100: 2.3%	Oil and gas same as IS92e Solar costs fall to $0.083/kWh Nuclear costs increase to $0.09/kWh

2.23 Low range emissions scenarios (IS92c) combined with low values for climate sensitivity predict a temperature increase of 1°C by 2100, the mid-range scenario (IS92a) predicts 2°C and the highest range (IS92e) scenarios 3.5°C. The IPCC stated that in all cases the rate of warming would be greater than the last ten thousand years, and that only 50 to 90 per cent of the total temperature change would have been realised by 2100 owing to the thermal inertia of the oceans. Temperatures would continue to increase beyond that time, even if the level of greenhouse gases had been stabilised.[23]

2.24 The same models also predict possible sea-level rises due to thermal expansion of the oceans and the melting of glaciers and ice-sheets. The mid-range IS92a scenario predicts a rise of 50 cm by 2100, whilst the highest emissions scenario projects a rise of 95 cm. Again, these rises would continue beyond 2100 even if emissions were stabilised. The IPCC states that models built on the scale of hemispheres or continents produce more certainty, while regional level changes are less easy to model, and that there is greater confidence in temperature projections than hydrological changes.[24]

2.25 In summary, the IPCC explained that:

> All model simulations… show the following features: greater surface warming of the land than the sea in winter; a maximum surface warming in high northern latitudes in winter; little surface warming over the Arctic in

23 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 2.7.

24 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 2.8.

> summer; an enhanced global mean hydrological cycle; and increased precipitation and soil moisture in high latitudes in winter… .
>
> Warmer temperatures will lead to a more vigorous hydrological cycle; this translates into prospects for more severe droughts and/or floods in some places and less severe droughts and or floods in other places. Several models indicate an increase in precipitation intensity, suggesting a possibility for more extreme rainfall events. Knowledge is currently insufficient to say whether there will be any changes in the occurrence or geographical distribution of severe storms such as tropical cyclones.[25]

2.26 The Second Assessment Report also sought to predict the impacts of these trends on ecosystems and human communities. Reviewing the available scientific studies, the IPCC suggested that global warming could have the following natural effects:

- a reduction in biodiversity;
- altered growing seasons and boundary changes between grasslands, shrublands and forests;
- major changes in the vegetation types of one third of the world's forests, with the greatest changes at high latitudes and the least in the tropics. Entire forest types could disappear while new ecosystems are established. During such periods of high forest mortality large amounts of CO_2 could be released into the atmosphere;
- higher temperatures in deserts, threatening sensitive organisms, and increased desertification in arid and semi-arid areas;
- the extinction of some high altitude species due to loss of habitat;
- a geographical redistribution of wetlands, and increased risks to sensitive coastal ecosystems such as saltwater marshes, mangroves, beaches, coral reefs and river deltas; and
- the extinction of aquatic species at the low-latitude boundaries of cold and cool water species ranges.[26]

2.27 Possible effects on human communities and productivity include radical and hard-to-predict changes to crop yields and productivity, which could vary markedly across localities. While the IPCC thought that mean global production levels could be maintained in the face of climate change, the potential effect of increased pests or

25 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clauses 2.10-2.12.

26 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clauses 3.6-3.10.

possible climate variabilities has not been factored into existing studies. There were serious concerns about the regional level impacts of climate change on food production and nutrition.[27]

2.28 The IPCC clearly stated that there was increased risk of hunger and famine in some locations. The world's poorest people, especially those living in tropical and sub-tropical areas or dependent on isolated agricultural systems in arid and semi-arid regions, were most at risk. The IPCC also said that warming would exacerbate other trends in reducing the availability of global wood supplies.[28]

2.29 Other projections indicate very serious potential impacts in the form of flooding, storms and land losses. Coastal populations are most at risk. With a 50 cm rise in sea-level, the numbers of people currently at risk from flooding as a result of storm surges would increase from 46 million per year to 92 million. A 100 cm rise would increase the vulnerable to 118 million, and while this is at the extreme end of IPCC estimates, they point out that sea-level rise will continue beyond 2100. They state that studies using the one metre projection indicate serious risks for small islands and deltas, which is of particular concern to some Pacific island nations.[29]

2.30 The IPCC estimates that land losses from sea-level rise would range from 0.05 per cent in Uruguay, one per cent for Egypt, six per cent for the Netherlands, 17.5 per cent in Bangladesh to 80 per cent in Majura Atoll in the Marshall islands. The IPCC stated that countries with higher population densities would be more vulnerable and that, in some cases, flooding 'could threaten entire cultures'. In such cases, 'sea-level rise could force internal or international migration of populations'.[30]

2.31 The assessment also stated that 'climate change is likely to have wide-ranging and mostly adverse effects on human health, with significant loss of life'. These include:

- increases in mortality and illness from the higher intensity and duration of heatwaves, with cardio-respiratory illness the most likely danger;
- fewer cold-related deaths due to temperature rises in cold regions;

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27 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 3.13.

28 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 3.13.

29 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 3.14.

30 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 3.14.

- indirect effects such as potential for increased incidence of vector-borne disease (malaria, dengue, yellow fever and viral encephalitis), because of the extended geographical and temperature range for vector organisms such as mosquitos;
- some increases in non-vector borne diseases like cholera, giardia and salmonella through higher temperatures and flooding; and
- a potential reduction in fresh water supplies and nutritious food, and increased air pollution.[31]

More Recent Scientific Findings

2.32 In the course of its inquiry, the Committee heard from a number of leading international and Australian scientists and scientific organisations on the latest global warming trends and impacts. A number of these witnesses are lead authors for the IPCC Third Assessment Report to be completed in 2001. The Committee was told that most research since the IPCC Second Assessment Report strengthens the conclusion that the balance of evidence suggests a discernible human influence on climate. Climate scientists believe that attempts to quantify the anthropogenic influence indicate that it may account for a substantial fraction of the observed global temperature change over the 20th century.

2.33 In recent years, estimation of anthropogenic signals has been improved through the use of newer climate models, ensemble simulations and the inclusion of additional anthropogenic and natural factors. Statistical techniques have been extended, in particular applying optimal detection methods and estimating both natural and anthropogenic signals based on spatial and temporal information. The robustness of results to the use of different assumptions and different model data has been improved.[32]

2.34 Most studies indicate that some human influence is needed to explain 20th century temperature changes. Regression techniques in a number of studies suggest that model estimates of anthropogenic temperature changes are broadly consistent with observed changes.[33]

2.35 The Director of the Australian Bureau of Meteorology, Professor John Zillman, told the Committee that the forthcoming Third Assessment Report of the IPCC ‘strengthens the conclusion that ‘the balance of evidence suggests a discernible human influence on global climate’. He listed a number of key messages coming out of the drafting process for the Report:

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31 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clauses 3.14-3.16.

32 Professor David Karoly, Submission 204, p 2.

33 Professor David Karoly, Submission 204, p 2.

> The first is that the evidence for sustained global warming over the past century, but particularly since 1945, is stronger than at the time of the finalisation of the Second Assessment Report of the IPCC in 1995. Most of the earlier discrepancies that have been debated between satellite measurements and surface measurements of temperature in the atmosphere appear to have been resolved. Also… new reconstructions of the temperature trends over the Northern Hemisphere for the past 1,000 years suggests that the recent warmth - that is in the last two decades - is unprecedented over this time frame.
>
> The second key message is that both the present atmospheric concentration of carbon dioxide and its rate of increase during the past 420,000 years are unprecedented and that the present concentration has probably not been exceeded during the past 15 million years.
>
> The third message is that most research since the Second Assessment Report of the IPCC in 1995 strengthens the conclusion that… the balance of evidence suggests a discernible human influence on global climate… . Furthermore, it now appears that, on the basis of more rigorous and comprehensive statistical techniques, human activity may account for a substantial fraction of the observed global temperature increase during the 20th century.[34]

2.36 Professor Zillman also cautioned that these strengthening conclusions were tempered by other uncertainties:

> The reliability of these conclusions, however, continues to be limited by uncertainties in the observation record and in the estimates of the internal natural variability of the climate system of the radiative forcing - that is the effects of the greenhouse gases - and of general climate system response to external influences such as volcanoes and fluctuations in the energy coming from the sun and so on.[35]

2.37 In evidence to the Committee, Dr Geoff Jenkins of the United Kingdom's Hadley Centre for Climate Prediction and Research, explained the recent findings of the Centre's latest climate change model, HADCM3. He argued that this model has achieved a better representation of climate and climate change than previous models through a better resolution of the ocean and the coupling of ocean, atmospheric and land surface measurements, and has largely confirmed the IPCC's Second Assessment Report climate predictions:

> We believe that the prediction in the future is pretty much as we would have expected, based on past climate change over the past 150 years. So the predictions in the future are maybe slightly too high, but not very much too high, and the uncertainty range of 5 per cent to 95 per cent… is not one million miles away from the IPCC figures of 1.5 to 4.5. So we do believe

34 *Proof Committee Hansard*, Melbourne, 20 March 2000, p 129.

35 *Proof Committee Hansard*, Melbourne, 20 March 2000, p 129.

> we have shown… that both the central prediction and range of predictions are pretty much as IPCC would have it.[36]

2.38 The Committee also heard evidence from the Chairman of the IPCC, Dr Robert Watson. Although the IPCC has not yet publicly released the results from its Third Assessment Report, which is currently under peer review, Dr Watson advised the Committee in general terms that the most recent modelling largely reinforces its previous findings and those of other modelling agencies such as the Hadley Centre:

> In the Second Assessment Report we came up with a range of plausible [increases] in global mean surface temperature of one to 3.5°C. If you use these more recent emission scenarios, which have yet to be approved, we are probably going to see a slightly larger range. If you take both the range of the socioeconomic conditions with the range of climate sensitivity, I would imagine we are going to see a range of something like 1°C to 5°C.[37]

2.39 Dr Robert Watson then outlined to the Committee the main consequences of increasing global temperatures over the next 100 years for issues such as water resources, agriculture, coral reefs, forests, human health and human settlements. Many of his statements in relation to these issues mirrored those listed earlier in this chapter, from the IPCC's Second Assessment Report. In summary, he told the Committee that:

- water resources will be significantly affected. Arid and semi arid areas of the world, especially in the northern parts of Africa, the southern parts of Africa, areas in Latin America, the Middle East and the southern Mediterranean will become considerably drier. These areas, which suffer from drought today, will also be more adversely affected by drought in the future;
- water stressed or water scarce areas, which currently occupy less than 10 per cent of the world today, will probably increase to 50 per cent by 2050;
- globally, agriculture may not be significantly affected due to the effects of carbon dioxide fertilisation in some parts of the world. However, regionally there could be significant changes in agricultural productivity with significant decreases in Africa, the Middle East and Latin America, areas where water resources will become more scarce;
- a sustained increase in temperature of 2°C to 4°C could lead to a significant adverse effect on coral reefs around the world;
- one-third of all forest tree species will no longer be viable in a world with double pre-industrial CO_2 levels;

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36 *Official Committee Hansard*, Canberra, 9 March 2000, p 22.

37 *Official Committee Hansard*, Canberra, 9 March 2000, p 35.

- there will be increases in vector-borne diseases, especially malaria and dengue fever. Water borne diseases such as cholera will also become more prevalent, as too will heat stress mortality; and
- tens of millions of people could be displaced, especially from small island states and deltaic systems in Egypt, Bangladesh and China.[38]

2.40 In particular, Dr Watson stressed that developing countries would be particularly vulnerable to climate change:

> Overall, if one were to try and summarise the impact of likely climate change, one would say that developing countries are much more vulnerable than developed countries, largely because they do not have the technical, economic and institutional capacity to deal with climate change and to adapt to climate change. The poor in these countries are the most vulnerable.[39]

2.41 Both Dr Jenkins and Dr Watson told the Committee that considerable evidence now exists which supports the contention that human activities are in part responsible for increases in global temperatures over the latter half of the 20th century:

- Dr Jenkins:

> On the attribution question… the more work we do - not just ourselves but other people as well - the more the pointers are in the direction of a substantial proportion of the temperature rise over the last 50 years being attributable to human activities.[40]

- Dr Watson:

> It is quite clear that human activities are increasing the atmospheric burden of greenhouse gases, in particular carbon dioxide, primarily from the combustion of fossil fuels, coal, oil, and gas and through land use change - [and] primarily at the moment [through] deforestation in the tropics.[41]

2.42 These conclusions are also shared by Australian climate scientist Professor David Karoly, Convening Lead Author of the IPCC Third Assessment Report chapter 'Detection of climate change and attribution causes'. Professor Karoly told the Committee:

> In the Second Assessment Report there was a conclusion that was reached that stated that the balance of evidence suggested discernible human influence on global climate. The evidence collected since that time… strengthens the evidence that there has been a discernible human influence

38 *Official Committee Hansard*, Canberra, 9 March 2000, p 35.

39 *Official Committee Hansard*, Canberra, 9 March 2000, p 35.

40 *Official Committee Hansard*, Canberra, 9 March 2000, p 22.

41 *Official Committee Hansard*, Canberra, 9 March 2000, p 34.

> on climate. The attempts to try to quantify that human influence on climate suggest that a substantial fraction of the global temperature change over the last century is most likely attributable or due to human activity. We cannot say exactly how much, but [it is] a substantial fraction.[42]

2.43 Recently, the robustness of climate change models, such as the Hadley Centre's HADCM3, have been improved by incorporating important climate change feedback mechanisms such as the sulphur cycle - the oxidation of sulphur dioxide into aerosol particles and the subsequent cooling effect on the atmosphere, and the carbon cycle - the effects of climate change on the natural carbon cycle.

2.44 In the case of the latter, Dr Jenkins told the Committee that a 'reasonably high positive feedback' will result from the carbon cycle which will accentuate global warming over the course of the 21st century. As temperatures rise the amount of carbon stored in soils increases, which in turn creates more emissions as soil temperatures increase and release carbon back into the atmosphere.[43]

2.45 In his evidence to the Committee, Professor Karoly also discussed the effects of feedbacks on climate system. He warned the Committee that carbon cycle feedbacks actually cause accelerated emissions of carbon because of the loss of plants in forests and other factors, making it even harder to achieve stabilisation of emissions. He went on to explain that:

> If those feedbacks are taken into account, we are in an even worse situation if the climate warms. If there are changes in the natural carbon cycle which produce natural reductions in carbon uptake, we are even worse [off] than that, and we have to come down to even lower human emissions. I think that we have to think of an analogy. We have a tap, which are the carbon emissions that are still running. Unless we effectively turn that tap off, the bucket, which is the atmospheric carbon concentrations, will keep on increasing. So unless that tap is really turned off to just a trickle, the bucket is going to keep on going up and up and up. To stabilise carbon dioxide concentrations requires very substantial reductions in how much that tap is turned on.[44]

2.46 The Hadley Centre's climate change modelling supports the mid-range sea-level rise predictions made by the IPCC's 1996 assessment: half a metre over the next 100 years. In addition, Dr Jenkins confirmed the IPCC's earlier conclusion that sea-level rise would continue beyond 2100, even if emissions were stabilised. In a recent Hadley Centre climate change model experiment, the effects of global warming on sea-level rise were simulated over a 70 year period. Greenhouse gases were allowed to increase at the rate of 1 per cent per year. After 70 years these gases were then

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42 *Official Committee Hansard*, Canberra, 9 March 2000, p 40.

43 *Official Committee Hansard*, Canberra, 9 March 2000, p 23.

44 *Official Committee Hansard*, Canberra, 9 March 2000, p 43.

stabilised at about double pre-industrial concentrations (about 550 ppmv) and the model was allowed to run for a further 800 years:

> We found that due to this penetration of the warming that starts at the top and penetrates deeper and deeper into the ocean, that the expansion of the ocean carries on for the whole of this period for many hundreds of years afterwards, and the melting of land ice carries on for maybe two or three centuries until basically all the land ice has gone. So the actual sea level rise over that few hundred year period carries on and on almost as if the climate change stabilisation after 70 years had not occurred at all. So you end up with sea level rises of maybe 10 times the original sea level rise even though climate change has been stabilised. We think that points to a very long commitment over a very long period with sea level rise that has to be borne in mind.[45]

2.47 The Committee received similar evidence on the effects of climate change on sea-level rise over the next few centuries from Dr Watson of the IPCC:

> … even if we stabilise atmospheric concentrations of greenhouse gases which then maybe 50 years later we would stabilise the earth's climate, sea-level would continue to rise for many, many centuries… .[Sea-level rise] would be somewhere between one-half and one-and-a-half metres over the next 200 or 300 years… .[46]

2.48 Dr Jenkins went on to inform the Committee that the implications of sea-level rise for small island nations and other states could be very significant, even if the increase is relatively small:

> Some island states and other countries such as India and Bangladesh, where even a relatively small rise in sea level combined with storm surges that you get when depressions, storms and cyclones go through, can produce quite a big change in the frequency of currents, given the high water levels. Because of the frequency of occurrence of high water and the high water itself - it is a logarithmic one - you do not have to change sea level much to get quite a large increase in the frequency of the occurrence of storm surges in some areas.[47]

Regional Climate Change: Australasia

2.49 According to Australian climate scientist Dr Barrie Pittock, Australia is the most vulnerable OECD country to the impacts of climate change because of its low latitudes and naturally occurring high temperatures which are already above optimum levels. In addition, Australia is relatively arid, particularly in the more populated parts of southern Australia and although the tropical north in the monsoon season has a

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45 *Official Committee Hansard*, Canberra, 9 March 2000, p 24.

46 *Official Committee Hansard*, Canberra, 9 March 2000, p 38.

47 *Official Committee Hansard*, Canberra, 9 March 2000, p 26.

surplus of water, the rest of Australia, with the exception of Tasmania, often suffers from drought:

> The suggestion is that the sort of stresses we have now will get much worse as a result of climate change. That has to be weighed in to our policy thinking. It is not an altruistic thing that we are talking about. It is something which is in our own interests.[48]

2.50 Dr Pittock's conclusions were echoed in evidence to the Committee by German climate scientist and coordinating lead officer for the IPCC's synthesis chapter on global vulnerability for the Third Assessment Report, Professor Dr Hans-Joachim Schellnhuber. Professor Schellnhuber told the Committee that Australia may be among the most vulnerable regions due to the isolated evolution of its ecosystems, to aridity and in part due to its immense coastline. The natural consequence of this was that:

> … it seems reasonable [for Australia] to support emissions reductions… but also to prepare for adapting to the unavoidable climatic change. Adaptation policy and risk management seem to be a major challenge for your country.[49]

Earlier regional impact studies

2.51 In 1997 the IPCC reported on its collation of regional level projections for Australasia and other regions of the world. In addition, the potential impacts on our region have been the focus of research efforts by the CSIRO.

2.52 In presenting their estimates, as part of an assessment of the potential impacts of global warming on a number of discrete global regions, the IPCC qualified their analysis by saying that regional level predictions were: 'necessarily qualitative… because the available studies have not employed a common set of climate scenarios and methods, and because of uncertainties regarding the sensitivities and adaptability of natural and social systems'.[50]

2.53 The IPCC said that 'some of the [Australasian] region's ecosystems appear to be very vulnerable to climate change, at least in the long term, because alterations to soils, plants and ecosystems are very likely, and there may be increases in fire occurrence and insect outbreaks'. Possible impacts of climate change on the region include:

- a 'highly likely' reduction of species diversity, despite some adaptation potential;

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48 Dr Barrie Pittock, *Proof Committee Hansard*, Canberra, 22 June 2000, p 736.

49 Professor Dr Hans-Joachim Schellnhuber, *Proof Committee Hansard*, Canberra, 22 June 2000, p 733.

50 Robert Watson, Marufu Zinyowera, Richard Moss, David Dokken ed. *The Regional Impacts of Climate change: An Assessment of Vulnerability, Summary for Policymakers,* Intergovernmental Panel on Climate Change, 1997, p 2.

- the exacerbation of existing problems of land degradation, weed and pest infestation;
- changes to river flows, flood frequencies and nutrient and sediment outputs particularly in drier areas;
- increased bleaching and death of coral due to higher sea temperatures;
- damage to coastal ecosystems and communities, especially indigenous communities, through sea-level rise, flooding and weather changes;
- vulnerability to falls in the availability of water, especially in drought prone areas;
- more frequent rainfall events which, while filling dams and replenishing groundwater, could worsen flooding, landslides and erosion;
- reduced snowpack, a shorter ski season, and further shrinkage of New Zealand's glaciers;
- a long term trend to increased agricultural vulnerability as initial growth gains are eroded by rainfall and soil changes, especially with irrigated crops and range pastoralism, and economic effects through changed prices of agricultural imports;
- longer maturity times for forests, increasing the financial risks involved in plantations; and
- other climate-related impacts on air quality, drainage, waste disposal, mining, insurance and tourism, which will interact with other human and economic factors.[51]

2.54 The IPCC's predictions about the impact of global warming on coral reefs were supported by analysis published in 1998 by Professor Ove Hoegh-Guldberg of the Coral Reef Research Institute at the University of Sydney. It stated that coral reefs were close to their upper thermal limits, due to an increase of 1°C in sea temperatures since 1900, and that 1998 saw some of the worst bleaching and coral death yet recorded in many reefs around the world. The report built four simulations from global climate models which predict that 'the thermal tolerances of reef-building corals are likely to be exceeded within the next few decades'. Bleaching events like those in 1998 could become commonplace within 20 years and are likely to occur annually within 50 years. The southern and central parts of the Great Barrier Reef

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51 Robert Watson, Marufu Zinyowera, Richard Moss, David Dokken ed., *The Regional Impacts of Climate change: An Assessment of Vulnerability, Summary for Policymakers,* Intergovernmental Panel on Climate Change, 1997, pp 9-10.

could be vulnerable to increased bleaching within the next 20 to 40 years, and northern parts of the reef in 60 years.[52]

2.55 In evidence to the Committee, Professor Hoegh-Guldberg and Dr Peter Doherty from the Australian Institute of Marine Science (AIMS), said that 1998 saw the warmest sea temperatures on record, both globally and in Australian waters. Professor Hoegh-Guldberg said that there had been six mass bleaching events since 1979, events which were largely unknown before that year and were caused by 'higher than normal temperature signals in the ocean'. During 1998, coral reefs in the Maldives, Okinawa and Palau were wiped out by bleaching. Areas of the Great Barrier Reef were also affected and, while some managed to recover within 18 months, two reefs north of Townsville sustained irreversible damage. Dr Doherty said that they 'were subjected to some of the hottest water for the longest periods, had the most complete bleaching, and there was substantial death of the coral subsequently'.[53]

2.56 Dr Hoegh-Guldberg emphasised the economic and environmental importance of the reefs, both for stabilising coastal ecosystems and tourism:

> … there is a possibility that the expected increase in mass bleaching and mortality may lead to the collapse of coral dominated ecosystems. If that happens you have to look at what coral reefs are to people in the world. One hundred million depend directly on coral reefs. In Australia, there are key fisheries - we have million-dollar industries; we have got billion-dollar tourism; and, of course, if we look at the state of Queensland, entire coastlines are stabilised by coral reefs.[54]

2.57 In November 1996 the CSIRO published a summary of its own research on the regional impact of global warming. In doing so, it used the assumptions underpinning the IPCC's 1996 Assessment Report and combined them with regional climate change models. Regional scenarios were then matched with the IPCC's range of possible changes (IS92a-f). The changes they discussed included:

- regional temperature increases;
- changes in precipitation;
- tropical cyclones; and
- soil moisture and runoff.[55]

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52 Professor Ove Hoegh-Guldberg, *Climate Change, Coral Bleaching and the Future of the World's Coral Reefs*, Coral Reef Research Institute, Sydney, 1998.

53 *Proof Committee Hansard*, Brisbane, 26 May 2000, pp 642-29.

54 *Proof Committee Hansard*, Brisbane, 26 May 2000, p 643.

55 Climate Impact Group, *Climate Change Scenarios for the Australian Region*, CSIRO Division of Atmospheric Research, Melbourne, 1996.

2.58 Regional sea-level changes are the subject of continuing research, and no special estimates were included in the 1996 paper. Temperature changes were plotted for three broad regions (the coast north of 25°S, the coast south of 25°S, and inland), and for high to low change scenarios.[56]

2.59 Inland temperatures were predicted to rise from between 0.4°C and 1.4°C by 2030, and from 0.7°C to 3.8°C by 2070. On the northern coast, increases range from 0.3°C to 1°C by 2030 and 0.6°C to 2.7°C by 2070. On the southern coasts, increases range from 0.3°C to 1.3°C by 2030 and 0.6°C to 3.4°C by 2070. These figures can be compared with the IPCC's global mean estimates of between 1°C to 3.5°C temperature increase by 2100.[57]

2.60 Precipitation changes were modelled using both 'coupled' (atmosphere plus ocean circulation temperature) and 'slab' (atmosphere plus surface ocean temperature only) models. It is believed that fully coupled models produce more reliable results, but results from slab models have also been developed because of uncertainties about coupled models and because, in the Australian region, the two models sometimes produce very different results.[58] Future rainfall patterns could also be affected by difficult-to-model local changes in ocean circulation, in large-scale atmospheric circulation (due to high sulphate aerosols in Asia) and changes in El Nino-Southern Oscillation (ENSO) behaviour. Rainfall changes were projected for winter across three broad regions and, in summer, for two broad regions.[59]

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56 Climate Impact Group, *Climate Change Scenarios for the Australian Region,* CSIRO Division of Atmospheric Research, Melbourne, 1996, p 2.

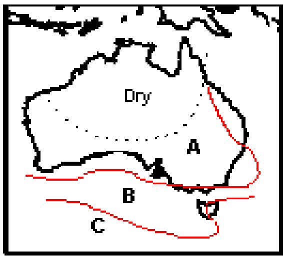
57 Climate Impact Group, *Climate Change Scenarios for the Australian Region,* CSIRO Division of Atmospheric Research, Melbourne, 1996, p 3.

58 The CSIRO states that, over Australia, coupled models tend to produce summer rainfall decreases and slab models summer rainfall increases. They also show that rainfall changes differ between the models because the coupled models include a strong delay in warming in the higher latitudes of the southern hemisphere. However, there is considerable uncertainty about the ocean processes which lead to this result. There are also conflicts between coupled model simulations and observed 20th Century trends in some aspects of warming in the southern hemisphere, although there are some doubts whether this is greenhouse related. Climate Impact Group, *Climate Change Scenarios for the Australian Region,* CSIRO Division of Atmospheric Research, Melbourne, 1996, p 4.

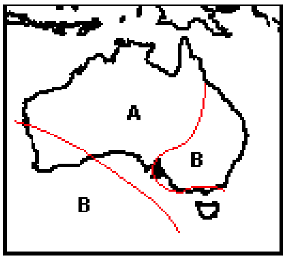
59 Climate Impact Group, *Climate Change Scenarios for the Australian Region,* CSIRO Division of Atmospheric Research, Melbourne, 1996, pp 3-4.

Figure 2.1

CSIRO Scenarios of precipitation change for the Australian region based on 'coupled' models



Winter



Summer

WINTER			
Location	**Response per degree of global warming**	**Change in 2030**	**Change in 2070**
Region A	-10 to 0%	-8 to 0%	-20 to 0%
Region B	-5 to +5%	-4 to +4%	-10 to +10%
Region C	0 to +10%	0 to +8%	0 to +20%

SUMMER			
Location	**Response per degree of global warming**	**Change in 2030**	**Change in 2070**
Region A	-10 to 0%	-8 to 0%	-20 to 0%
Region B	-5 to +5%	-4 to +4%	-10 to +10%

2.61 In both models, areas that had very low rainfall in winter, in the north and centre of Australia, would remain dry. Coupled models predicted the following changes:

- In *winter*, the area comprising most of the south and east, but not the Queensland coast, would see falls of between zero and 8 per cent by 2030 and zero and 20 per cent by 2070. The Queensland coast, parts of Tasmania and seas to the south of Australia would see a range from a fall of 4 per cent to an 8 per cent increase by 2030, and a fall of 10 per cent to an increase of 10 per cent by 2070.

Northeast Tasmania and the Southern Ocean would see increases of between zero and 8 per cent by 2030 and zero and 20 per cent by 2070.

- In *summer*, south, central and northern Australia (excluding the southwest of Western Australia and including Tasmania) would see falls of between zero and 8 per cent by 2030 and of zero to 20 per cent by 2070. In the eastern states south of Cairns, there would be a range of –4 to +4 per cent by 2030 and –10 to +10 per cent by 2070.[60]

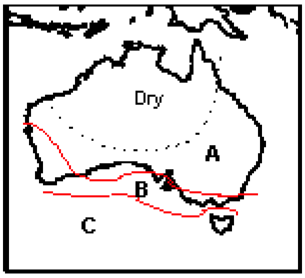
2.62 Using slab models, the predicted changes were:

- In *winter*, in the band from Shark Bay in Western Australia around to Cairns and the Victorian coast, falls of between zero and 4 per cent by 2030, and of between zero and 10 per cent by 2070. Southwest Western Australia, the northern part of the Southern Ocean and southern Victoria could experience a changes of –2 to +2 per cent by 2030 and –5 to +5 per cent by 2070. In the Southern Ocean and Tasmania there could be increases of between zero and 4 per cent by 2030 and zero and 10 per cent by 2070.

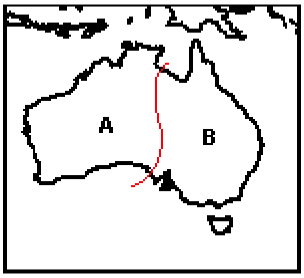
- In *summer*, the western half of the continent would see increases from 2 to 12 per cent by 2030 and from 4 to 30 per cent by 2070. The eastern half would see increases of between zero and 8 per cent by 2030 and zero to 20 per cent by 2070.[61]

Figure 2.2

CSIRO Scenarios for precipitation change for the Australian region based on 'slab' models



Winter



Summer

60 Climate Impact Group, *Climate Change Scenarios for the Australian Region*, CSIRO Division of Atmospheric Research, Melbourne, 1996, pp 3-4.

61 Climate Impact Group, *Climate Change Scenarios for the Australian Region*, CSIRO Division of Atmospheric Research, Melbourne, 1996, pp 3-4.

WINTER			
Location	**Response per degree of global warming**	**Change in 2030**	**Change in 2070**
Region A	-5 to 0%	-4 to 0%	-10 to 0%
Region B	-2.5 to +2.5%	-2 to +2%	-5 to +5%
Region C	0 to +5%	0 to +4%	0 to +10%

SUMMER			
Location	**Response per degree of global warming**	**Change in 2030**	**Change in 2070**
Region A	+5 to 15%	+2 to +12%	+4 to +30%
Region B	0 to +10%	0 to +8%	0 to +20%

2.63 The CSIRO also commented that where models simulated an *increase* in average rainfall, this would be accompanied by an increase in intensity, leading to heavier and more frequent rain. Where falls in rainfall were simulated this tendency was less marked or absent.[62]

2.64 Notwithstanding the manifest uncertainties regarding exact predictions between models and in some regions, in general the models predict large changes in rainfall in a relatively short period. The CSIRO also states that 'significantly larger or smaller changes would apply at the local scale, particularly in locations where topography still controls weather patterns'.[63] Should precipitation changes approach the extreme end of these predictions, substantial changes to Australian climate, agriculture, flooding patterns, vegetation and biodiversity could be expected.

62 Climate Impact Group, *Climate Change Scenarios for the Australian Region,* CSIRO Division of Atmospheric Research, Melbourne, 1996, p 5.

63 Climate Impact Group, *Climate Change Scenarios for the Australian Region,* CSIRO Division of Atmospheric Research, Melbourne, 1996, p 5.

2.65 The CSIRO stated that tropical cyclones were difficult to model and continued to be a research priority. Present indications were that their region of origin would be unchanged, that there may be some increase in intensity, that their paths may change and that their location and frequency were also affected by ENSO patterns.[64]

2.66 Soil moisture and runoff are particularly important for agriculture and biodiversity. They are sensitive to changes in temperature (increasing evaporation) and changes in rainfall. The CSIRO stated that uncertainties remain about quantifying the exact hydrological response for a given climate change scenario.[65]

More recent regional impact studies

2.67 New regional warming and rainfall change scenarios have recently been provided for the IPCC by an international group of authors for the Special Report on Emissions Scenarios (SRES).[66] Based on recent projections with seven different coupled ocean-atmosphere global climate models (AOGCMs), these scenarios suggest warmings over Australia by the 2050s, relative to mid-20th century conditions, of between 1°C and 4°C depending on location and scenario, with most warming in inland areas. Warmings in the 2080s are estimated to be in a range of approximately 2°C to 5.5°C.[67]

2.68 Corresponding rainfall change estimates are for rainfall decreases in the 2050s and 2080s in excess of one standard deviation (i.e. tens of per cent) compared with long term (30-year average) natural variability over much of southern, and especially south-western Australia, possibly as far north as southern Queensland. According to these results, only Tasmania will receive any substantial increase in rainfall.[68]

2.69 These conclusions have been supported by a recently released study by the Government of Western Australia, which endeavoured to examine the impacts of climate change on that State at a finer scale than had previously been undertaken. The Committee was told that the report:

> … indicates that in the south-west in the period 2010-39 we expect a temperature increase of between 0.5°C and 1.6°C, and by 2100 an estimate of between 2°C and 4.5°C. One of the other issues that is particularly significant for Western Australia - it is not consistent with the predictions for elsewhere in Australia - is a 20 per cent decrease in winter rainfall - most

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64 Climate Impact Group, *Climate Change Scenarios for the Australian Region,* CSIRO Division of Atmospheric Research, Melbourne, 1996, p 5.

65 Climate Impact Group, *Climate Change Scenarios for the Australian Region,* CSIRO Division of Atmospheric Research, Melbourne, 1996, p 6.

66 Intergovernmental Panel on Climate Change, *Special Report on Emission Scenarios,* A Special Report of Working Group III, May 2000.

67 Dr Barrie Pittock, Submission 220, p 4.

68 Dr Barrie Pittock, Submission 220, p 4.

> of the rainfall occurs in winter in Western Australia - in the period 2040-69.[69]

2.70 In his submission to the inquiry, Dr Barrie Pittock stated that the new IPCC regional warming and rainfall change scenarios suggest a more negative rainfall outlook than was presented by the CSIRO in its 1996 scenarios. His submission then proceeds to outline the implications of what he describes as 'the new global consensus on regional change over Australia'.[70]

2.71 Dr Pittock cites a number of examples from the AOGCMs which illustrate the likely consequences of the generally drier scenarios facing Australia, including:

- reductions in average river flow of between 12 and 32 per cent by 2030 for the Macquarie River catchment in New South Wales;
- decreased run-off over most of Australia, by 30 per cent in the Murray Darling Basin by the 2050s, with similar decreases in the south-west of Western Australia;
- increased drought severity in south-eastern and eastern Australia;
- significant problems associated with maintaining environmental flows in inland waterways and bird breeding ephemeral lakes, water allocation problems, and salinisation issues as a result of climate change;
- the exposure of the built environment, particularly Queensland coast, to tropical cyclones associated sea level storm surges;
- increases in flooding in other urban areas due to more intense rainfall as well as faster run-off due to more paving and buildings;
- possible threats to transport systems from increased climatic hazards; and
- the moderate to high likelihood of adverse effects on indigenous plant and animal species.[71]

2.72 The issue of climate change impacts on Australian fauna and flora was also brought to the attention of the Committee by the World Wide Fund for Nature. The Committee was told that:

> Here in Australia we are looking at the loss of quite a range of species in vegetation communities… Chances are we will lose our alpine communities in many parts of the country just simply because the low nature of Australia's terrain does not allow these species to migrate up very much. Unless things like the mountain pygmy possums identify means of building

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69 Dr Bryan Jenkins, *Proof Committee Hansard*, Perth, 17 April 2000, p 454.

70 Dr Barrie Pittock, Submission 220, p 4.

71 Dr Barrie Pittock, Submission 220, pp 5-6.

> towers or something like that fairly quickly, their habitat will simply cease to be. Migration between the high peaks in Australia is also quite difficult. Isolated populations will not be able to migrate simply by virtue of the fact that that is it - they are on the mountain in the district. It is not a question of moving down a chain that might be higher at the other end.[72]

2.73 The CSIRO admitted that there was 'less consistency when attempting to describe future climate at a regional scale' and told the Committee that their research, 'as well as examining changes on temperature and rainfall… is focusing on a limited number of issues that we regard as key to making more reliable our projections of climate in Australia'. These include:

- the impact of global warming on the El Nino-Southern Oscillation (ENSO);
- the implications of climate change for tropical cyclones; and
- extreme rainfall events.[73]

2.74 CSIRO emphasised that 'Australia's climate is subject to large year-to-year variations in rainfall':

> What scientists call 'climate variability' and 'climatic extremes', ordinary Australians think of as droughts, floods, tropical cyclones, heat waves, frosts and severe storms. Understanding the nature of these variations and how climate change may influence them is key to providing useful information on how climate change might affect us.
>
> Extreme events cause much of the impact of climate on agricultural enterprises, mining operations, transport, health, and natural ecosystems.[74]

2.75 Dr Robert Watson concurred with CSIRO's assessment that the interaction of global warming with ENSO patterns (El Nino and La Nina), was of great importance to understanding the potential impact of climate change on Australasia:

> I think one of the key questions for Australia is whether or not there will be a change in the frequency and magnitude of the El Nino phenomena. Obviously Australia is quite significantly affected when there is an El Nino year… it does appear that there is an increasing frequency of El Nino events and they also seem to be more severe… if indeed one were to see a trend in El Nino, one might start to project more dry events, hence having some potential impacts on agricultural productivity in Australia.[75]

2.76 In regard to current knowledge of ENSO patterns, CSIRO explained that:

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72 Mr Michael Rae, *Proof Committee Hansard*, Sydney, 23 March 2000, p 445.

73 CSIRO, Submission 206, p 2470.

74 CSIRO, Submission 206, p 2470.

75 *Official Committee Hansard*, Canberra, 9 March 2000, p 36.

> Changes associated with the ENSO are still far from clear. There is some indication from a number of climate model experiments that global warming will lead to an 'average' climate that resembles an El Nino-like state. This suggests that regions that currently experience droughts during El Nino years would experience these conditions more often, and areas where rainfall increases during El Nino years would become wetter. Year-to-year changes associated with ENSO variability will continue under climate change, but there is little consensus about the nature of this change.[76]

2.77 Dr Hans Schellnhuber, of the Potsdam Institute for Climate Impacts Research, said that El Nino could be affected, but that more time was needed for greater certainty about its impact:

> There is very definitely not a clear consensus of what will happen to El Nino in the course of global warming. There seems to be… a slight tendency to be seen in the model that there is a trend towards more El Nino like states, in general, in Australia… in this area we generally will need another decade to be definite about that… .[77]

2.78 Tropical cyclones could also increase in number and intensity:

> Several global climate model experiments have shown an increase in the maximum intensity of tropical cyclones (as measured by minimum central pressure or maximum wind speed) under enhanced greenhouse warming. Similar results are found in diagnostic studies, so an increase in intensity is considered likely. The number of extreme tropical cyclones would consequently increase. Other measures of changes in cyclone behaviour (e.g. total cyclone numbers, formation regions and tracks) exhibit variable results between models.[78]

2.79 CSIRO also informed the Committee that they had been commissioned to investigate possible climate change within particular states and territories. To do so, they 'used a regional climate model 'nested' within the global climate model to produce simulations of climate change with a spectral resolution of about 60 km':

> The major finding from this work is that within a relatively small *average* change, there exists the potential for significant changes in the frequency of extreme climatic events. Figure 2.3 illustrates this finding by showing modelled temperature changes in NSW. The left hand side of the Figure shows the number of summer days in the north-west of the State that exceeds a 35°C maximum. The right hand side of the Figure shows a decline in the number of nights where the temperature falls below 0°C. By the year 2050, hot days occur 20% more often, and frosty nights occur 40%

76 CSIRO, Submission 206, p 2470-71.

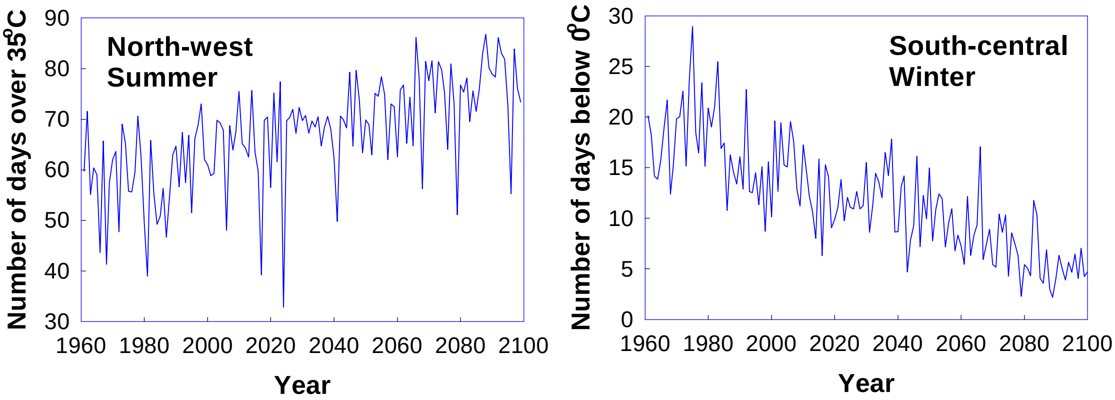
77 *Proof Committee Hansard*, Canberra, 22 June 2000, p 743.

78 CSIRO, Submission 206, p 2471.

less often, but the *average temperature* has risen by only 1.7°C. Note the significant inter-annual variability.[79]

Figure 2.3

Number of hot summer days in north-west NSW *Number of frosty winter days in south-central NSW*



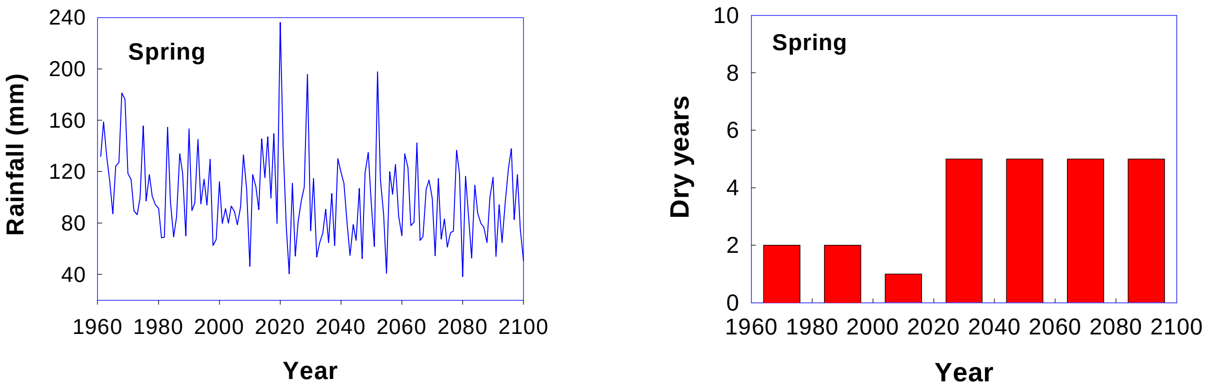
(As simulated by the CSIRO regional climate model in which greenhouse gas concentrations were increased according to the IS92a emissions scenario.)

2.80 CSIRO also modelled potential changes in rainfall. They said that:

> Figure 2.4 illustrates the way in which natural variations can obscure a small overall trend, which in turn masks substantial changes in the number of extremes. As described in the caption, the panel on the right indicates that from the middle of this century there is an increased chance that south-western NSW will receive an amount of spring rainfall that was regarded as 'dry' in the latter part of the twentieth century.[80]

Figure 2.4

Simulated spring rainfall over south-western New South Wales *The number of dry spring seasons experienced per 20 years.*



('Dry' is defined as a spring season where rainfall is below that of the 4th driest year in the period 1961-2000.)

79 CSIRO, Submission 206, p 2471.

80 CSIRO, Submission 206, p 2472.

2.81 However, in presenting their results for this modelling, CSIRO made an important qualification: ‘The problem for policymakers is that while these results are plausible, they are from a single experiment from a regional climate model. Different models are likely to show quantitatively different changes over the same regions’.[81]

2.82 Making exact predictions for climate change in the Australasian region is obviously subject to continuing uncertainties, caused by the difficulty in obtaining regional level resolutions from global climate models, uncertainty about ENSO patterns, and wide predicted ranges of rainfall change. However, scientists have been able to isolate probable changes including: dramatic changes in rainfall levels and intensities, with a strengthening view that large parts of Australia could become much drier; damage to the Great Barrier Reef; changes to river flows and flood frequencies; damage to biodiversity; worsening dryland salination problems; and resultant damage to important industries such as tourism and agriculture, and possible damage to built infrastructure through cyclones.

2.83 The lack of information about the potential costs of climate change impacts in Australia at both a national and regional level was of serious concern to the Committee during its inquiry. Although there are some uncertainties regarding impacts, there has been no attempt by the Government to translate these impacts into economic and social costs. The Committee acknowledges that making a better assessment will require progress on the resolution of regional climate models, and it urges the Commonwealth Government to devote adequate resources into such research, and into developing assessments of the possible environmental, social, and economic impacts of climate change within Australasia. In the Committee’s view, such costs ought to be as much a part of current debates about national abatement action as the costs associated with reducing emissions.

Stabilising the Global Climate System: The World Abatement Task

2.84 A particularly important issue presented to the Committee was that of the level at which the global climate system could be realistically stabilised, and how great a reduction in emissions would be required to do so. The IPCC has, in the Second Assessment Report modelled a range of pathways to a stabilisation of global greenhouse gas concentrations in the atmosphere at various levels: at 450 parts per million (ppmv), 550, 650, 750 and 1000 ppmv. They state that ‘the steeper the increase in emissions (hence concentrations) in these scenarios, the more quickly is the climate expected to change… for a given stabilisation concentration value, higher emissions in early decades require lower emissions later on’.[82] A diagram showing possible pathways to stabilisation is included overleaf.

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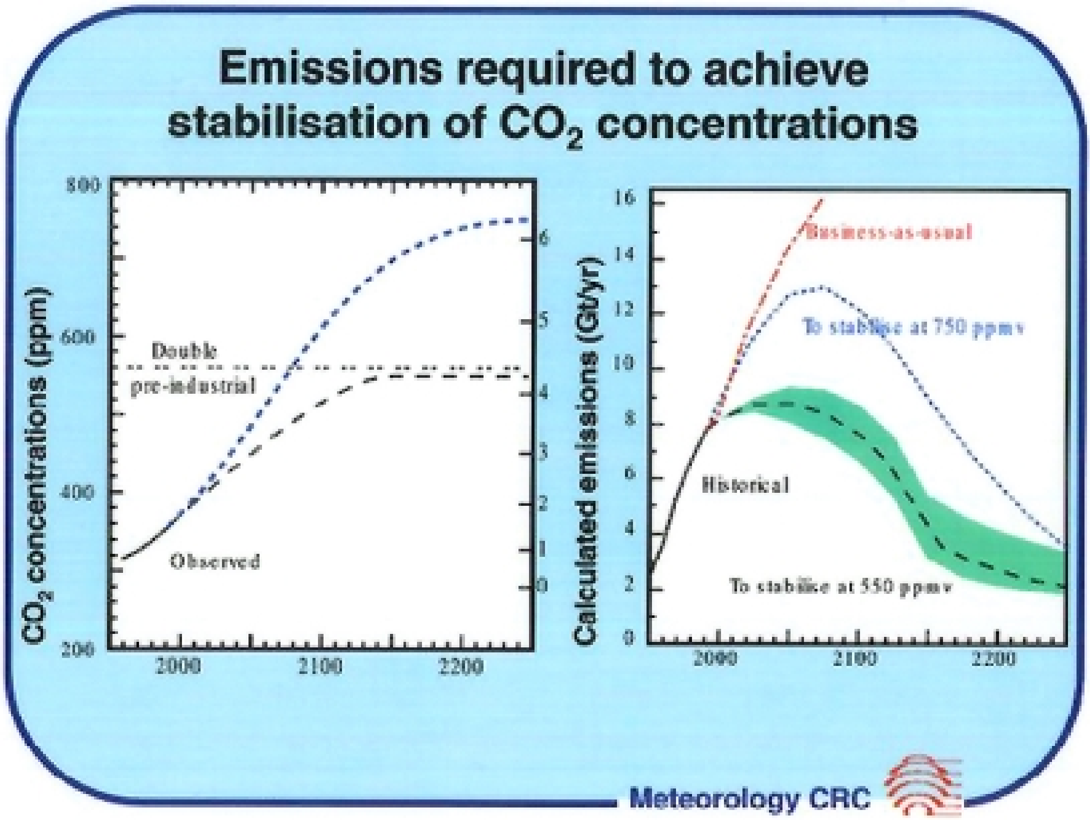
81 CSIRO, Submission 206, p 2472.

82 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clauses 4.6-4.8.

Figure 2.5

Co-operative Research Centre for Southern Hemisphere Meteorology, Monash University



2.85 The IPCC lists the temperature increases that would result from a stabilisation of the climate system at various levels:

- stabilisation at 450 ppmv would see a temperature increase of about 1°C (a range of between 0.5°C and 1.5°C);
- at 650 ppmv, an increase of about 2°C (between 1.5°C to 4°C); and
- at 1000 ppmv, of about 3.5°C (between 2°C to 7°C).[83]

2.86 These temperature increases would be the result of increasing concentrations of CO_2 *alone* (which accounts for 60 per cent of current concentrations, and will increase to 75 per cent by 2100), excluding other greenhouse gases with much higher forcings, and also excluding the effects of aerosols (which can cause a counteractive cooling). However, given the IPCC's statement that the greenhouse forcings of

83 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* Figure 1.

methane and nitrous oxide would also increase in absolute terms by a factor of between 2 and 3, such temperature estimates may be slightly conservative.[84]

2.87 As discussed earlier, even if the global concentration of emissions was stabilised at a level of 550 ppmv, sea levels would continue to rise for many centuries, potentially causing massive social and economic impacts and presenting enormous challenges for political stability and adaptation. The IPCC Second Assessment Report states that:

> The stabilization of greenhouse gas concentrations does not imply that there will be no further climate change. After stabilization is achieved, global mean surface temperature would continue to rise for some centuries and sea level for many centuries.[85]

2.88 The IPCC's Second Assessment Report discusses the task of stabilisation separately for the three major greenhouse gases, carbon dioxide, methane and nitrous oxide. The Committee also heard evidence about the level of abatement required to stabilise CO_2 concentrations.

Methane

2.89 Methane has a high greenhouse forcing (global warming potential, GWP) of about 21 times that of CO_2. However, according to the IPCC, 'atmospheric methane concentrations adjust to changes in anthropogenic emissions over a period of 9 to 15 years. If the annual methane emissions were immediately reduced by about 30 Tg CH_4 (about 8 per cent of current anthropogenic emissions), methane concentrations would remain at today's levels. If methane emissions were to remain constant at their current levels, methane concentrations (1720 ppbv in 1994) would rise to about 1820 ppbv over the next 40 years.[86] The CSIRO was optimistic about methane, saying that: 'the growth rate of methane is slowing, and if this trend continues, the concentration of methane will have stabilised by the first Kyoto commitment period'.[87]

Nitrous Oxide

2.90 The Second Assessment Report stated that nitrous oxide has a long lifetime of about 120 years, and that 'for the concentration to be stabilised near current levels (312 ppbv in 1994), anthropogenic sources would need to be reduced immediately by

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84 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clauses 4.16, Figure 1.

85 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 4.18.

86 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 4.13.

87 CSIRO, Submission 206, p 2459.

more than 50 per cent. If emissions of nitrous oxide were held constant at current levels, its concentration would rise to about 400 ppbv over several hundred years, which would increase its incremental radiative forcing by a factor of four over its current level'.[88]

2.91 The rapid reduction of nitrous oxide emissions obviously has to be a global priority, and the Committee urges the Government to develop a strong focus on the reduction of national N_2O emissions. Agriculture is by far the largest N_2O emitting sector, with transport, stationary energy and industrial processes also making smaller contributions. The major factors influencing N_2O emissions in the agricultural sector were the disturbance of land for tillage, along with biomass burning, the use of nitrogenous fertilisers and the management of animal wastes.[89]

Carbon Dioxide

2.92 The IPCC explains that carbon dioxide 'has a relatively long residence time in the climate system - of the order of a century or more'. They explain that current emissions levels would see an increase of global atmospheric concentrations to 500 ppmv by 2100:

> If net global anthropogenic emissions (ie., anthropogenic sources minus anthropogenic sinks) were maintained at current levels (about 7 Gt/yr including emissions from fossil fuel combustion, cement production and land use change), they would lead to a nearly constant rate of increase in atmospheric concentrations for at least two centuries, reaching about 500 ppmv (approaching twice the pre-industrial concentration of 280 ppmv) by the end of the 21st century. Carbon cycle models show that immediate stabilization of the concentration of carbon dioxide at its present level could only be achieved through an immediate reduction in its emissions of 50-70 per cent and further reductions thereafter.[90]

2.93 The Second Assessment Report suggests that to restrain atmospheric concentrations of CO_2 to below 550 ppmv (a level the Committee strongly advocates, given that it would still result in a 1°C increase in global mean temperatures, and sea level rises of between 25 and 50 cm by 2100) would require an enormous effort in greenhouse abatement during the 21st century:

> If the atmospheric concentration is to remain below 550 ppmv, the future global annual average emissions cannot, during the next century, exceed the

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88 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 4.14.

89 The Australian Greenhouse Office, *National Greenhouse Gas Inventory: Analysis of Trends and Greenhouse Indicators 1990-98*, pp 9, 54-55.

90 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 4.6.

> current global average and would have to be much lower before and beyond the end of the next century. Global annual average emissions could be higher for stabilization levels of 750 to 1000 ppmv. Nevertheless, even to achieve these latter stabilization levels, the global annual average emissions would need to be less than 50 per cent above current levels on a per capita basis or less than half of current levels per unit of economic activity.[91]

2.94 The IPCC also suggests that the relative importance of CO_2 to the global warming problem will increase over time:

> The importance of the contribution of CO_2 to climate forcing, relative to that of the other greenhouse gases, increases with time in all of the IS92 emission scenarios (a to f). For example, in the IS92a scenario, the CO_2 contribution increases from the present 60 per cent to about 75 per cent by the year 2100. During the same period, methane and nitrous oxide forcings increase in absolute terms by a factor that ranges between two and three.[92]

2.95 The Committee heard further evidence from scientists about what would be required to stabilise the global climate system, and the ideal level at which to aim to do so. Dr Geoff Jenkins of the UK's Hadley Centre argued that a level of 550 ppmv, whilst challenging, would avoid some of the worst potential impacts of climate change:

> We have done a recent study looking at impacts of several emission strategies, both unmitigated emissions - business as usual emissions, if you like, the sort of thing that IPCC has called the IS95 scenario emissions - and also emissions which are very much less than that and would lead to stabilisation of concentrations in the atmosphere at either 550 or 750 parts per million, over a very long period of a few hundred years. There are some interesting results from that on a global basis. So, for example, in the smallest of those emission scenarios, leading to a stabilisation at 550, we find that over the course of the next hundred years - as you might expect - because emissions are lower, then a lot of the impacts are lower. The negative and, indeed, in some cases the positive impacts on changes in vegetation and on changes in water resources, run-off from rivers, for example, changes in food production, crop yield, will be reduced as you reduce the emissions. That is perhaps not a very surprising result.
>
> What we can also see is that in the very long term, if we adopt a very low emission scenario approach, then some of the very large changes such as I

91 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 4.10.

92 Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 4.16.

> have mentioned over the Amazon region - dieback of forests over the Amazon region - will be avoided even over a 300-year period.[93]

2.96 Dr Jenkins explained that driving this work was an effort to interpret Article 2 of the UNFCCC:

> The reason for doing some of this work was to look at perhaps trying to interpret the word 'dangerous' that comes out of the UN Framework Convention on Climate Change, that 'dangerous' climate change to be avoided. Nobody really knows what dangerous means and we were trying to look at some of these impacts to see if there was any guidance on either the change in climate or the change in impacts which could help to define that word. So, if indeed the models are correct - as I said before, a lot of the results may be very model dependent - and if we look at some of the changes that we see over Amazonia and the quite rapid dieback in forests there and define that as a dangerous climate change, then that sort of thing could be avoided by going on really quite a low emissions pathway which would stabilise at 550 parts per million.[94]

2.97 The Chairman of the IPCC, Dr Watson, also emphasised the importance of Article 2 of the UNFCCC as an objective in stabilisation analyses:

> If indeed we take seriously the overall objective of the climate convention Article 2 - that is to say, stabilisation of the atmospheric concentrations of greenhouse gases and hence eventually stabilisation of the climate system - one would want to say quite categorically that the Kyoto Protocol is only a small, albeit very important, first step towards the ultimate objective of the convention. The reason for that is very simple: if we were to want to stabilise the earth's climate, we would have to have global emissions lower than they are today.[95]

2.98 Dr Watson explained what kind of emissions reductions would be required to stabilise global concentrations of CO_2 at 550 ppmv:

> If we were to take, for example, stabilisation at 550 parts per million of atmospheric carbon dioxide - and let me just remind you that pre-industrial levels of carbon dioxide were 280 and today we currently have about 360 parts per million - and I am not saying that is the right level, I am just saying if we did, and that is the target of the European Union, global emissions of CO_2 could go up from today's around seven to somewhere around eight to nine, or maybe 9½ billion tonnes per year, over the next two or three decades, and then they would have to significantly come down. They would have to, as I say, come down so that by the end of this century we would be

93 *Official Committee Hansard*, Canberra, 9 March 2000, p 25.

94 *Official Committee Hansard*, Canberra, 9 March 2000, p 25.

95 *Official Committee Hansard*, Canberra, 9 March 2000, p 40.

> roughly where we are today or less, and over the next 100 years they would have to decrease to, say, two to three billion tonnes.[96]

2.99 The Committee notes that this amount - 2 to 3 billion tonnes - would require a fall to emissions to between 30 and 40 per cent of 1990 levels by 2200. Dr Jenkins also offered a view on the possible path to stabilisation:

> There is not a unique pathway of emissions in order to stabilise concentrations in the atmosphere. The sorts of pathways that IPCC have come up with in order to stabilise at twice the preindustrial levels, 500 parts per million, involve allowing a small change up to maybe nine or 10 gigatonnes per annum globally over the next 100 years or so but then really a quite rapid decrease and eventually, over a few hundred years, down to levels of maybe 70 per cent cutback in emissions compared to today's. This is nothing too novel. It has been known for 10 or 15 years but because of the way the carbon cycle operates you do need to make dramatic cutbacks in order to stabilise the atmospheric concentrations.[97]

2.100 The IPCC has also stated that 'a range of global carbon cycle models indicates that stabilisation of atmospheric CO_2 concentrations at 450 ppmv… could be achieved only if global anthropogenic CO_2 emissions drop to 1990 levels by approximately 40… years from now, and drop substantially below 1990 levels subsequently'.[98]

2.101 Professor David Karoly echoed these analyses, stating that: 'global greenhouse gas emissions need to be reduced to about one-third or less of 1990 levels to stabilise atmospheric concentrations… .That would need to take place in the future in an environment of increasing population and increasing energy use, particularly in developing countries. My estimate is that developed countries, to achieve a global 30 per cent level - a 70 per cent reduction - are likely to need to reduce their emissions to around 10 per cent of present emissions levels'.[99]

2.102 In the Committee's view, this is a daunting prospect for Annex 1 countries (given even the 150 to 200 years time frame), but one which will have to be faced if the worst impacts of climate change are to be avoided. Professor Karoly emphasised that reductions needed to begin soon if such a target was to be viable:

> … the reductions over business as usual need to start quite soon - in fact, immediately… [in] the order of 30 per cent reductions over the next 20 years… Kyoto is an average six per cent reduction in developed countries

96 *Official Committee Hansard*, Canberra, 9 March 2000, p 40.

97 *Official Committee Hansard*, Canberra, 9 March 2000, p 26.

98 IPCC Working Group 1, *Summary for Policymakers: The Science of Climate Change*, http://www.ipcc.ch/pub/arsum.htm (01/09/00), p 1.

99 *Official Committee Hansard*, Canberra, 9 March 2000, p 40.

> only. The Kyoto Protocol will have no noticeable effect on observed atmospheric carbon dioxide concentrations.[100]

2.103 The Committee notes that this would require a cut in emissions to 70 per cent of 1990 levels by around 2020. It is a challenging objective, and underlines the need for Kyoto signatories to begin planning and implementing their transition to a low emissions economy immediately. On the other hand, Dr Watson argued that companies such as Shell had developed scenarios which plausibly suggested that the world could make a transition to a low carbon economy this century:

> The question I think one has to ask is - and I pose it as a question, not as a policy statement: are there simpler options of more efficient use of the current energy, more efficient production of current energy and, where appropriate, decarbonising our energy systems? If one looks at some of the plausible scenarios of Shell, they show that, by 2050, one could envisage half the world's energy still coming from fossil fuels and half the world's energy coming from a mix of renewable energies. The most contentious part of it, in my opinion, is the use of nuclear power, but that is a public issue. If, indeed, one had realised the Shell scenarios and then pushed them out for the next 50 years as well, one could envisage… where the world would stabilise atmospheric CO_2 at about 550 parts per million. Indeed, I think one can actually limit projected changes in climate to a very interesting mix of efficiency and production without just saying that no longer should we have fossil fuels… .[101]

2.104 Professor Karoly's views, in addition to those expressed by Dr Jenkins and Dr Watson, give a valuable insight into the scientific context in which future Kyoto targets will be negotiated. It can be realistically expected that future targets will be substantially lower than those for 2008 to 2012, beginning as early as the second commitment period (2013 or after). This would mean that Australia will need to set its economy on a path to a national emissions total substantially below 108 per cent of 1990 levels during the second commitment period, with an expectation that we may need to reduce emissions to around 70 per cent of 1990 levels by 2030 or possibly earlier.

Scientific Uncertainty and the Precautionary Principle

2.105 The Committee acknowledges that there are a number of areas of scientific uncertainty in relation to climate change. Principle among these are the effect of aerosols on greenhouse forcing, the identification of regional impacts, and the release and sequestration of carbon by soils and plants. Of some debate has been whether the existence of uncertainty suggests either a need to delay abatement action, or the adoption of the precautionary principle, which requires action now while existing

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100 *Official Committee Hansard*, Canberra, 9 March 2000, pp 43-44.

101 *Proof Committee Hansard*, Canberra, 9 March 2000, p 38.

uncertainties are further explored. The precautionary principle is specifically recognised in the UNFCCC, and it is a principle the Committee strongly endorses.

2.106 The IPCC states that there are a series of uncertainties, and advocates further work, in relation to:

- Estimation of future emissions and biogeochemical cycling (including sources and sinks) of greenhouse gases, aerosols and aerosol precursors and projections of future concentrations and radiative properties.
- Representation of climate processes in models, especially feedbacks associated with clouds, oceans, sea ice and vegetation, in order to improve projections of rates and regional patterns of climate change.
- Systematic collection of long term instrumental and proxy observations of climate system variables (eg, solar output, atmospheric energy balance components, hydrological cycles, ocean characteristics and ecosystem changes) for the purposes of model testing, assessment of temporal and regional variability, and for detection and attribution studies.[102]

2.107 The IPCC also explains that the non-linear nature of the climate system will produce ‘surprises’ that are, by their nature, difficult to model:

> Future unexpected, large and rapid climate system changes (as have occurred in the past) are, by their nature, difficult to predict. This implies that future climate changes may also involve ‘surprises’. In particular, these arise from the non-linear nature of the climate system. When rapidly forced, non-linear systems are especially subject to unexpected behaviour. Progress can be made by investigating non-linear processes and sub-components of the climatic system. Examples of such non-linear behaviour include rapid circulation changes in the North Atlantic and feedbacks associated with terrestrial ecosystem changes.[103]

2.108 Dr Watson also commented on the difficulties of modelling the impact of the sulphate aerosols. He explained that:

> Sulphur actually offsets parts of global warming… firstly, they are particles and therefore they reflect incoming solar radiation; and, secondly, they change the optical properties of clouds... we believe the emissions of sulphur will probably go up for a period of time, largely because of energy needs and the use of coal in Asia - largely India and China - but then they

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102 IPCC Working Group 1, *Summary for Policymakers: The Science of Climate Change,* http://www.ipcc.ch/pub/sarsum1.htm, (01/09/00).

103 IPCC Working Group 1, *Summary for Policymakers: The Science of Climate Change,* http://www.ipcc.ch/pub/sarsum1.htm (01/09/00).

will start to decrease. So, over time, they will be less and less of a cooling offset to the greenhouse gases.[104]

2.109 Dr Watson warned that sulphur emissions, while suspected of having a global cooling effect, were otherwise environmentally damaging because of their role in acid rain:

> Sulphur will be controlled independently, in my opinion, of global warming climate policies, largely because of its local and regional effects. Indeed,… our latest projections from a special report are probably slightly less emissions of CO_2 than what we had a few years ago, but much lower emissions of sulphur. The end product will be either the same or slightly larger projections of climate change.[105]

2.110 The IPCC's Second Assessment Report also discusses uncertainties in relation to the overall complexity of not merely the global climate system and the forcing effects of multiple gases and particulates, but in relation to the additional stresses provided by human activities:

> Although our knowledge has increased significantly during the last decade,… our current understanding of many critical processes is limited; and systems are subject to multiple climatic and non-climatic stresses, the interactions of which are not always linear or additive.[106]

2.111 The IPCC also cautions that existing studies were limited in scope, and that further work should take account of the difficulty of factoring in very complex dynamic interactions:

> Most impact studies have assessed how systems would respond to climate change resulting from an arbitrary doubling of equivalent atmospheric carbon dioxide (CO_2) concentrations. Furthermore, very few studies have considered dynamic responses to steadily increasing concentrations of greenhouse gases; fewer still have examined the consequences of increases beyond a doubling of equivalent atmospheric CO_2 concentrations or assessed the implications of multiple stress factors.[107]

2.112 It is sometimes said that such uncertainty justifies a delay of greenhouse abatement action. However, the IPCC has strongly established that the balance of evidence suggests a discernible human influence on climate to date, and that greenhouse gas emissions are likely to cause a range of devastating impacts if they increase unchecked.

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104 *Official Committee Hansard*, Canberra, 9 March 2000, p 37.

105 *Official Committee Hansard*, Canberra, 9 March 2000, p 37.

106 IPCC Working Group II, *Summary for Policymakers: Scientific-Technical Analyses of Impacts, Adaptations and Mitigation of Climate Change*, Part 3.

107 IPCC Working Group II, *Summary for Policymakers: Scientific-Technical Analyses of Impacts, Adaptations and Mitigation of Climate Change*, Part 3.

2.113 Furthermore, the application of the precautionary principle requires that action be taken now. The precautionary principle is recognised in Commonwealth environmental legislation (the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act), in the National Strategy for Ecologically Sustainable Development, and in the UNFCCC:

- The EPBC Act states, in its section 3A:

> If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.[108]

- Article 3.3 of the UNFCCC commits Parties to:

> … take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost effective so as to ensure global benefits at the lowest possible cost.[109]

2.114 The IPCC makes a strong argument for the application of the precautionary principle in the face of scientific uncertainty, in its advice to policymakers on adaptation and mitigation. It makes the point that it is important 'to consider these uncertainties in the context of information indicating that climate-induced environmental changes cannot be reversed quickly, if at all, due to the long time-scales associated with the climate system':

> Decisions taken during the next few years may limit the range of possible policy options in the future because high near-term emissions would require deeper reductions in the future to meet any given target concentration. Delaying action might reduce the overall costs of mitigation because of potential technological advances but could increase both the rate and the eventual magnitude of climate change, hence the adaptation and damage costs.
>
> Policymakers will have to decide to what degree they want to take precautionary measures by mitigating greenhouse gas emissions and enhancing the resilience of vulnerable systems by means of adaptation. Uncertainty does not mean that a nation or the world community cannot position itself better to cope with the broad range of possible climate changes or protect against potentially costly future outcomes. Delaying such measures may leave a nation or the world poorly prepared to deal with

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108 *Environmental Protection and Biodiversity Conservation Act 1999,* section 3A, p 4.

109 Cited in Intergovernmental Panel on Climate Change, *IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change,* clause 1.10.

> adverse changes and may increase the possibility of irreversible or very costly consequences.[110]

Greenhouse Science and Greenhouse Sceptics

2.115 The Committee acknowledges that there exists a small minority of scientists and others who strongly dispute the claims of the IPCC about current and future climate change. Within Australia, a small group was established in mid-2000 under the chairmanship of former Hawke Government minister, the Hon Peter Walsh AO, known as the Lavoisier Group. The Group publicly opposes the IPCC's conclusions about climate change and the Kyoto Protocol.

2.116 The Committee received a submission from the Lavoisier Group in June 2000, some 8 months after the closing date for submissions in 1999, and a few days before its final substantive hearing. Given the lateness of the submission, the Committee was not able to hear evidence from and question the claims of the Group. The submission was primarily a critique by the American meteorologist Professor Richard Lindzen of the submission made to this inquiry by the CSIRO. In order to deal properly with its substantive claims, a response to the submission was sought from the CSIRO. As at the conclusion of its inquiry, the Committee had not received a response from CSIRO, who explained that that they were busy preparing a submission to, and hosting a visit of, the Joint Standing Committee on Treaties' Inquiry into the Kyoto Protocol. The Lavoisier Group submission is publicly available from the secretariat of this Committee.[111]

2.117 A similar submission was made by the consultant Mr Bob Foster. He claimed that:

- the Kyoto Protocol itself constitutes an environmental threat because it draws funds away from other environmental problems in favour of a 'long term, and as yet unsubstantiated threat';
- IPCC reports 'take the implausible line that climate change is driven by changes in atmospheric composition alone, rather than by ice, oceans and atmosphere acting in concert', and that climate change is a gradualist system amenable to computer modelling unaffected by extreme non-atmospheric effects;
- the 'only way we have of judging the numerical models used for climate change forecasting is to require them to hindcast the known climate record. Despite IPCC claims to the contrary, they fail the test'.[112]

2.118 In reference to Mr Foster's first claim, the Committee does not support the claim that climate change is an 'as yet unsubstantiated threat'. In the Committee's

110 IPCC Working Group II, *Summary for Policymakers: Scientific-Technical Analyses of Impacts, Adaptations and Mitigation of Climate Change*, Part 2.

111 The Lavoisier Group, Submission 222.

112 Bob Foster Consultancy, Submission 36.

view, the funds dedicated to addressing climate change do not, therefore, constitute an environmental threat as claimed.

2.119 The Committee does not believe that Mr Foster's second claim is tenable. Evidence from a wide range of climate change scientists emphasised that climate change was the result of complex system which included oceans, land and atmospheric factors. Understanding the interaction of such factors is a priority of research, including carbon cycle feedbacks and ocean atmosphere interactions. As Dr Jenkins of the Hadley Centre told the Committee:

> The models at the moment - the sort of model we run, the models that you run at CSIRO and BMRC in Australia - couple together the ocean, the atmosphere and the land surface. That needs to be coupled because there are a lot of interactions between those elements of the climate system which are very important in determining feedbacks which can either accentuate or reduce the global warming, or the radiative forcing - the heating effect if you like - of additional man-made gases. So it is very important to link all those parts of the climate system together.[113]

2.120 Similarly, the Committee is not convinced by Mr Foster's claim that climate change forecasting has failed the 'hindcast test'. The Committee received evidence from scientists about their efforts to 'hindcast' known atmospheric changes using their models. These show that models are having some success in this regard, and that naturally observed changes such as solar radiation and volcano activity cannot account for temperature change of the past 50 years. For example, the Hadley Centre has specifically sought to model backwards, and to incorporate known external events rather than smooth out climate. Their new model, HADCM3, they claimed 'has a better representation of climate and climate change than previous models. It has a much better resolution, for example, in the ocean, than most models It does not use so-called flux adjustments to get the climate into a stable condition with low drift':

> We use that to try and simulate changes over the past 50 years due to factors which are naturally forced - in other words, largely solar and volcanic - and factors which are human. These are the greenhouse gas rise, the rise in aerosol, changes in ozone and so on. Then we look at the model without any changes at all, either natural or human, to look at the natural internal variability of climate. We find that, only by incorporating all three of those types of changes - in other words, the internal changes, the solar, the volcanic and the human activities - can we really get a good representation of the changes that have occurred over the past 50 years or so.[114]

2.121 Dr Jenkins further explained the results that were arising from this approach:

> If we do it just with the natural activity alone, for example the way in which volcanic activity has been quite high over the past two or three decades, and

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113 *Official Committee Hansard*, Canberra, 9 March 2000, p 23.

114 *Official Committee Hansard*, Canberra, 9 March 2000, p 21.

> the way that solar changes may have risen to a certain extent but have not been as great as this, we find that cannot give the sort of signal of quite rapid temperature change that has occurred particularly since about 1975. Because the forcing agents have gone down over that period in total that cannot simulate the sort of change that has occurred over that period. But when we include the effect of the human activities increasing greenhouse gases, despite increases in aerosol, we do find we are able to simulate reasonably well the temperature change on a global average basis that has occurred over that period.[115]

2.122 Although a response has not been received from the CSIRO, the Committee did receive evidence relating to one of Professor Lindzen's central criticisms - that satellite data support an argument that 'there is no evidence of any warming in the atmosphere', and that there are also problems in the surface record such as variations due to urban concentrations, coverage over oceans and 'the fact that much of the warming of the 90s comes from Siberia where, since the breakup of the Soviet Union, data quality control has been, to be generous, inadequate'.[116]

2.123 CSIRO's argument in regard to satellite observations was that:

> There is likely to be a real difference between the warming at the earth's surface and the lowest five miles of the atmosphere. This difference was ascribed to three factors: the thinning of the ozone layer, emissions from the Mt Pinatubo volcanic eruption and greenhouse gases.
>
> Additionally, comparing the two sets of measurements is complicated because the observations are different. The ground-based measurements are taken at points usually about 2 m above the earth surface. The satellite observations represent the temperature in a layer of the atmosphere in the region 1,500 – 10,000 m above the Earth's surface.
>
> It should also be noted that the satellite record covers the period from 1979, whereas the ground-based record contains data from about 1860. It is important to have available the longer record in order to evaluate the extent to which recent trends might be due to decadal-scale natural variations in planetary temperature.[117]

2.124 The Hadley Centre maintained that other upper atmosphere records did not show the same conflict with ground records:

> You may be aware that particularly in America there has been some controversy as to the extent to which changes in global warming at the surface disagree with measurements of warming made by satellites higher in the atmosphere at about a height of maybe three or five kilometres. What

115 *Official Committee Hansard*, Canberra, 9 March 2000, p 21.

116 The Lavoisier Group, Submission 222, pp 2870, 2874.

117 CSIRO, Submission 206, p 2462.

> we have done is to not use satellite measurements but measurements from weather balloons and look at the trends in temperature that have occurred since about 1960 to the present day in the atmosphere. That has shown us that the overall trends in temperature in the atmosphere have not been very much different from those at the surface which sees quite a clear warming in the atmosphere reasonably similar to that at the surface overall over that period.[118]

2.125 The Centre was quite open with the Committee about the uncertainty generated by upper atmosphere observations, but stressed that it did not negate the plausibility of the warming shown in the surface record and in the atmosphere:

> What we however see is that there are differences between the atmosphere warming and the surface warming in periods of a few years or a decade long which we do not understand. The atmosphere does not warm as quickly as the surface does in those periods. We do not fully understand the reasons for that. We believe there is work to be done in that area to ensure that the models can simulate that correctly. That would then increase our confidence in the models. There is an issue there that still has to be resolved, but it does not negate the fact that the warming at the surface is very robust and that we believe the warming of the atmosphere is quite substantial as well.[119]

2.126 The Hadley Centre also cited work which compared a wide range of evidentiary data on past climate. This data buttressed surface records and suggested that temperature changes over the past 100 years were out of the ordinary:

> Another area which is not our work but which I think is a very strong pointer is the work done by Michael Mann at the University of Massachusetts. There is also some work from Keith Briffa and Phil Jones at the University of East Anglia in England. What they have done is to reconstruct paleo records going back over the last thousand years, largely in the Northern Hemisphere. When they put these paleo records from tree rings, ice cores, corals and so on all together to look at the temperature change over the past thousand years, despite the very large uncertainties in these measurements, you can see a reasonably clear trend of very little change or perhaps a small decrease in temperature over that period.
>
> That is until the last 100 years or so, when there is a very significant upward trend over that period, both in the proxy data and in, obviously, the instrumental records that we all know about. So again to see that diagram does make it very clear, if indeed you believe the proxy data of that period, that what is happening over the last 50 or 100 years is unusual in the context of the last thousand years or so. Of course, being unusual does not prove that it is human activities that are to blame, but it does very clearly show that there has been a detection of climate change. On the attribution

118 Dr Geoff Jenkins, *Official Committee Hansard,* Canberra, 9 March 2000, pp 23-24.

119 Dr Geoff Jenkins, *Official Committee Hansard,* Canberra, 9 March 2000, p 24.

> question, to summarise, as I said at the beginning: the more work we do - not just ourselves but other people as well - the more the pointers are in the direction of a substantial proportion of the temperature rise over the last 50 years being attributable to human activities.[120]

2.127 Dr Robert Watson, Chairman of the IPCC also strongly asserted that observed climatic changes accorded with those expected from global warming:

> Indeed, if you ask the question, 'What would you expect in a warmer world is caused by greenhouse gases?' you would expect warmer temperatures. We have obviously observed that. You would expect the night time temperatures to have warmed more than day time temperatures; hence there will be less of a diurnal variability. We have observed that. We have observed land warming faster than oceans. We have seen that. We would expect to see more precipitation globally. We have seen that. We would expect to see more precipitation falling in heavy precipitation events. We have observed that. We have also seen what we would call the right latitudinal distribution of temperature changes. So while the models and the data are not in perfect accord there are lots of similarities to suggest that the observed changes in climate have the right fingerprint of human induced activities, not natural phenomena. So we do see a pattern where we would now say the likely reason for the changes in climate are at least in part due to human activities.[121]

2.128 In the Committee's view, climate change scientists have been scrupulously honest about areas where uncertainty exists, and are making credible efforts to reduce that uncertainty through further research. Existing uncertainties (as discussed above) do not lead to a conclusion that concern about both existing and potential climate change is unwarranted or scientifically invalid. IPCC reports are a consensus of hundreds of scientists from around the globe, are exhaustively peer reviewed, and the texts are carefully examined by UNFCCC member governments before they are made public. In such a context, the Committee is confident that human induced climate change is a fact, and that the various IPCC scenarios (given various estimates of emissions, population and economic growth) are plausible. In the face of uncertainty, as noted earlier, the precautionary principle should be followed.

2.129 The Australian Government has also stated that it accepts the scientific consensus established by the IPCC. The Chief Executive of the AGO, Ms Gwen Andrews, emphasised to the Committee that accepting the scientific consensus on climate change was important in developing a long term response to the problem:

> This is the time now to start demonstrating that this is a serious matter. Certainly the Government takes very seriously the commitment it has made internationally with regard to the UN framework convention on climate change and its commitment to the Kyoto Protocol and its implementation.

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120 Dr Geoff Jenkins, *Official Committee Hansard*, Canberra, 9 March 2000, p 22.

121 *Official Committee Hansard*, Canberra, 9 march 2000, p 34.

> The extent of the change that can be achieved in the short term and the targets that have been set are not the end of the story. It is important that the public understand, as Mr Carruthers said, that this is a long term issue and that there will be a long term response….It is important that the public accept the science and the strengthening consensus on the science.[122]

Recommendation 1

The Committee recommends that the Commonwealth Government make a strong public statement on its position on the science of climate change, and initiate an awareness raising campaign to communicate the issue of climate change to the broader community.

Understanding Regional Climate Change: Funding and Research Issues

2.130 Australia is at the leading edge of global atmospheric and climate change research, with a range of prominent scientists involved in the drafting of IPCC assessments and developing regional climate change models. However, current levels of funding to other areas of research are inadequate to ensure a better understanding of potential climate change in this region, and its impacts on communities, the environment and economic activity.

2.131 Since the late 1980s Australian Governments have spent approximately $55 million on climate change research. In the 1999-2000 budget the Government committed an additional $14 million over four years for the Greenhouse Science Program which aims to improve global, regional and national understanding of climate change, potential impacts on Australia, and options for adaptation and mitigation.[123]

2.132 The Greenhouse Science Advisory Committee (GSAC) recommends the additional application of $10 million per year in their report, *Advancing Greenhouse Science Strategy and Business Plan 2000-2005*, which was submitted to the Commonwealth Government for consideration in November 1999. The Government has not yet made a decision in regard to these funds, which the GSAC argues would be 'a minimum investment to support Australia's national greenhouse commitments. The funds would target gaps in research that need strengthening in the national interest rather than solving all the problems or satisfying all scientific interests'.[124]

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122 *Official Committee Hansard*, Canberra, 22 June 2000, p 705.

123 The Australian Greenhouse Office, Submission 169, p 1703; and Greenhouse Science Advisory Committee, *Advancing Greenhouse Science Strategy and Business Plan 2000-2005*, November 1999, p 5.

124 Greenhouse Science Advisory Committee, *Advancing Greenhouse Science Strategy and Business Plan 2000-2005*, November 1999, p 2.

2.133 The Committee is strongly of the view that much greater effort and resources need to be directed to understanding the potential impact of climate change on the Australasian region. Such efforts will be crucial to efforts to mitigate potential climate change and adapt to inevitable climate change. They will also help to clarify our national interests in ensuring that a serious global effort to stabilise climate occurs.

2.134 The Director of the CSIRO Atmospheric Research Division, Dr Graeme Pearman, explained the growing demands on Australian scientists:

> The amount of science that is required in order to respond to the so-called greenhouse issue today, in the year 2000, is so much different than it was in the year 1990. That is because we are not only required to now continue to develop the underpinning science, which is really mainly pointed at predicting at a regional level the kinds of things that people really need to know, but we are also being asked as a scientific community to provide guidance on issues of sequestration, technological innovation and alternatives of impacts and adaptation and so on. These are areas in which the commitment of the science community has been there but the resources have been very light. So I think there is a question of insufficient resources to do all of those areas.[125]

2.135 Dr Pearman stated that while funding for the underpinning science on regional impacts was probably adequate, he intimated that these extra areas were lacking:

> With respect to the underpinning areas of science, the Government has a commitment to maintaining the $4 million a year support to that research over the next triennium. As long as that continues, I think we are reasonably well based, remembering of course that science is becoming, like everything else, dearer to do.[126]

2.136 However, a former CSIRO scientist, Dr Albert Pittock, expressed serious concerns about the ability to continue regionally focused work. He praised CSIRO’s efforts to develop global climate models, but added that there was no certainty that such progress could be continued:

> The climate model in CSIRO went from non-existence about 15 years ago to now being one of the three or four most reputable in the world. I think we can be very proud of that. It was as the result of a lot of investment by the Government in supercomputing facilities, but that is a big gain for Australia for other reasons. The certainty that we can keep up is not there at the moment. If you come to the more local modelling, the nested modelling and the climate impacts and adaptation work, then Federal funding has pretty well dried up in the last several years. Most of our funding now comes from state governments and some other instrumentalities, so we are particularly getting work in Queensland and New South Wales and to some extent

125 *Proof Committee Hansard*, Melbourne, 20 March 2000, p 122.

126 *Proof Committee Hansard*, Melbourne, 20 March 2000, p 122.

> Victoria. It has been a big struggle… . We have, I think, some of the best scientists in the world. The risk assessment vulnerability work is being pioneered by somebody in our lab who has only a temporary position because we do not have the certainty to employ them on a more permanent basis.[127]

2.137 Dr Pearman also admitted that there was a dearth of regionally focused predictions:

> There are two levels of impact assessment. There is one level in which you effectively take some scenario - potential future - and you test the response of a component or sector of the society. A lot of that has been done in Australia… . The second level… actually trying to make a real prediction and saying, even with the uncertainties of the projections of the gases and the climate response, can we then say what will actually happen with some uncertainty limits drawn on it. There is virtually none of that being done in this country.[128]

2.138 Dr Pittock argued that funding in this area needed to be increased:

> in broad terms it would need to be in the multimillion dollar category, and not just for the CSIRO. There needs to be funding of a lot of regional groups that will have a local knowledge and interest in their own region and be in contact with local stakeholders.[129]

2.139 Professor Garth Paltridge, Director of the Antarctic Cooperative Research Centre, argued that, while basic science was reasonably well resourced in Australia, research on the potential impacts in Australasia was seriously lacking:

> What is lacking is good, solid, hard, disciplined research into the impact of climate change on society and on productivity of agriculture and so on. That has always been an area where people tend to wave their hands a lot, but in terms of the actual hard scientific research that is done on the subject of the potential impact of climate change, there is very little indeed that you would say comes out of the reputable scientific journals.[130]

2.140 The Antarctic CRC's Professor William Budd, also said that work was also needed on adaptation, given that irreversible climate change was likely to occur, whatever efforts were made to reduce emissions in the future:

> There is another area that also needs attention and that is adaptation. The things that I spoke about with climate change and changes in the ocean appear to be going ahead, even in spite of the best efforts of reducing

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127 *Proof Committee Hansard*, Canberra, 22 June 2000, p 747.

128 *Proof Committee Hansard*, Melbourne, 20 March 2000, p 133.

129 *Proof Committee Hansard*, Canberra, 22 June 2000, p 747.

130 *Proof Committee Hansard*, Hobart, 5 May 2000, p E495.

> emissions. If we are concerned about these long term changes then we need to think about adaptation. For example, within Australia what we see is the reduction in rainfall over the long term but, in spite of that, still similar frequencies of floods but greater frequencies of the drier episodes. We need to learn how to adapt to that because this is happening on the decadal and century time scales. It means that these things need to be taken into account in terms of land planning and water usage and all the other agricultural and industrial activities. The main thing is that from the modelling we get a good idea of the time frame in which these things can be expected to develop.[131]

2.141 Professor David Karoly, Director of the Cooperative Research Centre for Southern Hemisphere Meteorology at Monash University, strongly argued that there was a serious gap in research and training opportunities for climate change science in Australian universities:

> There have been either direct or indirect reductions in funding for university training groups in atmospheric and climate sciences associated with changes in government policy for university education. This has led to significant reductions in the training of climate specialists and professionals with expertise in climate change and climate change impacts. In fact, it has probably led to a 50 per cent reduction in academic staff in these areas in the last 10 years. This seems to be somewhat inconsistent with an apparent need for increased scientists and professionals with an understanding of climate change and climate change impacts.[132]

2.142 Professor Karoly told the Committee that there is no department of climate or atmospheric science at any university in Australia, and that existing co-operative research centres (CRCs) were also under substantial funding pressures:

> A department of atmospheric and climate sciences could or should be established. There have been two significant groups established: the Antarctic CRC that you would be familiar with, in Hobart, has been established with cooperative research centre funding and my own cooperative research centre has been established. My own cooperative research centre [Monash University] will be closing in June this year and the funding for the Antarctic CRC [University of Tasmania] is essentially going to run out in 2003 unless significant changes are made. Those are the two largest groups in climate sciences in Australia at present and both of them are due to close within three years.[133]

2.143 The Committee is very concerned by this evidence. It is of the view that Australia needs to continue to participate in international scientific efforts at a high level, to ensure that a growing body of researchers across a range of disciplines is

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131 *Proof Committee Hansard*, Hobart, 5 May 2000, p E495.

132 *Proof Committee Hansard*, Canberra, 9 March 2000, p 40.

133 *Proof Committee Hansard*, Canberra, 9 March 2000, p 41.

being trained for future efforts, and in particular, to significantly increase efforts to understand the nature and impact of climate change on this region to adequately inform policy development.

Recommendation 2

The Committee recommends that adequate funding be provided to:

- **enable the CSIRO to continue work on the underlying science of climate change;**
- **work on the nature of potential impacts of climate change in the Australasian region possibly through new or existing CRCs; and**
- **work on the potential social, economic and environmental costs of the impacts of climate change on Australia, particularly at a regional level.**

Recommendation 3

The Committee recommends that Australian universities be encouraged to establish departments and courses that focus on atmospheric or climate change science, and that funding be provided to support such initiatives.

Australian Democrats Recommendation 1

The Australian Democrats recommend that a minimum of $100 million in funding should be provided over the next four years for climate change science.

Conclusions

2.144 The Committee accepts the growing consensus that human activity is leading to increasing atmospheric concentrations of greenhouse gases with significant changes to global climate predicted as a result.

2.145 Notwithstanding existing uncertainties, it is clear that predicted climate change will have severe implications for Australia, which is already subject to drought, El Nino/La Nina, tropical cyclones and extremes of climate. Coastal communities and low-lying areas will be particularly vulnerable and changes to temperature and rainfall could affect biodiversity and ecological communities, agricultural systems, flooding patterns and river flows, and worsen drought and dryland salinity. Increases in sea temperatures could cause irreversible damage to coral reefs.

2.146 Australia has a strong dependence on climate-vulnerable industries such as agriculture and tourism, and is the custodian of a vast array of unique biodiversity, much of which is recognised in national parks and World Heritage Listed areas.

2.147 Scientists have already identified emissions reduction pathways that would stabilise the global climate system at global CO_2 concentrations of around 550 parts per million, which could pre-empt much damaging climate change. While challenging, these reductions are achievable if concerted global efforts begin now.

2.148 In the Committee's view, Australia has a clear national interest in seeing the global community work towards stabilising the climate system. If predicted climate change does occur, it will have significant social, economic and environmental implications for Australia.

2.149 The emission reduction pathways outlined by scientists and the IPCC, to stabilise atmospheric concentrations of greenhouse gases, also indicate a need for Australia to begin long term planning. Such pathways, which may require a global emissions reduction of 70 per cent within 150 to 200 years, are likely to be reflected in future global responses.

2.150 The Committee concludes that the balance of evidence strongly suggests that Australia will be very negatively affected by climate change given the size of its land mass and its long coastline, its current extremes of climate, its vulnerability to cyclones and the El Nino/La Nina cycle, its existing problems with soil salinity, and its economic dependence on agriculture and tourism.