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Climate change: the case for action

Research Paper Index

Climate change: the case for action

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- Scientific evidence demonstrates unequivocally that the climate is changing. Furthermore, the overwhelming weight of evidence suggests that most of this change is very likely due to human influences on the climate system. The likely consequences of unmitigated climate change present serious risks to our environment and consequently to our socioeconomic productivity, security, and health. These risks can be reduced to manageable levels with mitigation action.
- The climate system responds slowly to small changes in its driving forces, such as the changes in atmospheric composition and energy balance that it is now experiencing. Therefore, the Earth and its inhabitants will continue to experience the effects of current and previous greenhouse gas emissions for centuries to come. Delaying action to mitigate climate change increases the risk that adverse climate change impacts, including possibly irreversible changes, will occur before greenhouse gas concentrations can be stabilised at a desired level.
- Delaying action to mitigate climate change may preclude the successful realisation of more ambitious greenhouse gas stabilisation targets over the next century, as continued investment in long-lived, emissions-intensive technologies commits us to continued high rates of emissions.
- Delaying action will require more drastic measures to achieve a desired mitigation target than early action. Early action enables businesses and industries to adjust gradually and allows time for new technologies to emerge and be commercially deployed.
- The costs of unmitigated climate change are likely to be substantially higher over the next century than the costs of mitigation. Mitigation action is likely to cause a net cost to GNP growth in the first half of the century, but a net benefit in the second half.
- Australia is particularly vulnerable to the impacts of climate change, both environmentally and economically. It is in Australia's interests to do all we can to secure an effective international agreement to mitigate climate change. Through existing agreements, Australia has committed to contributing our fair share of global responsibility in reducing greenhouse gas emissions. In implementing effective domestic action, Australia would demonstrate this commitment while facilitating the process of reaching an international agreement, easing the integration of our economy into an international mitigation framework, and safeguarding the future of our country and planet.

Glossary of terms and acronyms

Albedo	The proportion of light (or other forms of electromagnetic radiation, such as infrared) that is reflected off a surface. An ideal, perfectly reflective, white surface would have an albedo of 1. A perfectly absorptive, black, non-reflective surface would have an albedo of 0. All real materials have an albedo between 0 and 1.
Aerosol	A suspension of fine particles or droplets in the air. Atmospheric aerosols scatter and absorb sunlight, and affect the Earth's energy balance by reflecting sunlight back into space and through indirect effects on cloud formation and atmospheric chemistry. Aerosols are produced from both natural and human processes such as volcanic eruptions, forest fires, desert dust storms, and burning of coal and oil.
Anthropogenic	Human-induced.
Carbon capture and storage (CCS)	The capture of carbon dioxide (e.g. from power station effluent) and its transport and storage in a long term reservoir such as a geological basin.
Carbon dioxide equivalent (CO_2e)	CO_2-equivalents account for the abilities of different greenhouse gases to absorb infrared radiation over a given timeframe, which determines their relative warming effect compared to CO_2. For example, over a 100-year timeframe, methane is 25 times more potent than CO_2 per unit of mass, and nitrous oxide is 298 times more potent than CO_2.

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Carbon Pollution Reduction Scheme (CPRS)	The Government's proposed emissions trading scheme.
Carbon sequestration	The absorption of CO_2 from the atmosphere or at the source of emissions and its long-term storage in 'carbon sinks'. Various potential sinks have been identified that can be utilised or enhanced for carbon storage, including forests, soils, geological reservoirs, oceans and minerals.
Chlorofluorocarbons (CFCs)	Compounds that contain carbon, fluorine and chlorine. Chlorofluorocarbons have been used as refrigerants, propellants and solvents. Their use has been banned by the Montreal Protocol on Substances that Deplete the Ozone Layer. They are also powerful greenhouse gases.
CPRS-5	Treasury modelling scenario based on the CPRS with a 5 per cent emissions reduction target by 2020, consistent with a greenhouse gas stabilisation target of 550 ppm CO_2e by 2100.
CPRS-15	Treasury modelling scenario based on the CPRS with a 15 per cent emissions reduction target by 2020, consistent with a greenhouse gas stabilisation target of 510 ppm CO_2e by 2100.
Greenhouse gases (GHGs)	Gases in the atmosphere that absorb and emit infrared radiation, causing heat to be trapped in the lower atmosphere. The dominant greenhouse gas is carbon dioxide, but other important greenhouse gases include methane, nitrous oxide, and halocarbons.
Gross domestic product (GDP)	The value of all final goods and services produced in a country in one year.
Gross national product (GNP)	The value of all goods and services produced in a country in one year, plus income that residents receive from abroad, minus income received by non-residents.
Halocarbons	Compounds consisting of carbon and one or more halogens, with the remainder of the carbon bonds, if any, attached to hydrogen atoms. Halogens include fluorine, chlorine, bromine and iodine. Halocarbons are used, among other things, as refrigerants and pesticides.
Hydrochlorofluoro-carbons (HCFCs)	Compounds containing hydrogen, carbon, fluorine and chlorine. They are being used to replace chlorofluorocarbons, but are subject to caps in their production and consumption, and a phase-out schedule. They contain chlorine and thus are an ozone-depleting substance, but to a much lesser extent than chlorofluorocarbons. They are also a strong greenhouse gas.
Hydrofluorocarbons (HFCs)	Compounds containing carbon, hydrogen and fluorine. These synthetic molecules are up to 14 000 times more powerful per unit of mass than carbon dioxide as greenhouse gases over a 100-year time frame.

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Hydrofluoroethers (HFEs)	Otherwise known as fluorinated ethers. They are chemical compounds that consist of an ether group (an oxygen atom connecting two hydrocarbon chains) with fluorine atoms attached. These compounds do not deplete the ozone layer but are very strong greenhouse gases with long lifetimes in the atmosphere.
Infrared radiation	Radiation in the range 750 nm to 1 mm. Far infrared radiation (at the longer end of the infrared wavelength spectrum) is thermal, and we experience it as heat. Infrared radiation represents a significant portion of the sun's solar radiation spectrum, and most of the radiation emitted from the Earth.
Intergovernmental Panel on Climate Change (IPCC)	The IPCC was established in 1988 to provide a comprehensive, objective, open and transparent assessment of the latest scientific, technical and socio-economic literature produced worldwide relevant to climate change and its risks and impacts, and options for mitigation and adaptation. Participation in the IPCC is open to all member countries of the World Meteorological Organisation and the United Nations Environment Programme (more than 180 countries in total). Governments participate in review of the IPCC reports and plenary sessions where the reports are approved and accepted. Thousands of scientists contribute to the IPCC Assessment Reports.
Kyoto Protocol	A protocol to the United Nations Framework Convention on Climate Change that establishes legally binding commitments for greenhouse gas emissions reductions over the commitment period (2008–2012) for Annex I parties (consisting of developed countries and countries with economies in transition), and general commitments for non-Annex I parties (developing countries).
Long-lived greenhouse gases (LLGHGs)	Those greenhouse gases that are only slowly removed from the atmosphere by natural processes. They include carbon dioxide, methane, nitrous oxide, chlorofluorocarbons, hydrochlorofluorocarbons, hydrofluorocarbons, hydrofluoroethers, perfluorocarbons and other halocarbons.
Organisation for Economic Cooperation and Development (OECD)	An international organisation consisting of governments of countries committed to democracy and the market economy. Most members are high income economies and are considered developed countries.
Ozone (O_3)	A molecule consisting of three atoms of oxygen. In the lower atmosphere it is a pollutant produced from emissions of other compounds during fuel combustion. It is toxic to animals and plants, and damages human respiratory systems. However, ozone in the upper atmosphere occurs naturally and acts to reduce the amount of dangerous ultraviolet radiation reaching the Earth's surface.
Perfluorocarbons (PFCs)	Compounds consisting of carbon and fluorine. They do not deplete the ozone layer but are very strong greenhouse gases with long lifetimes in the atmosphere.
ppm	Parts per million by volume—a unit that measures concentration of gases in the atmosphere.

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Radiation	The emission or transmission of energy as waves or as particles. Radiation is classified according to the frequency or wavelength of the wave, and includes radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, x-rays and gamma rays (from longest to shortest wavelengths). Radiation is emitted from all objects with a temperature above absolute zero (absolute zero on the Celsius temperature scale is -273.15°C).
Radiative forcing	Radiative forcing refers to the influence on the Earth's climate of various radiative components. These components include the amount of solar radiation reaching the atmosphere and the Earth's surface, as well as the influence of individual greenhouse gases within the atmosphere and their warming contribution through their ability to absorb infrared radiation emitted from the Earth's surface. Radiative forcing is measured as the change in net (down minus up) irradiance at the top of the lower part of the Earth's atmosphere, in units of Watts per square metre (W m^{-2}).
Solar radiation	The spectrum of radiation emitted from the sun, which includes ultraviolet (100 to 400 nanometres or nm; 1 nm = 10^{-9} m), visible (400 to 700 nm) and infrared radiation (700 nm to 1 mm), with the peak of the emission spectrum in the visible range. Solar radiation is the main energy source for life on Earth, and it drives the Earth's atmospheric and oceanic circulation patterns.
Ultraviolet (UV) radiation	Radiation emitted from the sun in the range 100 to 400 nm. Almost all of the higher frequency UV radiation (UV-B and UV-C) is absorbed by ozone in the upper atmosphere. UV-B radiation reaching the Earth's surface can be very damaging to living organisms. It damages DNA, which in humans can lead to skin cancer and eye damage.
United Nations Framework Convention on Climate Change (UNFCCC)	The UNFCCC is an international treaty that entered into force in 1994. It sets out a framework for intergovernmental efforts to address the issue of climate change and act to stabilise greenhouse gas concentration levels in the atmosphere. Parties to the UNFCCC submit information on national greenhouse gas emissions and implement strategies for mitigating emissions, adapting to anticipated climate change impacts, and providing assistance to developing countries.

Introduction

Climate change is an issue that scientists first raised and seriously considered decades ago, and it has been hotly debated ever since. Considerable effort and resources have been invested in observing and understanding the climate system both past and present, and we are now at the point where the results of these efforts paint a clear picture of the changes in climate that are currently occurring and the likely causes of these changes.

There is no doubt that the climate has changed over the past 150 years. These changes are documented by an enormous range of data analysed by scientists in many different countries and institutions. The evidence tells us with a high degree of confidence that human activities are responsible for most of the changes in climate that have been observed over recent decades, and that the most powerful influence has been the alteration of the composition of the atmosphere caused by emissions of greenhouse gases since the industrial revolution.

The changes to climate are having effects on ecosystems and other environmental processes and functions that directly impinge on human society. These changes are occurring already, and are projected to continue and intensify. There is increasing recognition that climate change poses a real and present threat to the social and economic structure of human society, as well as to the environmental and ecosystem functions upon which we depend.

The scientific evidence demonstrating the reality of climate change and the leading role of humans in driving this change in recent decades is so compelling that the overwhelming majority of scientists in the relevant disciplines do not doubt th greenhouse gas emissions from human activities are causing the climate to change. It has taken decades, but the weig the climate change debate has finally moved on to the economics and politics associated with the challenges of mitigation

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and adaptation. This acceptance of the problem and challenge is multi-partisan, multi-national and at all levels of government. It has been explicitly acknowledged and emphasised by the Australian Government and Opposition as well as every Australian state and territory government. [1]

Given the overwhelming acceptance of the reality of human-induced climate change, this paper is not about proving, once again, the scientific case. Rather, it discusses the scientific, economic and moral imperatives for Australia and the world to act, and act soon, to mitigate climate change and reduce the risks of damaging or even catastrophic consequences that may result from inaction. Presented first is an overview of the science of climate change and the human contribution, followed by implications of delaying or avoiding action, then a discussion of Australia's situation and responsibilities in the global context.

Human influence on the climate system

There is increasing evidence of human influence on the climate system. [2] Human activities are directly affecting the composition of the atmosphere, by increasing the concentration of the naturally occurring greenhouse gases, by adding new greenhouse gases, and also by changing the mix of suspended particles and droplets (aerosols) in the atmosphere. We are also changing the reflectivity (known as the albedo) of parts of the Earth's surface, which influences how much of the arriving solar radiation is absorbed. The two main human activities that are contributing to climate change are emissions of greenhouse gases and aerosols, and land use and land conversion practices. These are discussed in turn below, followed by a summary of evidence showing that these activities have caused clearly discernible changes in climate over the past century.

Greenhouse gas and aerosol emissions

Increasing levels of greenhouse gases in the atmosphere is by far the most influential amongst the factors causing contemporary climate change. [3] Greenhouse gas emissions from human activity derive mainly from combustion of fossil fuels (coal, oil and natural gas), with additional significant contributions from industrial processes, agriculture, and land use change. Changes in levels of black carbon particulates (for example from soot), snow albedo (from settling dust and particulates), and some atmospheric pollutants have small additional impacts on global warming. These factors all tend to act as warming agents, but other factors that can act as cooling agents are changes in cloud albedo, aerosols, land albedo change, and, periodically, dust from volcanic eruptions.

Global warming is a result of the atmospheric 'greenhouse effect'. [4] This is the process by which solar radiation passes through the atmosphere relatively freely but infrared radiation (or heat) emitted from the Earth's surface is absorbed and re-radiated by greenhouse gases. Some of this re-radiated heat escapes to space, but some is re-absorbed by the atmosphere or Earth's surface, so the net effect is to trap heat within the Earth-atmosphere system. This leads to a higher temperature at the surface than would otherwise be experienced.

The greenhouse effect is a natural phenomenon on Earth, brought about by the presence of low concentrations of carbon dioxide and water vapour in the atmosphere, and is responsible for maintaining the Earth's temperature at a habitable level. However, greenhouse gases emitted or generated by human activities are enhancing the natural greenhouse effect. The main such gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halocarbons (including chlorofluorocarbons, hydrofluorocarbons, hydrochlorofluorocarbons, perfluorocarbons, and hydrofluoroethers), and ozone (O_3).

The relative contribution of each of the greenhouse gases to the enhanced greenhouse effect depends on their infrared radiation absorption characteristics, as well as on their lifetime and concentration in the atmosphere—the impact of many of these gases is accentuated owing to their long-lived nature in the atmosphere. The rate at which we are emitting greenhouse gases currently far exceeds the rate at which those gases are removed from the atmosphere by natural processes. CO_2 is responsible for most of the enhanced warming effect because it is emitted in the largest volume, followed by methane, combined halocarbons and nitrous oxide, which all have a much greater warming effect than CO_2 for a given mass but are emitted in smaller quantities. The global warming potential of different greenhouse gases is compared by using a common scale of 'CO_2-equivalents' (CO_2e).

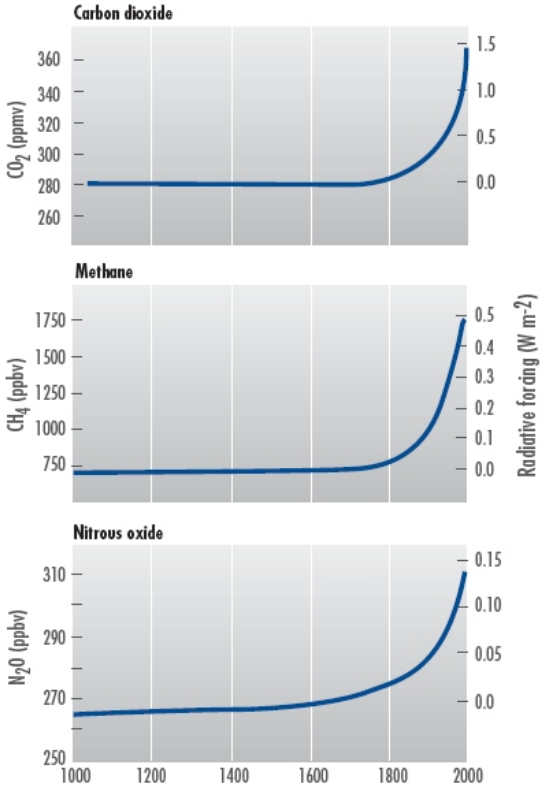
Ozone is also a powerful greenhouse gas but is not classified as a long-lived greenhouse gas (LLGHG) because in the upper atmosphere it is constantly being broken down by ultraviolet (UV) radiation and reformed by natural processes. The absorption of UV radiation in the upper atmosphere by ozone is a vital process that protects life on Earth from damaging influences of high levels of UV. In the lower atmosphere, ozone is produced as a result of human activities. It is formed by chemical reactions between atmospheric oxygen and 'precursor' gases such as volatile organic compounds and nitrogen oxides that are emitted from burning of fossil fuels and biomass, and other industrial processes. It is the additional ozone in the lower atmosphere that contributes to the enhanced greenhouse effect.

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As a result of burning of fossil fuels and changes in land use practices, carbon dioxide, methane and nitrous oxide concentrations have all grown steeply in the last century relative to earlier levels, as shown in Figure 1 (halocarbon records show similar trends). These increases in concentration are accompanied by increases in the contribution of these gases to radiative forcing. The term 'radiative forcing' refers to changes in the overall amount of solar radiation absorbed by the Earth's surface and atmosphere, or to the amount of heat radiated to space. Greenhouse gases affect the latter process, trapping heat within the lower atmosphere.

The disturbing trend in CO_2 concentrations was first observed in the 1960s in pioneering work at Mauna Loa in Hawaii, where the first reliable long-term measurements of atmospheric CO_2 concentrations were established. This work was instrumental in demonstrating the influence of fossil fuel emissions on atmospheric concentrations, and establishing the basis for concern that human activities could alter the climate system. [5]

Figure 1 : Trends in the main greenhouse gas concentrations in the atmosphere in the last 1000 years



Source: Bureau of Meteorology, *The greenhouse effect and climate change*, 2003, Figure 26, p. 19, viewed 18 March 2009, <http://www.bom.gov.au/info/GreenhouseEffectAndClimateChange.pdf>.

Land use change

Through farming, harvesting of natural resources and urbanisation, humans have significantly modified the Earth's landscape from its natural state, and the rate of modification has accelerated dramatically since the industrial revolution. Such changes can reduce or increase the ability of soil and vegetation to absorb, store and release carbon. [6] In addition, the way in which we use the land and change the type and extent of vegetation alters the albedo of the planet's surface, which affects the amount of solar energy absorbed by the surface and hence the temperature.

Plants absorb carbon dioxide from the atmosphere during photosynthesis, and forests represent a significant ongoing carbon sink while they are actively growing. This may continue for hundreds of years, until the trees and forest ecosystem reach an age where losses of carbon through shedding of leaves and limbs and decaying dead woody debris above and below ground may start to exceed the gains of carbon through new growth. Deforestation and land clearing releases much of the carbon that was stored in the plant biomass, either quickly if the slash and burn approach is used, or slowly as the plant matter decays over time.

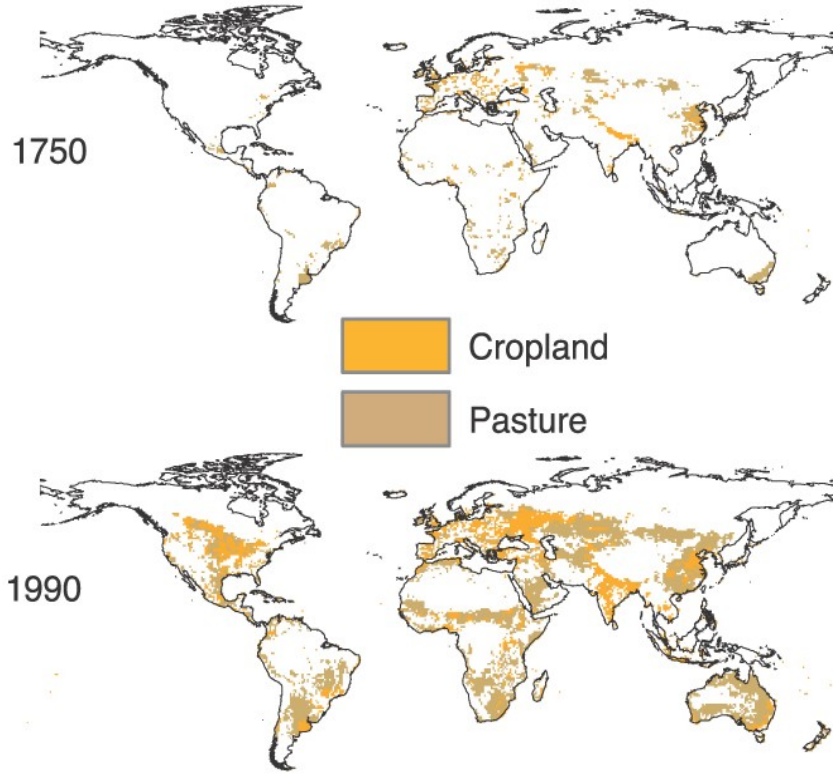
Since 1850, deforestation is estimated to have reduced the total global forest area by about 17 per cent, but the percentage is much higher in some regions. [7] The issue is of particular interest to Australia because of the high deforestation rates in neighbouring countries, as well as our own record of deforestation and potential for carbon sequestration through reforestation. [8] Indonesia has one of the fastest deforestation rates in the world, and the rate has been accelerating;

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the forests existing in Indonesia in 1950 have since been cleared. [9] Deforestation in Papua New Guinea (PNG) has also been accelerating in recent years, with an annual loss rate of 1.4 per cent. Fifteen per cent of PNG's forests existing in 1972 were cleared in the following 30 years, and it is projected that more than half will be lost or seriously degraded by 2021. [10] In Australia, deforestation rates have declined since the early 1990s, but it is estimated that about 25 per cent of the total forest area that existed before European settlement has been cleared, and much of the remaining forest area has been substantially modified and fragmented. [11]

Figure 2 illustrates the global extent of conversion of land to crops and pasture between 1750 and 1990.

Figure 2 : Anthropogenic changes in land cover from 1750 to 1990



Notes: Anthropogenic (human) modifications of land cover up between 1750 (top panel) and 1990 (bottom panel)—reconstructions from the History Database of the Environment. Source: 'Chapter 2 Changes in atmospheric constituents and in radiative forcing', in IPCC, *Climate change 2007: the physical science basis*, contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 2007, Figure 2.15, p. 181.

Activities associated with agriculture, such as land clearing, burning, deforestation and tillage, change the reflectivity, texture and composition of the land surface, which in turn change the level of absorbed radiation and the amount of evaporation. In addition, deforestation tends to degrade the land, by removing organic matter and nutrients and disturbing the soil structure, which reduces the capacity of the land to re-establish a healthy ecosystem with strong plant growth and carbon uptake. Removal of vegetation also reduces the ability of soils to retain moisture and may make it harder for rainwater to infiltrate, commonly exacerbating erosion.

The soil is thought to contain three times more carbon than the atmosphere. Agricultural practices causing changes in soil structure, soil moisture loss and over-cultivation reduce soil organic content by reducing the density of soil organisms and accelerating oxidation of organic carbon compounds to produce carbon dioxide. It is estimated that most agricultural soils have lost 50 to 70 per cent of the soil organic carbon pool that existed before their conversion and cultivation. However, modified farming practices can help retain soil carbon and hence maximise the potential of soil to act as a carbon sink. [12] It is estimated that about 15 per cent of current global emissions from agricultural soils can be mitigated at no additional cost by reducing or eliminating tillage to maintain higher soil organic carbon content, and optimising timing and application of fertilisers to reduce nitrous oxide emissions. [13]

Observations and attribution of climate change

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In the past century, the average surface temperature of the Earth has warmed by over 0.7°C. [14] Much of that warming has been in the past three decades. The temperature rise varies regionally and seasonally. Regional climate change in some areas, therefore, has been more dramatic—Arctic sea ice is melting rapidly and is 40 per cent thinner than it was in the 1970s. Most of the world's glaciers have been retreating since the 1850s, and the rate of retreat has increased since 1990. The movement of glaciers in Greenland and in much of the world is also speeding up, apparently lubricated by melt water seeping down to the ice–rock boundary and in some cases by loss or reduction of ice shelves at their outlet, which is accelerating the loss of ice mass.

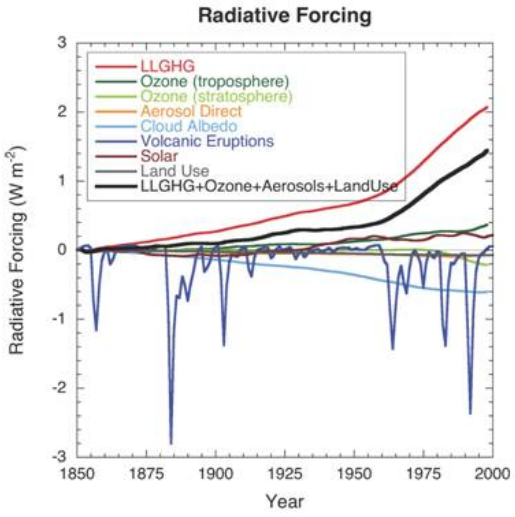
The sea level is also rising. [15] This is partly from thermal expansion as the surface layers of water heat up (water occupies more volume when it is warmer), and partly from ice loss from glaciers and ice caps. Ice losses from the huge ice masses in the Greenland and Antarctic ice sheets have also contributed significantly to sea level rise, and observations show that loss from these ice sheets is accelerating.

Though an average global temperature increase of 0.7°C may not seem dramatic, an increase in mean temperature also has implications for the temperature extremes that we experience. Most temperature recording stations around the world show that average night-time minimum and day-time maximum temperatures have both increased over the last few decades. Periods of sustained and unusually high temperatures are becoming more common in some places, such as the 2003 heatwaves in central Europe thought to be responsible for the premature deaths of up to 35 000 (mainly elderly) people, and the 2003 pre-monsoon heatwave in India which had severe impacts on human health and contributed to the deaths of 1400 people.

Although any individual weather event cannot be attributed unequivocally to climate change, the probability of such high temperature events increases with the underlying trend of rising mean temperature.

The estimated relative contribution of human and natural factors to global warming is illustrated in Figure 3 . The contribution is measured in terms of radiative forcing, with a positive change representing a warming effect and a negative change representing a cooling effect.

Figure 3 : Globally and annually averaged radiative forcing due to various agents since 1850



Notes: This is an illustrative example of the forcings as implemented and computed in one of the climate models participating in the IPCC Fourth Assessment Report. Note that there could be differences in the radiative forcings among models. Most models simulate roughly similar evolution of the long-lived greenhouse gases' radiative forcing. Source: 'Chapter 2 Changes in atmospheric constituents and radiative forcing', in IPCC, *Climate change 2007: the physical science basis*, contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 2007, Figure 2.23, p. 208.

The concentrations of long-lived greenhouse gases (LLGHGs) have increased rapidly over the past 20 years. These contribute the most to radiative forcing, exceeding the level of contribution from all other anthropogenic agents throughout the latter half of the 20th century. The black line in Figure 3 indicates the net effect of all greenhouse gases, aerosols and land use.

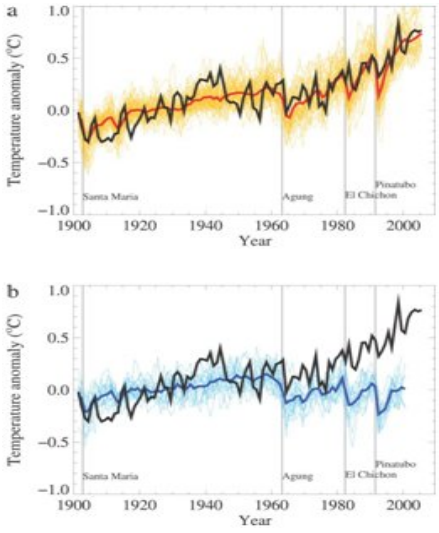
The input from solar effects (the sun varying slightly in its output of radiation) is around 20 per cent of the combined effect of all anthropogenic agents, and about ten times less than the total greenhouse gas contribution. Volcanic eruptions have a large but transitory effect, which is usually negative (i.e. cooling).

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Scientists are confident that natural factors cannot account for the observed warming in recent decades. Figure 4 demonstrates that when climate models incorporate only these natural factors (see bottom panel), they are able to reproduce the general pattern of global temperature up until about 1960. The cooling influence of volcanic eruptions (marked with vertical lines and labelled in the figure for each volcano) is also clearly discernible—these cause large emissions of aerosols into the atmosphere that act to reflect incoming sunlight. Models incorporating only natural factors, however, are not able to reproduce the pronounced rise in temperature observed since 1960. Note that the high variability in observed temperature from year to year is not well simulated, because this arises from random and unpredictable processes in the climate system that cannot be effectively modelled. The models are more concerned with accurate simulation of the trend in temperature over several decades. [16] As shown in the top panel of Figure 4 , in order to reproduce the warming of the past several decades, anthropogenic forcing (the change in radiative balance due mainly to greenhouse gas emissions from human activities) must be included.

This result presents some of the most convincing evidence that human activities are causing global warming—there are no known natural processes that can account for the observed warming, and the increase in greenhouse gas concentrations due to human activities is necessary and sufficient to explain the observations. This and other evidence led the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) to conclude that natural processes have played little or no contributing role in driving climate change over the last 50 years. [17]

Figure 4 : Global mean surface temperature anomaly observations (black lines), simulations with combined natural and anthropogenic forcing (red line) and simulations with natural forcing only (blue line)



Notes: Comparison between global mean surface temperature anomalies (°C) from observations (black) and atmosphere–ocean general circulation model simulations forced with (a) both anthropogenic and natural forcing and (b) natural forcing only. All data are shown as global mean temperature anomalies relative to the period 1901 to 1950, as observed (black, Hadley Centre/Climatic Research Unit gridded surface temperature data set (HadCRUT3)) and, in (a) as obtained from 58 simulations produced by 14 models with both anthropogenic and natural forcing. Significant volcanic eruptions are indicated by grey vertical lines with labels. Source: 'Chapter 9 Understanding and attributing climate change', in IPCC, *Climate change 2007—the physical science basis*, contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 2007, Figure 9.5, p. 684.

To summarise, a wide range of evidence from a number of sources covering trends over the last two centuries and comparing those to trends over timescales ranging from millennia to several hundred thousand years demonstrate that the rate and extent of recent changes in climate are unprecedented in human history. [18] Furthermore, there is a strong consensus within the scientific community that recent climate change has been largely, or possibly wholly, driven by human activities since the industrial revolution, particularly emissions of greenhouse gases from fossil fuel combustion and land use change.

Importance and timing of action to mitigate climate change

If we take as a starting point the premise that climate change is occurring and is caused mainly by human activities, as is argued in the previous section, we then come to the issue of what, if anything, should be done about it. An assessment of whether climate change mitigation action is necessary and urgent requires answers to the following questions:

- How much is the climate likely to change if we do nothing, and how much will this change be moderated if we do something (with 'something' quantified through one or more scenarios involving specified mitigation action)?
- What are the likely impacts of climate change on our economy, society and environment?

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- How may these impacts be moderated or exacerbated under mitigation or no-mitigation scenarios and how are they affected by the timing of mitigation action?

There have been a number of studies addressing these questions, examining the economics and science of climate change, and reviewing the knowledge that has accumulated over the past several decades. Of particular note for their comprehensive and widely-sourced information are the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports, the *Stern review on the economics of climate change*, and the *Garnaut climate change review*. [19]

The IPCC was established in 1988 to provide a comprehensive, objective, open and transparent assessment of the latest scientific, technical and socio-economic literature produced worldwide relevant to climate change and its risks and impacts, and options for mitigation and adaptation. Since its establishment, it has delivered four comprehensive assessment reports, in 1990, 1995, 2001 and 2007. It has also published many special and technical reports covering topics such as socioeconomic emissions scenarios and emissions from land use practices. The Fourth Assessment Report, in 2007, includes three volumes dealing respectively with the physical science basis; impacts, adaptation and vulnerability; and mitigation of climate change. More than 1200 authors and 2500 expert reviewers examined the full body of work on climate science to produce the Fourth Assessment Report, and its Summary for Policymakers was agreed to line by line by government representatives of each of the more than 100 participating member countries. [20]

In 2005, Sir Nicholas Stern was commissioned by the British Chancellor of the Exchequer to assess the economic challenges of climate change in the UK and globally, and advise on how these challenges may best be met. The Stern Review, released in October 2006, became the most comprehensive and widely known report of its kind. [21]

In April 2007, Professor Ross Garnaut was commissioned by then opposition leader Kevin Rudd and the Premiers and Chief Ministers of Australia's states and territories to examine the impacts of climate change on the Australian economy and recommend policy measures to support Australia's long-term prosperity in the face of these impacts. The final report of the Garnaut Review was released in September 2008. The Garnaut Review was essentially an Australian version of the Stern Review, but significant advances in the science and economics had emerged in the intervening period, notably the release of the IPCC's Fourth Assessment Report in 2007. The Garnaut Review currently represents the most comprehensive and up-to-date scientific and economic assessment of climate change available, and as an Australian study, it is of particular relevance to the Australian situation. [22]

The following sections draw heavily from these sources, particularly the IPCC Fourth Assessment Report and the Garnaut Review, to address the questions posed above. While many additional studies, both economic and scientific, have been published, the above-mentioned sources are unique in their treatment of the issue. Firstly, they are unique in the comprehensive nature of their assessment, which covers all or nearly all aspects of the complex and interacting scientific and socioeconomic implications of climate change. Secondly, they are not motivated by particular interest groups or industry perspectives: they are independent reviews of all the available evidence, and their projections and recommendations are a result of the objective application of the best available models and interpretation of their output. Thirdly, as a corollary to the second point, in reviewing and incorporating information from a large range of sources, they represent 'moderate' assessments of the impacts and challenges presented by climate change: they are not able to 'cherry pick' data or studies to either downplay or exaggerate the risks of climate change. Of course, there exist many studies, interest groups and individuals who disagree with the findings of the above reviews. The fact that these disagreements are fairly evenly distributed in both directions along the spectrum of climate change risk level assessment suggests that the reviews took a fairly moderate position.

Below, the questions posed at the beginning of this section regarding the importance and timing of global mitigation action are addressed by consideration of environmental and economic aspects in turn.

Environmental considerations

Before human industrial development, the concentration of carbon dioxide in the atmosphere was about 280 ppm. The burning of hydrocarbon fuels, notably coal and oil, together with activities such as large scale deforestation, has caused the atmospheric CO_2 concentration to increase to its current level of over 380 ppm. In addition to this increase in CO_2 in the atmosphere, emissions of non-CO_2 greenhouse gases, some of which were absent from the atmosphere in pre-industrial times, has brought current total greenhouse gas concentrations to more than 450 ppm CO_2e. Furthermore, the rate of CO_2 and other greenhouse gas emissions has been accelerating over recent years. [23] While most developed countries are in the process of stabilising or slightly reducing their emissions, the rapidly expanding economies of large, populous countries such as China and India are causing a concurrent rapid growth in emissions from those countries. [24] Achieving significant global emissions reductions will, in the first instance, require substantial action on the part of developed countries, which have the greatest capacity to implement these reductions. Ultimately though, it will require a concerted global effort involving a countries.

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The longer that action to mitigate climate change is delayed, the more drastic will be the measures required to stabilise atmospheric greenhouse gas concentrations at a given level, and the more likely that the ultimate stabilisation level will be higher. Conversely, achieving lower stabilisation levels will require almost immediate action: for example, it has been estimated that to stabilise at around 450 ppm CO_2e, global emissions will need to have peaked and be starting to decline by 2015. Table 1 illustrates the implications of different greenhouse gas stabilisation targets in terms of what those targets correspond to in CO_2 levels alone (compare columns 2 and 3), the best estimate and likely range of warming that would result (columns 4 and 5), and the timing and magnitude of emissions reductions required to achieve those targets (columns 6 and 7).

Table 1 : Properties of emissions pathways for alternative ranges of CO_2 and CO_2e stabilization targets

Mitigation class	Multi-gas concentration level (ppm CO_2e)	Stabilization level for CO_2 only, consistent with multi-gas level (ppm CO_2)	Global mean temperature C increase above pre-industrial at equilibrium, using best estimate of climate sensitivity[c]	Likely range of global mean temperature C increase above preindustrial at equilibrium[a]	Peaking year for CO_2 emissions[b]	Change in global emissions in 2050 (% of 2000 emissions)[b]
I	445–490	350–400	2.0–2.4	1.4–3.6	2000–2015	−85 to −50
II	490–535	400–440	2.4–2.8	1.6–4.2	2000–2020	−60 to −30
III	535–590	440–485	2.8–3.2	1.9–4.9	2010–2030	−30 to +5
IV	590–710	485–570	3.2–4.0	2.2–6.1	2020–2060	+10 to +60
V	710–855	570–660	4.0–4.9	2.7–7.3	2050–2080	+25 to +85
VI	855–1130	660–790	4.9–6.1	3.2–8.5	2060–2090	+90 to +140

Notes: Estimates are based on 177 independent scenario studies, most (118) corresponding to a doubling of CO_2 concentrations from pre-industrial or current levels (class IV, 590–710 ppm CO_2e).

a. Warming for each stabilization class is calculated based on the variation of climate sensitivity between 2°C–4.5°C, which corresponds to the likely range of climate sensitivity

b. Ranges correspond to the 70% percentile of the post-Third Assessment Report scenario distribution.

c. 'Best estimate' refers to the most likely value of climate sensitivity

Source: 'Chapter 3 Issues related to mitigation in the long-term context', in IPCC, *Climate Change 2007: Mitigation of Climate Change*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 2007, Table 3.10, p. 229.

The Stern Review found that to achieve a stabilisation level of 550 ppm CO_2e, if global emissions peak by 2015, then a reduction rate of 1 per cent each year should be sufficient. If, however, the peak in emissions is delayed by 15 years, until 2030, then the reduction required per year is more than doubled, to between 2.5 per cent and 4.0 per cent per year, depending on the height of the peak. [25] Stern notes:

> Pathways involving a late peak in emissions may effectively rule out lower stabilisation trajectories and give less margin for error, making the world more vulnerable to unforeseen changes in the Earth's system... [O]vershooting paths lead to particularly high risks, as temperatures rise more rapidly and to a higher level than if the target were approached from below. [26]

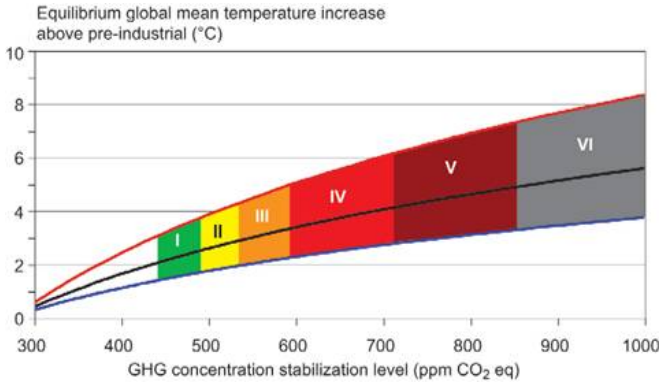
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The Garnaut Review notes it is increasingly recognised that it will be impossible to achieve ambitious stabilisation targets such as 450 ppm CO_2e without initial overshooting of the target. The potential adverse impacts of this overshooting (the amount of additional warming and other changes in climate that will result) will depend on the length of time the concentrations stay above the target and how far above the target concentrations rise:

> … due to inertia in the climate system, a large and lengthy overshooting will influence the transient temperature response, while a small, short one will not. [27]

It is clear that a higher greenhouse gas concentration stabilisation level will result in warmer mean global temperatures, as shown in Figure 5 . The figure shows the likely temperature range resulting from different stabilisation targets, which are grouped into different mitigation classes corresponding to the mitigation classes in Table 1 .

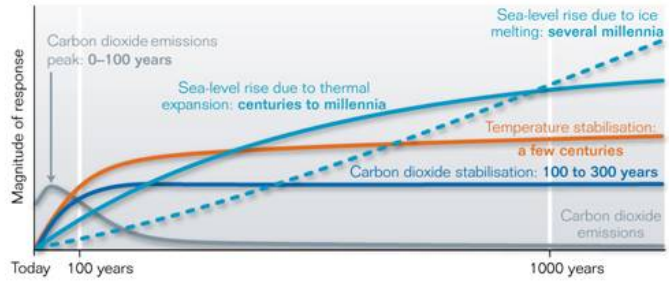
Figure 5 : Relationship between global mean equilibrium temperature change and stabilization concentration of greenhouse gases



Notes: Results from: (i) 'best estimate' climate sensitivity of 3°C (black), (ii) upper boundary of likely range of climate sensitivity of 4.5°C (red), (iii) lower boundary of likely range of climate sensitivity of 2°C (blue). Roman numerals in coloured blocks refer to classes of emissions pathways as described in Table 1 . Source: IPCC, *Climate Change 2007: Mitigation of Climate Change*, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 2007, Figure 3.38, p. 228.

These temperature increases, along with associated sea level rise and other changes in the climate system, will not happen immediately, but will continue to occur over the next several centuries. This is because some aspects of the climate system respond slowly to changes in radiative forcing caused by changes in greenhouse gas concentrations (i.e., they have high inertia). The oceans have an enormous heat capacity, and heat absorbed into the oceans from the atmosphere is redistributed from one region to another and between deep and shallow waters through large-scale circulation patterns over thousands of years. [28] Other processes in the climate system may respond more quickly, but as Figure 6 illustrates, the impacts of emissions taking place now and in the next few decades will be felt for many centuries to come.

Figure 6 : Inertia in the climate system



Source: IPCC (2001b: Figure 5.2), reformatted for this publication.

Source: R Garnaut, *The Garnaut climate change review: final report*, Cambridge University Press, Cambridge, 2008, Figure 2.6, p. 42.

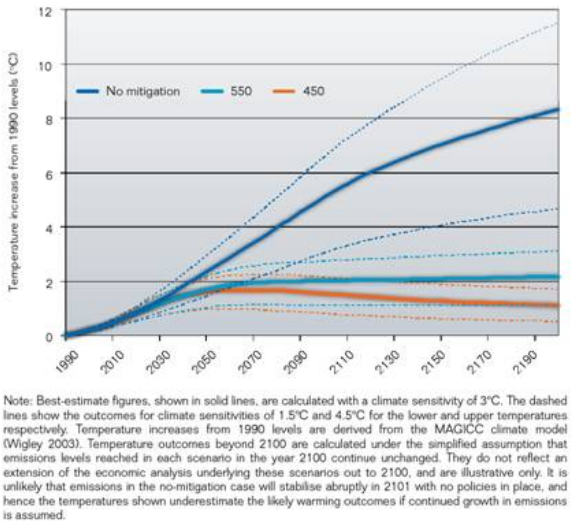
In considering the likely warming and other climate change impacts of higher atmospheric greenhouse gas concentrations, the Garnaut Review considers two mitigation cases as well as a no-mitigation case:

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- Under the no-mitigation case, atmospheric greenhouse gas concentrations are projected to reach over 1550 ppm CO_2e by 2100.
- Under the 550 mitigation case, emissions peak and decline steadily so that atmospheric concentrations stabilise at around 550 ppm CO_2e by 2100.
- Under the 450 mitigation case, emissions are immediately reduced and decline more rapidly than the 550 case. Concentrations overshoot to about 530 ppm CO_2e in mid-century before stabilising at around 450 ppm CO_2e early in the 22nd century.

Figure 7 shows the projected temperature increase under each of these scenarios out to 2200.

Figure 7 : Projected temperature increases to 2200 above 1990 levels for the three Garnaut emissions cases



Note: Best-estimate figures, shown in solid lines, are calculated with a climate sensitivity of 3°C. The dashed lines show the outcomes for climate sensitivities of 1.5°C and 4.5°C for the lower and upper temperatures respectively. Temperature increases from 1990 levels are derived from the MAGICC climate model (Wigley 2003). Temperature outcomes beyond 2100 are calculated under the simplified assumption that emissions levels reached in each scenario in the year 2100 continue unchanged. They do not reflect an extension of the economic analysis underlying these scenarios out to 2100, and are illustrative only. It is unlikely that emissions in the no-mitigation case will stabilise abruptly in 2101 with no policies in place, and hence the temperatures shown underestimate the likely warming outcomes if continued growth in emissions is assumed.

Source: R Garnaut, *The Garnaut climate change review: final report*, Cambridge University Press, Cambridge, 2008, Figure 4.7, p. 92.

Higher temperatures present greater risks to the environment, both regionally and globally, and consequently to our socioeconomic productivity, security and health. The IPCC report lists key vulnerabilities relating to a given increase in global mean temperature as shown in Table 2 . [29] The table also indicates the approximate stabilisation levels of greenhouse gas concentrations in the atmosphere corresponding to each temperature increase.

Table 2 : Key vulnerabilities corresponding to given ranges of temperature increase

Temperature increase	Stabilisation target	Vulnerabilities
>4°C	>700 ppm CO_2e	Near-total deglaciation; at least 35 per cent of species committed to extinction; increase in severity of floods, droughts, erosion and deterioration in water quality; decline in global food production; increased frequency and intensity of extreme weather events and fire risk.
3–4°C	>590 ppm CO_2e	Widespread to near-total deglaciation, 2–7 metre sea level rise over centuries to millennia; global vegetation becomes a net source of CO_2; extended salinisation of ground water, decreasing freshwater availability in coastal areas.
2–3°C	>450 ppm CO_2e	Lower risk of near-total deglaciation; 20 to 50 per cent of species committed to extinction; hundreds of millions of people would face reduced water supplies; global food production peaks and declines.

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1–2°C	<450 ppm CO_2e	Localised deglaciation; 10–40 per cent of species committed to extinction; increased flooding and drought severity; reduced low latitude food production, increased high latitude production; increased fire frequency and intensity.
0–1°C	<450 ppm CO_2e	Lower risk over all vulnerabilities.

Source: IPCC, *Climate change 2007: mitigation of climate change*, contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 2007, Table 3.101 p. 230.

The Garnaut Review finds significant reductions in environmental risks and damages could be achieved with global mitigation action. For example, the Garnaut Review suggests that the percentage of species at risk of extinction under the no mitigation case is 88 per cent, which is reduced to 12 per cent under the 550 scenario and 7 per cent under the 450 scenario. Large-scale melting of the Greenland ice sheet is certain to be initiated with no mitigation, but the likelihood is reduced to 26 per cent under the 550 scenario and 10 per cent under the 450 scenario. [30]

The recent climate change science congress in Copenhagen in March 2009 highlighted the importance of implementing rapid and substantial measures to respond to the changes in climate that we are continuing to observe. The congress was convened to provide a synthesis of existing and emerging scientific knowledge since the IPCC Fourth Assessment Report, to help inform policymakers at the UNFCCC climate change conference in Copenhagen in December 2009. [31] A full synthesis report from the science congress will be published in June 2009. The following points list some of the key messages that emerged: [32]

- Recent observations show that climate change is proceeding at rates corresponding to the worst-case scenarios of the IPCC Fourth Assessment Report, or worse. These include observations of temperatures, sea level rise and extreme climatic events.
- There is more information available now that suggests our societies, particularly those of poor nations, will struggle to adjust to climate change even at moderate levels of change.
- Rapid action is required to effectively mitigate the risks of climate change. Committing to weak emissions reduction targets for 2020 will increase the risk of irreversible damaging climate change and make it more difficult to meet substantial targets in 2050.

Economic considerations

The Garnaut Review assessed the relative costs of likely climate change impacts and mitigation measures. It considered four types of costs of climate change:

- Type 1 costs are the expected market impacts of climate change that can be assessed quantitatively through general equilibrium economic models. Garnaut focuses on impacts on primary production, human health, infrastructure, tropical cyclone damage, and international trade. The costs are realised through their effects on GDP or consumption.
- Type 2 costs are market impacts that are not currently readily measurable. These impacts are similar in nature to Type 1, but there are insufficient data at present for detailed modelling of Type 2 costs. However, Garnaut provides a rough estimate of the likely magnitude of these costs based on available knowledge. An example is the impact on the tourism industry.
- Type 3 costs relate to the insurance value provided by mitigation, for avoided risks. Garnaut poses the question of how much we would be willing to pay to avoid a small probability of a catastrophic outcome. Such catastrophic events with potentially highly damaging consequences to human society include irreversible melting of the Greenland and West Antarctic ice sheets, each contributing a 7-metre rise in sea level; melting of the summer Arctic sea ice; disruption of the Atlantic circulation system (which includes the Gulf Stream and the North Atlantic Drift); disruption of the Indian monsoon; disruption of the El Niño–Southern Oscillation; disruption of the Sahara/Sahel and West African monsoon; dieback of the Amazon rainforest; and dieback of high-latitude forest. For example, the tipping point of melting of the Greenland ice sheet has been put at a temperature increase of between 1.9°C and 4.6°C above pre-industrial levels. [33] Thus, the Greenland ice sheet could begin to melt irreversibly, leading to its complete loss over the next centuries, even under the most stringent stabilisation targets (see temperature projections corresponding to stabilisation targets in Table 1). Other major impacts are considered likely to occur only under relatively high stabilisation levels (see Table 2). The desire to avoid or substantially reduce the risk of such events occurring presents a compelling argument for strong and early mitigation action.
- Type 4 costs relate to non-market impacts, or a reduction in the utility of non-monetary services such as environ amenity (e.g. the value that Australians place on the integrity of the Great Barrier Reef, Kakadu, coastal ecosyste

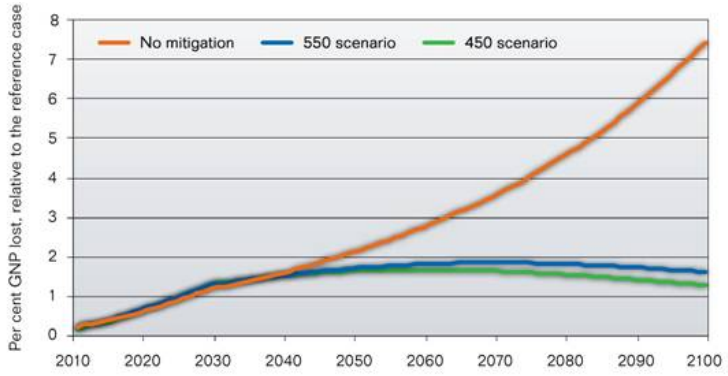
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biodiversity and species conservation), longevity, health and welfare of people in other countries. Although in principle monetary values can be assigned to such outcomes, the Garnaut Review assesses this type of cost qualitatively.

All of the four cost types are important. All four are costs that Australia would want to avoid if at all possible, even though only types 1 and 2 can be quantified with any accuracy.

The Garnaut Review's findings clearly indicate that the costs of no action would be considerably higher than the costs of action in the long term, as illustrated in Figure 8 , which shows the cumulative cost of mitigation or no mitigation compared to the reference case in which there are no adverse climate change impacts. Figure 9 shows that after an initial shock to GNP growth of around 0.8 per cent and a slight reduction in GNP growth over the next 50 years compared to the no-mitigation case, in the later part of the century mitigation results in a net increase in GNP growth as the avoided damaging climate change impacts outweigh the costs of mitigation.

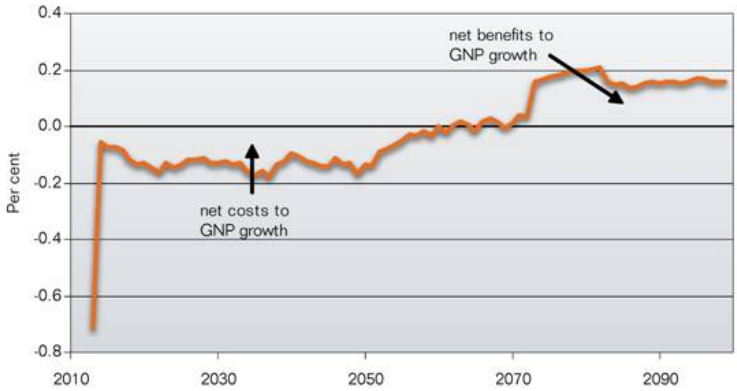
Figure 8 : A comparison of the modelled expected market costs for Australia of unmitigated and mitigated climate change up to 2100



Notes: The graphs show the cost as a percentage of GNP of expected market damages from the level of climate change associated with the three scenarios. These estimates are achieved by 'shocking' the reference case with the differing levels of impact associated with the temperatures expected from the three scenarios.

Note: includes Type 1 costs only. Source: R Garnaut, *The Garnaut climate change review: final report*, Cambridge University Press, Cambridge, 2008, Figure 11.6, p. 267.

Figure 9 : Change in annual Australian GNP growth (percentage points lost or gained) due to net mitigation costs under the 550 scenario compared to no mitigation, 2013–2100



Notes: Modelled results from Type 1 costs, adjusted to incorporate Type 2 costs, which are estimated at about 30 per cent of Type 1 GNP costs. Source: R Garnaut, *The Garnaut climate change review: final report*, Cambridge University Press, Cambridge, 2008, Figure 11.4, p. 265.

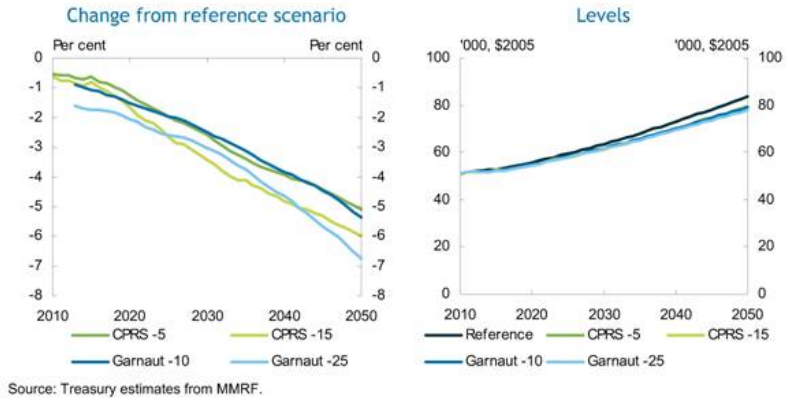
The Australian Treasury undertook a similar analysis of the costs of mitigating climate change, comparing the two Garnaut mitigation scenarios (labelled Garnaut–10 and Garnaut–25, corresponding to stabilisation targets of 450 and 550 ppm CO_2e, respectively, and emissions reductions targets of 10 per cent and 20 per cent by 2020, respectively), as well as two scenarios corresponding to the framework of the Carbon Pollution Reduction Scheme (CPRS) with 5 per cent (scenario CPRS–5) and 25 per cent (scenario CPRS–25) emissions reduction targets by 2020, respectively. It is important to note that unlike the Garnaut projections, the Treasury modelling projects only the costs of mitigation compared to a reference case that excludes th and impacts of climate change and its associated costs. Furthermore, the Treasury projections extend only to 2050. Li

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Garnaut scenarios, the Treasury scenarios assume coordinated global action is established. The Treasury scenarios assume that developed countries take comparable action, and that developing countries join the scheme over the period 2015 to 2025.

Figure 10 illustrates that under all mitigation scenarios, the Treasury modelling projects that GNP continues to grow, but the cumulative difference between the mitigation scenarios and the reference case amounts to between 5 per cent and 7 per cent of GNP by 2050. The Treasury modelling also examined the effect of delaying global mitigation action by seven years (from 2013 to 2020) but retaining a stabilisation target of 550 ppm CO_2e by 2100. The analysis found that under delayed action, global costs were about 10 per cent higher in 2050 and remained higher to 2100. [34]

Figure 10 : Treasury modelling of GNP per capita as (a) change from reference scenario and (b) levels, 2010 to 2050, for the CPRS-5, CPRS-15, Garnaut-10 and Garnaut-25 scenarios



Source: Australian Treasury, *Australia's low pollution future: the economics of climate change mitigation—report*, Commonwealth of Australia, 2008, Chart 6.9, p. 144.

In relation to the no-mitigation case, the Garnaut Review concludes:

> …[T]emperature increases of the order of magnitude associated with no mitigation—an expected increase by 2100 of 5.1°C, a 6.6°C warming at the top of the likely band, and a smaller probability of a double-digit temperature increase—would not lead to a marginal reduction in human welfare. Their impacts on human civilisation and most ecosystems are likely to be catastrophic. [35]

While the science is clear that any delay in implementing effective and substantial mitigation measures increases the risks of damaging climate change, it is also clear that the costs of mitigation will be higher the longer we wait. Acting early enables businesses and industries to adjust gradually to make the transition to a low-carbon economy, with time for new technologies to emerge and compete to replace old carbon-intensive technologies. Such effort will take time, and will only be justified with the aid of the economic incentives provided by mitigation measures. Such measures, of which emissions trading is likely to be central, can be introduced with, for example, gradually increasing carbon prices so as to ease the transition while stimulating innovation and development. [36]

Regarding paths to stabilisation levels and timing of mitigation action, Stern notes:

> Early abatement may imply lower long-term costs through limiting the accumulation of carbon-intensive capital stock in the short term. Delaying action risks getting 'locked into' long-lived high carbon technologies. It is crucial to invest early in low carbon technologies. [37]

As an example illustrating this point, Australia, like many other countries including the US and China, relies heavily on coal to meet its energy needs, and it is unrealistic to expect that Australia will be able to abruptly end this reliance. However, in order for the coal industry to remain viable in a carbon-constrained world, much effort will need to be invested in developing and commercialising clean coal technologies and carbon capture and storage (CCS), to improve efficiency of coal-fired power stations and eventually reduce their emissions to near zero. In the absence of mitigation measures, Treasury modelling projects coal production to increase by 82 per cent by 2050 (from 2008 production levels). With an emissions trading scheme and in the absence of CCS, however, coal production is projected to decrease by 18 per cent by 2050. With CCS, production is lower than in the no-mitigation scenario, but increases by 42 per cent by 2050. [38] The Garnaut Review projects that global emissions trading scheme, zero-leakage (i.e., 100% efficient) CCS would result in an increase in global electricit

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generation from coal from current levels of around 10 gigawatt-hours (GWh) to over 100 GWh by 2100 to meet the increase in electricity demand. [39] Australian coal production would be expected to increase in line with global demand for exports. [40] If CCS is only 90% efficient, Garnaut projects electricity production from coal to peak by about 2070 and then decline.

These results clearly demonstrate that the future of Australia's coal industry is highly dependent on market responses to both domestic and international carbon trading and the development of zero-emission technologies. In the short to medium term, to begin the transformation of our energy industry that will be required under a low-carbon economy, the most painless path may involve domestic investment in implementing clean coal technologies and bringing carbon capture and storage technologies into fruition. [41]

Many other industries, including aluminium and agriculture, will similarly need time to adjust to market changes resulting from emissions trading. This will be necessary to minimise abrupt disruptions, which may include job losses and hardship in local communities that depend on these industries.

Australian emissions and mitigation action in the global context

Though developing countries are projected to account for an increasingly significant share of global emissions as their economies expand to meet their development needs, developed countries are responsible for the majority of greenhouse gas emissions to date, and have a greater capacity to implement mitigation and adaptation strategies. Climate change is a global problem that will require a global solution, but in order to achieve a global agreement on emissions reduction targets, each country has a responsibility to commit to and implement mitigation measures commensurate with its level of economic development.

The United Nations Framework Convention on Climate Change (UNFCCC) recognises the differentiated responsibilities of developed and developing countries. The UNFCCC has been ratified by 192 countries (including Australia and the US). Parties to the UNFCCC agreed that developed countries should take the lead in combating climate change and its impacts, and provide financial assistance to developing countries to facilitate sustainable development and to build resilience against adverse impacts of climate change. [42] The Kyoto Protocol builds on these principles, and commits developed countries and countries with economies in transition to specific emissions targets, while establishing the Clean Development Mechanism to encourage developed countries to invest in emissions reduction activities in developing countries: [43]

> Recognizing that developed countries are principally responsible for the current high levels of [greenhouse gas] emissions in the atmosphere as a result of more than 150 years of industrial activity, the Protocol places a heavier burden on developed nations under the principle of 'common but differentiated responsibilities.' [44]

Although home to only 0.3 per cent of the world's population, Australia's greenhouse gas emissions contribute about 1.5 per cent of the world total. Australia's emissions per capita are the highest in the Organisation for Economic Co-operation and Development (OECD) and among the highest in the world. [45] This is largely due to Australia's high reliance on coal for electricity production, as well as its high agricultural production per capita. The amount of carbon burned per dollar of wealth created in Australia is higher than the US and nearly double that of Europe and Japan. The average growth rate of Australia's emissions over the last 25 years was twice that for the US and Japan, and five times that for Europe. [46]

Garnaut notes that the costs of mitigation are relatively higher when they are carried by the poor than when they are carried by the rich, because an increment of money is generally more valuable to the poor than the rich. He supports greater mitigation efforts by developed countries than developing countries and further notes that this is in Australia's interest because:

> Australia has a strong interest in the burden of mitigation being borne equitably across countries and therefore disproportionately by developed economies, as Australia's terms of trade would be damaged most by any setback to income growth in developing countries. [47]

Garnaut highlights the role Australia can play in facilitating an international agreement. He notes that action so far by individual countries and states within countries such as Australia have helped gather momentum and provide the impetus for and confidence in such an agreement, and that:

> Pending international agreement, it will be helpful for individual countries to move forward unilaterally, so long as this is within policy frameworks that are designed to integrate productively with an emerging international agreement. [48]

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Australia has a disproportionately high stake in ensuring that an international effort to reduce greenhouse gas emissions is realised for the following reasons: [49]

- Australia has very high climate variability compared to other developed nations and our ecosystems and livelihoods are particularly vulnerable to the potential adverse impacts of climate change. An international agreement is urgent and absolutely necessary to avoid damaging environmental impacts and associated consequences of climate change, and such an agreement will only be possible if individual countries, including Australia, attach enough importance to it.
- With our large aluminium export industry and as the world's largest exporter of coal, which is the most emissions-intensive major energy source, Australia is also particularly vulnerable to the risks of economic distortion that may result from domestic assistance to trade-exposed emissions-intensive industries in the absence of an international agreement.
- An effective international agreement lowers the cost of Australian mitigation, and allows more ambitious emissions reduction targets to be achieved with correspondingly lower risks of adverse impacts.
- Unchecked global climate change would cause significant economic damage to Australia's major trading partners, in both developed and developing nations. As a trading nation, it is in Australia's long term economic interests to minimise this damage through an effective international greenhouse gas emissions control agreement, thereby maintaining its overseas markets.

In summary, of all the developed countries, Australia stands to lose the most if an international agreement to reduce global emissions is not achieved. It would be difficult for Australia to justify any other position than playing its full and fair part in committing to mitigate emissions. Implementing our own domestic measures consistent with that responsibility will both facilitate the successful realisation of an effective international agreement and ease the integration of our economy and industries into a carbon-constrained world. Australia is also likely to benefit from continuing to work with regional and international partners to develop and maintain mutual capacities to anticipate and respond to the challenges posed by climate change. [50]

From debate to action

Understanding climate change and its risks and reaching a consensus on whether and what action is required to mitigate climate change is an enormous challenge. As noted earlier, there is a strong consensus within the scientific community on the fundamental reality of anthropogenic climate change. However, the climate system is complex, and some aspects are not well understood. [51] The complexities and uncertainties are often amplified, distorted, misrepresented and perpetuated through the media and interest groups, whose vested interests, corporate ideology, personal beliefs or desire to garner attention lead them to publicise extreme views or incomplete evidence to sensationalise or deny the reality of climate change.

Another powerful force driving the nature of the debate and public opinion is government attitude. At its extreme, this has stifled scientific research and censored publication of findings, with the recent Bush administration in the US being criticised as an example of such practices. As James McCarthy, President of the American Association for the Advancement of Science recently said:

> I think many people don't realise how difficult it was for this science community in the United States over the last eight years, seeing five years ago the need to really publicly call into question the scientific integrity of the United States administration; government scientists who were not permitted to talk to the press, the reports that were edited by people who had no scientific credentials whatsoever, the testimonies that had large segments deleted or altered before they could be made public. [52]

It is increasingly recognised, however, that climate change is real and here to stay, and that substantial ongoing mitigation measures must be implemented within a short timeframe in order to reduce the risks of adverse impacts over the next century and beyond to manageable levels. The US and Australia, the two countries among developed economies notable for their intransigence during and in the decade following the Kyoto negotiations, have now both had changes in government with new administrations prepared to act more decisively, and opposition parties in both countries are also changing their stance. [53]

Committing to action will not be an easy process, however. It essentially requires us to value lifestyles, wealth and commodities a hundred years from now over those we enjoy at present. But many economists argue that the 'discount rate', which determines the relative value of future utility or economic status relative to the present in economic modelling, should be set at zero, giving equal value to the future. Ross Garnaut judged a near-zero discount rate to be appropriate, because:

> The only reason for a positive rate of pure time preference is the risk of human extinction in any one year. [54]

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For most people, the issue of whether to value future utility does not require economic arguments. Our commitment to our children and grandchildren, to the continued social wellbeing of the human race, and to doing what we can to reduce human suffering is strongly embedded in our psyche. Witness the enormous outpouring of public support and donations in response to natural disasters that frequently occur throughout the world, and the culture of philanthropy embedded in many of our societies in both developed and developing countries.

Furthermore, polls repeatedly indicate that Australians are deeply concerned about climate change and that most people are prepared to make sacrifices to minimise the risks of disastrous consequences. [55] The 2007 Australian election has been described as the first climate change election, and the Labor Party's perceived progressiveness on the issue was thought to be a major factor contributing to its success in gaining government. [56]

Public concern and individual preparedness to act are not sufficient to address the challenge of climate change, however. The challenge requires an integrated, directed effort to transform our energy industry and carbon-intensive way of life. Mitigating the threat presented by climate change requires immediate and substantial action now—action that in its initial form may prove to be suboptimal, but that if it retains enough flexibility should ultimately pave the way to a sustainable future. The challenge we face also presents us with an opportunity: if we act early, our businesses, industries and economy can undergo the transformations that will be necessary to maintain or gain a competitive advantage and grow sustainably in a carbon-constrained world.

Prime Minister Rudd has described climate change as the great moral challenge of our generation. [57] Professor Ross Garnaut described it as a diabolical problem. [58] Little doubt remains, however, that the problem will persist and worsen until we act to address it. It seems sensible to conclude, therefore, that Australia should act urgently to initiate a framework of climate change mitigation so that our people, our industries and our nation will be ready to integrate into the international framework that will be required to slow and eventually halt global climate change.

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[1] . See, for example, comments from national and state leaders and departments in the following sources: P Wong (Minister for Climate Change and Water), *Climate change, global financial crisis, international negotiations on climate change, Carbon Pollution Reduction Scheme*, Transcript of interview with Reuters TV, New York, USA, 27 March 2009; M Turnbull (leader of the Opposition), *Climate change, economics and tax reform*, Speech to the Sydney Institute, 27 March 2008; ACT Government, *Weathering the change: The ACT climate change strategy 2007–2025*, Canberra, 2007, p. 5; Victorian Climate Change Summit, 'A message from Minister Jennings', Melbourne, 4 April 2008; M Rann (South Australian Premier, Minister for Sustainability and Climate Change), *Opening address—Climate leaders summit*, Poznań, Poland, 8 December 2008; C Barnett (West Australian Premier), *Transcript—Premier's speech—Greenhouse Convention 2009*, 25 March 2009; Queensland Department of Premier and Cabinet, 'Climate change in Queensland', Queensland Government; NSW Department of Environment and Climate Change, 'What is climate change', New South Wales Government; Department of the Chief Minister, *Discussion paper on NT climate change issues*, Northern Territory Government, 5 June 2008, p. 11; Tasmanian Climate Change Office, Department of Premier and Cabinet, *Tasmanian framework for action on climate change*, Tasmanian Government, 2008.

[2] . Much of the information in this section is derived from the Intergovernmental Panel on Climate Change (IPCC), *Climate change 2007: the physical science basis*, contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 2007, viewed 9 April 2009, <http://www.ipcc.ch/ipccreports/ar4-wg1.htm>. Further information is available from that publication as well as from the Parliamentary Library's 'Climate change' publication, viewed 14 March 2009, <http://www.aph.gov.au/Library/pubs/ClimateChange/>.

[3] . IPCC, Climate change 2007: the physical science basis, p. 10.

[4] . For an explanation of the difference between 'climate change' and 'global warming', see 'Climate change and global warming—what's the difference?', Parliamentary Library, Canberra, 2008–09, viewed 14 March 2009, <http://www.aph.gov.au/Library/pubs/ClimateChange/theBasic/climate.htm>, and for more information on the greenhouse effect see 'The greenhouse effect', viewed 14 March 2009, <http://www.aph.gov.au/Library/pubs/ClimateChange/theBasic/theGreenhouse.htm>, Parliamentary Library, Canberra, 2008–09.

[5] . For a history of the science of global warming, see S Weart, 'The discovery of global warming: The carbon dioxide greenhouse effect', American Institute of Physics, 2008, viewed 27 February 2009, <http://www.aip.org/history/climate/co2.htm>.

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[6] . Plants store carbon mostly in the form of carbohydrates, but the source of this carbon is CO_2 that is absorbed from the atmosphere. Soil carbon exists in many different forms. Various processes, including plant respiration, decay of plant matter and break-down of soil organic matter by soil micro-organisms, will release the carbon in plants and soil. When the carbon is released to the atmosphere, it is in the form of CO_2 or methane.

[7] . RA Houghton, 'The annual net flux of carbon to the atmosphere from changes in land use 1850–1990', *Tellus*, vol. 51B, 1999, pp. 298–313.

[8] . For more information on potential sinks for carbon sequestration, see 'Carbon sequestration', Parliamentary Library, Canberra, 2008–09, viewed 3 March 2009, <http://www.aph.gov.au/library/pubs/ClimateChange/responses/mitigation/carbon.htm>.

[9] . Global Forest Watch, 'Indonesia's forests in brief', viewed 26 February 2009, <http://www.globalforestwatch.org/english/indonesia/forests.htm>.

[10] . P Shearman et al., The state of the forests of Papua New Guinea: mapping the extent and condition of forest cover and measuring the drivers of forest change in the period 1972–2002, University of Papua New Guinea, 2008, viewed 26 February 2009, <http://gis.mortonblacketer.com.au/upngis/Downloads/State%20of%20Forests%20of%20PNG.pdf>.

[11] . Montreal Process Implementation Group for Australia, *Australia's state of the forests report*, Bureau of Rural Sciences, Canberra, 2008, p. xvi, viewed 26 February 2009, <http://adl.brs.gov.au/forestsaustralia/_pubs/sofr2008reduced.pdf>.

[12] . For further discussion of soil carbon sequestration, see 'Soil sequestration', Parliamentary Library, Canberra, 2008–09, viewed 2 March 2009, <http://www.aph.gov.au/library/pubs/ClimateChange/responses/mitigation/carbon.htm#soil>.

[13] . United Nations Framework Convention on Climate Change, *Challenges and opportunities for mitigation in the agricultural sector*, Technical Paper, 21 November 2008, p. 5, viewed 2 March 2009, <http://unfccc.int/resource/docs/2008/tp/08.pdf>.

[14] . IPCC, Climate change 2007: the physical science basis, p. 5.

[15] . IPCC, Climate change 2007: the physical science basis, p. 5.

[16] . See 'Scientific uncertainties', Parliamentary Library, Canberra, 2008–09, viewed 8 March 2009, <http://www.aph.gov.au/library/pubs/ClimateChange/uncertaintyAndScepticism/scientific.htm>.

[17] . Additional evidence is detailed in 'Climate change', Parliamentary Library, Canberra, 2008–09, viewed 18 March 2009, <http://www.aph.gov.au/library/pubs/ClimateChange/index.htm>. See, for example, the section 'The climate is changing', viewed 26 February 2009, <http://www.aph.gov.au/library/pubs/ClimateChange/theClimate/theClimate.htm>. The following publications also provide a comprehensive assessment of the evidence, causes, and projections of climate change: IPCC, *Climate change 2007: the physical science basis*; CSIRO/Bureau of Meteorology, *Climate change in Australia*, Technical Report, 2007, viewed 26 February 2009, <http://www.climatechangeinaustralia.gov.au/resources.php>; and R Garnaut, *The Garnaut Climate Change Review: final report*, Cambridge University Press, Cambridge, 2008, viewed 26 February 2009, <http://www.garnautreview.org.au/index.htm>.

[18] . For an explanation of drivers of climate change over longer timescales, see 'What we know about climate change', Parliamentary Library, Canberra, 2008–09, viewed 3 March 2009, <http://www.aph.gov.au/library/pubs/ClimateChange/uncertaintyAndScepticism/what.htm>, and links therein.

[19] . The CSIRO and Bureau of Meteorology have also published a comprehensive report and supporting website on the past and projected impacts of climate change specific to Australia: see CSIRO/Bureau of Meteorology, 'Climate Change in Australia', 2007–2008, viewed 4 March 2009, <http://www.climatechangeinaustralia.gov.au/>.

[20] . Information about the IPCC and its reports are available at the IPCC website, viewed 3 March 2009, <http://www.ipcc.ch/index.htm>.

[21] . Information about the Stern Review and its report are available at the Office of Climate Change website, viewed 3 March 2009, <http://www.occ.gov.uk/activities/stern.htm>.

[22] . Background to the Garnaut Review and its reports and resources are available from the Garnaut Climate Change Review website, viewed 3 March 2009, <http://www.garnautreview.org.au/domino/Web_Notes/Garnaut/garnautweb.nsf>.

[23] . MR Raupach et al., 'Global and regional drivers of accelerating CO_2 emissions', *Proceedings of the National Ac of Sciences*, vol. 104, 2007, pp. 10288–10293.

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[24] . For further information on emissions trajectories and mitigation policies of the fast expanding economies of Brazil, China, India and Russia (the 'BRIC' countries), see L Neilson, 'Climate change policy: Brazil, China, India and Russia', *Background Note*, Online 25 February 2009, Parliamentary Library, Canberra, 2009, viewed 18 March 2009, <http://www.aph.gov.au/library/pubs/bn/2008-09/ClimateChange.htm>.

[25] . Nicholas Stern, *The economics of climate change: the Stern Review*, Cambridge University Press, Cambridge, 2006, p. 227.

[26] . Stern, pp. 228–229.

[27] . R Garnaut, *The Garnaut climate change review: final report*, Cambridge University Press, Cambridge, 2008, p. 46, viewed 26 February 2009, <http://www.garnautreview.org.au/index.htm>.

[28] . See 'Ocean–atmosphere heat exchange', Parliamentary Library, Canberra, 2008–09, viewed 18 March 2009, <http://www.aph.gov.au/library/pubs/ClimateChange/whyClimate/naturalClimate/oceanAtmosphere.htm>.

[29] . For more information on regional ecosystem vulnerabilities see 'Chapter 4 Ecosystems, their properties, goods and services', in IPCC, *Climate change 2007: impacts, adaptation and vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 2007, Table 4.1, pp. 242–245, viewed 8 April 2009, <http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter4.pdf>.

[30] . Garnaut, Table 4.1, p. 102.

[31] . The Copenhagen climate change conference in December 2009 will be the 15th Conference of the Parties (COP 15) to the UNFCCC. It is hoped that negotiations at the conference will lead to an international agreement for mitigation action and targets beyond the 2008–2012 Kyoto commitment period. See 'COP 15', United Nations Climate Change Conference Dec 7 – Dec 18 2009, viewed 18 March 2009, <http://en.cop15.dk/>.

[32] . 'Key messages from the Congress', Climate Change: Global Risks, Challenges and Decisions, International Scientific Congress, Copenhagen, 10–12 March 2009, viewed 18 March 2009, <http://climatecongress.ku.dk/newsroom/congress_key_messages/>.

[33] . IPCC, Climate change 2007: the physical science basis, p. 829.

[34] . Concept Economics was commissioned by the Senate Select Committee on Fuel and Energy to provide a report representing a peer-review of the Treasury modelling. The report criticised many of the Treasury's assumptions, including those employed in the analysis of delayed action. See Concept Economics, *A peer review of the Treasury modelling of the economic impacts of reducing emissions*, Prepared for the Senate Select Committee on Fuel and Energy, 30 January 2009, viewed 18 March 2009, <http://www.aph.gov.au/SENATE/committee/fuelenergy_ctte/senate_ets_report_020209_final.pdf>.

[35] . Garnaut, p. 263.

[36] . Putting a price on emissions of carbon dioxide and other greenhouse gases is generally accepted to be necessary to correct the 'market failure' that has resulted in allowing climate change to occur. Implementation of an emissions trading scheme was a key recommendation of the Garnaut Review, and is part of the stated policy positions of both the Australian Government and the Opposition. A 'cap and trade' emissions trading scheme, such as proposed in the Government's Carbon Pollution Reduction Scheme, involves putting a cap on the total allowed national emissions by creating a set number of permits corresponding to a given unit of emissions (such as a tonne of CO_2e), and allowing permits to be traded among emitters. Such a scheme aims to allow the market to determine the cheapest solution to reducing emissions. For further information and discussion of various economic mitigation measures, see 'Economic responses', Parliamentary Library, Canberra, 2008–09, and its subsections, viewed 3 March 2009, <http://www.aph.gov.au/library/pubs/ClimateChange/responses/economic/economic.htm>. Information on other climate change mitigation policy measures internationally and within Australia is available under 'Governance and policy', Parliamentary Library, Canberra, 2008–09, viewed 3 March 2009, <http://www.aph.gov.au/library/pubs/ClimateChange/governance/governance.htm>.

[37] . Stern, p. 231.

[38] . Australian Treasury, *Australia's low pollution future: the economics of climate change mitigation—report*, Commonwealth of Australia, 2008, Chart 6.20, p. 167, viewed 2 March 2009, <http://www.treasury.gov.au/lowpollutionfuture/report/default.asp>.

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[39] . Electricity generation is measured in Watt-hours (Wh), which are units of energy. One Gigawatt-hour (GWh) is equal to 1000 million Watt-hours (1 GWh = 10^9 Wh).

[40] . Garnaut, pp. 496–497.

[41] . Australia is already progressing well in these areas, with many clean coal projects underway or in the proposal stage, including both retrofitting existing plants and constructing new, highly efficient plants. Australia is a world leader in the area of geological carbon storage (geosequestration) as part of carbon capture and storage, with its Australian Petroleum Cooperative Research Centre (CRC) undertaking groundbreaking work in geosequestration from 1999 to 2003, followed by the CRC for Greenhouse Gas Technologies, which has further developed and assessed geosequestration potential in Australia. The Rudd Government has also been active in promoting and supporting CCS within Australia and internationally. To date, legislation governing geosequestration has been passed in Federal Parliament (relating to offshore Commonwealth basins), Victoria and Queensland.

[42] . *United Nations Framework Convention on Climate Change*, United Nations, 1992, viewed 26 February 2009, <http://unfccc.int/resource/docs/convkp/conveng.pdf>.

[43] . The Clean Development Mechanism allows developed countries that are parties to the Kyoto Protocol to help them meet their emissions targets. They can offset their national emissions with emissions reductions gained through development projects in developing countries that support sustainable development in those countries. For more information see UNFCCC, Clean Development Mechanism, viewed 19 March 2009, <http://cdm.unfccc.int/index.html>.

[44] . 'Kyoto Protocol', United Nations Framework Convention on Climate Change, viewed 16 February 2009, <http://unfccc.int/kyoto_protocol/items/2830.php>.

[45] . Garnaut, p. 153; Australian Treasury, p. 51.

[46] . CSIRO, *CO_2 emissions increasing faster than expected*, media release, 2 May 2007, viewed 27 February 2009, <http://www.csiro.au/news/GlobalCarbonProject-PNAS.html>.

[47] . Garnaut, p. 252.

[48] . Garnaut, p. 285.

[49] . Garnaut, pp. 277–278.

[50] . Australia has been working with nations such as Indonesia, Papua New Guinea and China to develop mutually beneficial strategies to address climate change issues. Such strategies include cooperation on technology development and transfer, and reducing emissions from deforestation. See Penny Wong (Minister for Climate Change and Water), *Australia and China strengthen co-operation on climate change*, media release, 18 November 2008, viewed 26 February 2009, <http://www.environment.gov.au/minister/wong/2008/mr20081118a.html>; Kevin Rudd (Prime Minister), *Australia-Indonesia joint leaders' statement on climate change, with the President of the Republic of Indonesia, Jakarta*, media release, 13 June 2008, viewed 26 February 2009, <http://www.pm.gov.au/media/release/2008/media_release_0315.cfm>; Stephen Smith (Minister for Foreign Affairs) and Samual Abal (Minister for Foreign Affairs, Trade and Immigration, Papua New Guinea), *Joint Statement*, 18th Papua New Guinea–Australia Ministerial Forum, Madang, 23 April 2008, viewed 26 February 2009, <http://www.dfat.gov.au/geo/png/18_forum_joint_statement.pdf>.

[51] . See 'Scientific Uncertainties', Parliamentary Library, Canberra, 2008–09, viewed 27 February 2009, <http://www.aph.gov.au/library/pubs/ClimateChange/uncertaintyAndScepticism/scientific.htm>.

[52] . 'Climate concern in the US and science in the new Obama administration', *The Science Show*, transcript, Australian Broadcasting Corporation (ABC), 21 February 2009, viewed 19 March 2009, <http://www.abc.net.au/rn/scienceshow/stories/2009/2493652.htm>.

[53] . Until the newly elected Rudd Government ratified the Kyoto Protocol in December 2007, the United States and Australia were the only two major developed countries not to have ratified. The commitment period of the Kyoto Protocol has since commenced and the US is now the only developed country not participating.

[54] . Garnaut, p. 19.

[55] . A Gyngell, *The Lowy Institute Poll 2007*, Australia and the world: Public opinion and foreign policy, Lowy Institute for International Policy, 2007; Australian National University, *ANU poll reveals nation worried about climate change*, News, 29 October 2008, viewed 17 April 2009,

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<http://www.anu.edu.au/anupoll/content/news/article/anupoll_reveals_nation_worried_about_climate_change/>; The Climate Institute, *Climate of the nation: Australian attitudes to climate change and its solutions*, April 2008.

[56] . J Glover, 'The lucky country?', guardian.co.uk, 23 November 2007, viewed 17 April 2009, <http://www.guardian.co.uk/environment/2007/nov/23/climatechange.australia>; P van Onselen and P Senior, *Howard's end: the unravelling of a government*, Melbourne University Publishing, 2008.

[57] . Kevin Rudd (Prime Minister), *Transcript of opening remarks to the National Climate Change Summit*, (then leader of the Opposition), Parliament House, Canberra, 31 March 2007, viewed 9 March 2009, <http://parlinfo.aph.gov.au/parlInfo/download/media/pressrel/H4OM6/upload_binary/h4om62.pdf>; *Speech to the high level segment of the 13th conference of the parties*, United Nations Framework Convention on Climate Change, Bali, 12 December 2007, viewed 9 March 2009, <http://parlinfo.aph.gov.au/parlInfo/download/media/pressrel/HK8P6/upload_binary/hk8p63.pdf;fileType=application/pdf>; *Joint press conference with President Susilo Bambang Yudhoyono*, State Palace, Jakarta, 13 June 2008, viewed 9 March 2009, <http://parlinfo.aph.gov.au/parlInfo/download/media/pressrel/W7RQ6/upload_binary/w7rq61.pdf>.

[58] . Garnaut, p. 287.

About the author

Dr Julie Styles has been a research scientist in the broad area of climate change for over 15 years, working in Australia, Germany, Siberia and the US. Her PhD and much of her research dealt with understanding the role of forests and other land ecosystems in absorbing carbon dioxide from the atmosphere and mitigating anthropogenic emissions. Julie's research appears in international peer-reviewed journals and she has presented her work at more than 20 international scientific conferences and meetings. She has served as a review panel member for NASA, and has been awarded grants amounting to over $1 million to fund her research. Julie joined the Parliamentary Library in mid-2008 as a senior researcher and is an author and editor of the Library's climate change web publication (http://www.aph.gov.au/Library/pubs/ClimateChange/).

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