Cumulus congestus and cumulonimbus capillatus with incus (anvil), Parkdale, Victoria
Photo by Ken Hayes

Atmosphere

3

Key findings

Earth is warming.

Since the release of the *Fourth assessment report: climate change 2007* from the Intergovernmental Panel on Climate Change, observations and research outcomes have further confirmed and strengthened the position that Earth is warming and that human emissions of greenhouse gases are the primary cause. Even in 2007, mainstream science held this view with a high level of certainty, and now this certainty has increased. Internationally, there is a clear consensus among atmospheric scientists that mean global temperatures have generally risen compared with pre-industrial levels in 1750.

Large step-changes in climate may occur.

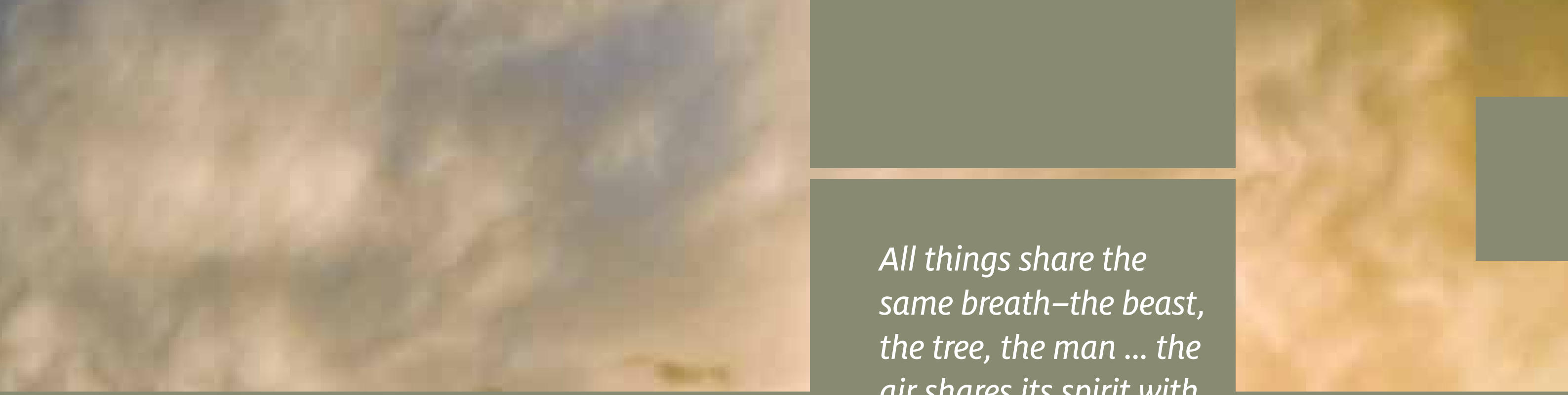
Smooth changes are the exception rather than the norm in the global climate system, which is nonlinear in nature. This means that a number of feedback mechanisms exist that can amplify or accelerate climate change and have the potential to cause large step-changes (sudden or major changes) in regional and global climate. Should such changes occur, adaptive strategies framed around incremental change are unlikely to be adequate to prevent major harmful impacts on key sectors. Instead, what the Commonwealth Scientific and Industrial Research Organisation describes as ‘transformational’ change will be needed and ‘a major scientific and societal challenge [will be needed] to understand and decide how, where, and when this transformational change is required’.

We are already seeing changes in Australia’s variable climate.

Although Australia’s climate is naturally highly variable, evidence continues to accumulate that temperatures are increasing and rainfall distribution patterns are changing.

Major reductions in greenhouse gas emissions are urgently needed nationally and internationally.

Per person, Australia’s greenhouse gas emissions are the largest of any country in the Organisation for Economic Co-operation and Development (OECD)—26.8 tonnes in 2008, which is nearly twice the OECD average. If the world’s current emissions path is projected to 2070, warming in Australia is expected to be in the range of 2.2–5.0 °C, with widespread and significant risk to Australia’s natural ecosystems, water security and coastal communities. Even if national and international mitigation efforts increase dramatically over the next decade or two, leading to a rapid stabilisation of greenhouse gas emissions, temperatures will remain at elevated levels for centuries to come.



We will need both a national approach and approaches at the state and territory level to mitigate and adapt to climate change.

Australia's *Fifth national communication on climate change* sets out the Australian Government's strategic approach to the challenge of climate change. Such an overarching strategy—implemented via a range of policies, plans and programs—is essential if Australia is to succeed in mitigating climate change and addressing key areas of vulnerability through adaptation. At the same time, as the communication notes, all three levels of government share responsibility for addressing climate change and are involved in planning and implementing a diverse range of climate-related programs.

Despite the success of the Montreal Protocol in controlling ozone depleting substances (ODSs), depletion of stratospheric ozone will continue for some decades.

Concentrations of chlorofluorocarbons and other ODSs in the atmosphere have been decreasing since the mid-1990s, but many of these substances are long lived and will continue to affect stratospheric ozone for some decades. Nevertheless, the prospects for recovery of the stratospheric ozone layer by around mid-century continue to be good.

> *All things share the same breath–the beast, the tree, the man ... the air shares its spirit with all the life it supports.*
>
> Attributed to
> Chief Seattle, 1854

Australia has met its targets in controlling ODSs.

Australia continues to be a leading supporter of international action to control the production and use of ODSs, meeting or exceeding its phase-out obligations under the Montreal Protocol.

Ambient air quality in Australia's major urban centres is generally good.

National health-based standards are rarely exceeded for prolonged periods, and very high levels of pollution are usually associated with short-lived extreme events such as bushfires and dust storms that generate very high levels of particulate pollution. Levels of carbon monoxide, nitrogen dioxide, sulfur dioxide and lead in urban air have decreased over the past two decades, but ozone and particle levels have not declined. Prospects for achieving reductions in levels of these two pollutants will be influenced by a number of factors, most notably vehicle technology, the extent of ongoing low-density suburban development and the availability of reliable public transport, and the impact of climate change on urban airsheds (regions sharing a common flow of air).

Key findings

Despite this broadly favourable situation, the impact of urban air quality on health is still a matter of serious concern.

There is clear evidence that periods of poor urban air quality impact adversely on human health (particularly on the health of susceptible individuals). One source estimates that urban air pollution accounts for 1% of deaths and illness in Australia, with some 3000 deaths attributable to this cause in 2003—nearly twice the national road toll. Research into the health effects of particles and ozone, as well as pollutants such as sulfur dioxide, indicates there is no threshold level below which they have no health effect. This means that sensitive individuals, such as asthmatics and people with respiratory or cardiovascular disease, may be affected even when air quality standards are met.

Management of pollution affecting our air quality is generally good, but ongoing effort will be required to secure past gains and achieve further improvements.

The generally good quality of our urban air is largely due to the progressive tightening of national vehicle emission and fuel standards over the past 20 years, and the control of industrial, commercial and domestic sources of air pollution. The outlook for the next decade is that this favourable situation is likely to continue, despite the pressures associated with population and economic growth. However, this outcome is not assured, and there are sound public health, economic and social equity arguments to support ongoing efforts to reduce pollutant emissions and associated impacts on health and amenity.

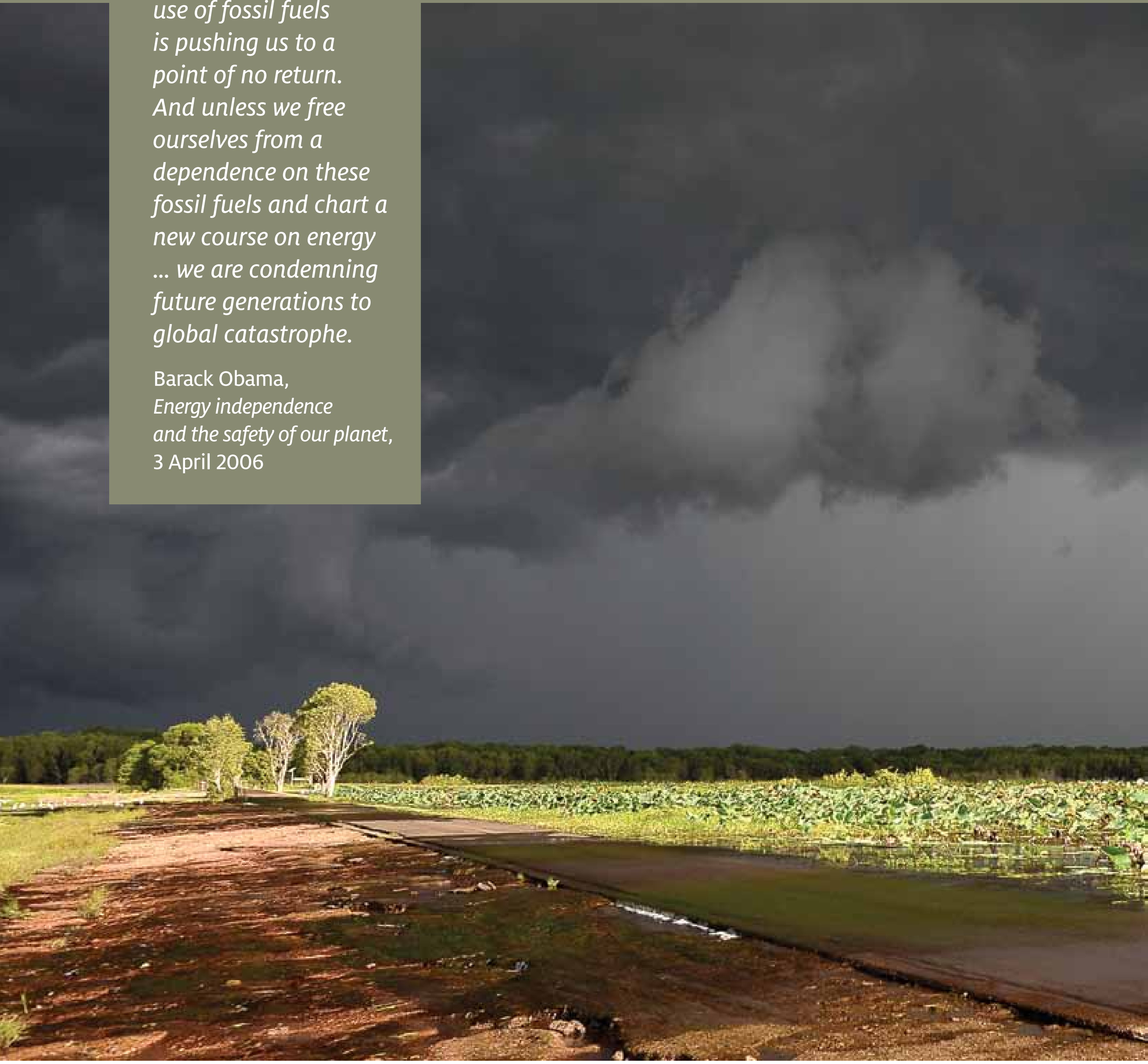
Most Australians spend more than 90% of their time indoors.

The quality of indoor air is affected by many factors, notably building materials (particularly volatile materials like glues and paints), ventilation, furnishings and appliances (particularly unflued gas appliances), environmental tobacco smoke and cleaning agents. Despite the potentially significant health effects of indoor air, data on indoor air quality in Australia are limited. Australia has no specific guidelines for indoor air quality and therefore no firm basis upon which to form assessments of overall status and trend. Over the past decade, Australian governments have employed regulatory and nonregulatory approaches to improve indoor air quality, chiefly through interventions targeting environmental tobacco smoke (in commercial premises where food is prepared or consumed, shopping malls and public buildings) and unflued gas heaters (particularly in schools).

Ominous: this shelf cloud was created by an outflow boundary from a decaying thunderstorm east of Nightcliff, Northern Territory, January 2011
Photo by Jacci Ingham

Contents

> *The issue of climate change is one that we ignore at our own peril. … our continued use of fossil fuels is pushing us to a point of no return. And unless we free ourselves from a dependence on these fossil fuels and chart a new course on energy … we are condemning future generations to global catastrophe.*
>
> Barack Obama,
> *Energy independence and the safety of our planet*,
> 3 April 2006



Thunderstorm, Fogg Dam Conservation Reserve, Northern Territory
Photo by Jacci Ingham

1

Introduction

In the seventh year of the reign of the Emperor Nero, the philosopher Seneca commented on the quality of the air in Rome:

> As soon as I had gotten out of the heavy air of Rome and from the stink of the smoky chimneys thereof, which, being stirred, poured forth whatever pestilential vapours and soot they have enclosed in them, I felt an alteration of my disposition. *Lucius Annaeus Seneca*[1]

Seneca was probably not the first, and certainly not the last, to comment adversely on the quality of urban air. Until quite recently, the histories of major cities such as London have been punctuated by complaints from kings and commoners alike about pollution of the air and its effects on amenity and health. Throughout the 19th and much of the 20th centuries, uncontrolled industrial emissions, lack of effective collection and treatment of sewage, and widespread burning of fossil fuels combined to make most large cities unattractive and unhealthy places to live. The great London smog of December 1952, which is now reckoned to have claimed as many as 8000 lives, was but one of a number of instances of killer smogs.[2-3]

Historically, Australian cities too have suffered from poor air quality—Melbourne was known as 'Smellbourne' in the 1880s, due largely to the lack of an effective system for treating and disposing of sewage well away from the city.[4] By the mid-1960s, air pollution in some of Australia's largest cities had reached levels prompting broad public and political concern:

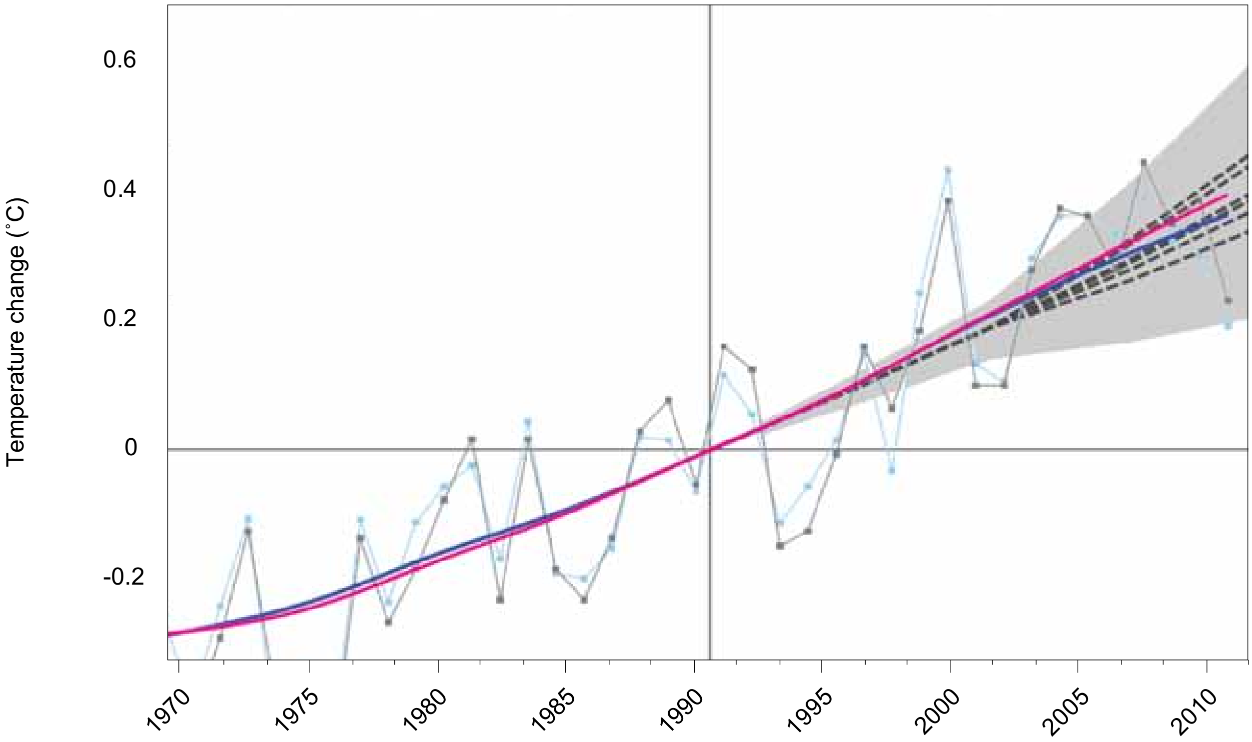
> Evidence received by the Committee indicates that an air pollution problem already exists in some parts of Australia and while not yet a problem of the magnitude existing in well known centres of pollution such as London, New York, Los Angeles and Tokyo, [it is] a problem which nevertheless warrants urgent planning and action. *Parliament of Australia,*[5] *p. 4*

Fortunately, the quality of the air in Australian cities has improved significantly during the past 20–30 years in response to a mix of regulatory and nonregulatory approaches to controlling both point and diffuse sources of pollution, applied at national, state and local levels. Such improvements have occurred despite growing populations, expansion of industry and greatly increased use of motor vehicles. Monitoring of the air in our cities against national health-based standards shows that episodes of poor and very poor air quality are limited, often being associated with extreme events such as bushfires and dust storms.[6] Despite this, each year, urban air pollution is estimated to account for more deaths than the nation's road toll.[7]

Clearly there is still a need to press for further improvements in our urban air quality, particularly as new scientific knowledge emerges about the impacts of pollutants such as fine particles. Nevertheless, the focus of scientific, political and community concern has shifted to another essential issue for the atmosphere—the effects on the world's climate of changes in the atmosphere caused by human activities. Here, over the relatively short span of 250 years and for the first time in human history, we have changed and are continuing to change the composition of the atmosphere on a global scale. This has led to a clearly defined trend of increasing average global temperatures (Figure 3.1), and there is increasing evidence of consequent changes in the complex set of interlinked atmospheric, oceanic and terrestrial processes that shape climate at the global, continental and regional scales.[8-11]

Australians, on a per capita basis, contribute disproportionately to the emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) that are driving these changes. As inhabitants of the driest of the world's inhabitable continents—much of which is unsuitable or only marginally suitable for agriculture—Australians have more at risk than most in a warming world.[12-13]

This chapter is divided into two sections: climate, and ambient air quality and other atmospheric issues. The climate section discusses the influence of GHGs, particularly those generated by human activities, on Earth's climate and some of the likely impacts of global climate change on human health and the environment. The second part of the chapter discusses other aspects of the atmosphere, including stratospheric ozone, ambient air quality and indoor air quality.



Source: Richardson et al.[9]

Figure 3.1 Changes in global average surface air temperature (smoothed over 11 years) relative to 1990

The dark blue line represents data from Hadley Centre (United Kingdom Meteorological Office); the red line is GISS (NASA Goddard Institute for Space Studies, United States) data. The broken lines are projections from the Intergovernmental Panel on Climate Change Third Assessment Report, with the shading indicating the uncertainties around the projections.

2

Climate

References to Australia's variable climate abound in both academic literature and the arts, with Dorothea Mackellar's description of her love for a 'sunburnt country, a land … of drought and flooding rains …' springing readily to mind. Marked variability in temperature and rainfall, together with frequent but irregular occurrences of extreme weather events, has long been recognised as a key characteristic of climate in most parts of our continent. On more than one occasion, confusion of short-term runs of favourable climate with long-term norms led farmers to push into areas where their agricultural systems proved to be unsustainable. As we move into the second decade of the 21st century, we are increasingly recognising signs that our already variable climate is changing.[14]

At a glance

From 1970 to 2010, Australia's mean daily temperature rose in almost all parts of the country. Although total annual rainfall declined over much of eastern Australia and south-west Western Australia, increases were observed in central and northern areas of Western Australia and in the north-western part of the Northern Territory. The 13-year period from April 1997 to March 2010 was characterised by severe rainfall deficiencies that covered much of south-western and south-eastern Australia and south-eastern Queensland. For many places, the severity and duration of drought were unprecedented, with profound environmental, social and economic implications. Then, in the 12 months from March 2010, large parts of the continent experienced above-average rainfall, associated with an extremely strong La Niña event. Most notably, eastern Australia received widespread record-breaking rains, with associated loss of life and massive damage to agriculture, homes and infrastructure.

The summer of 2010–11 will be remembered as one of extremes and variability, with Perth experiencing a record run of temperatures above 30 °C. By contrast, when averaged across the continent, summer maximum temperatures were 0.72 °C below the norm, making them the lowest since 2001. Despite this, the decade ending in 2010 was the hottest 10-year period on record for Australia, with the average land surface temperature 0.52 °C above the 30-year average from 1961 to 1990.

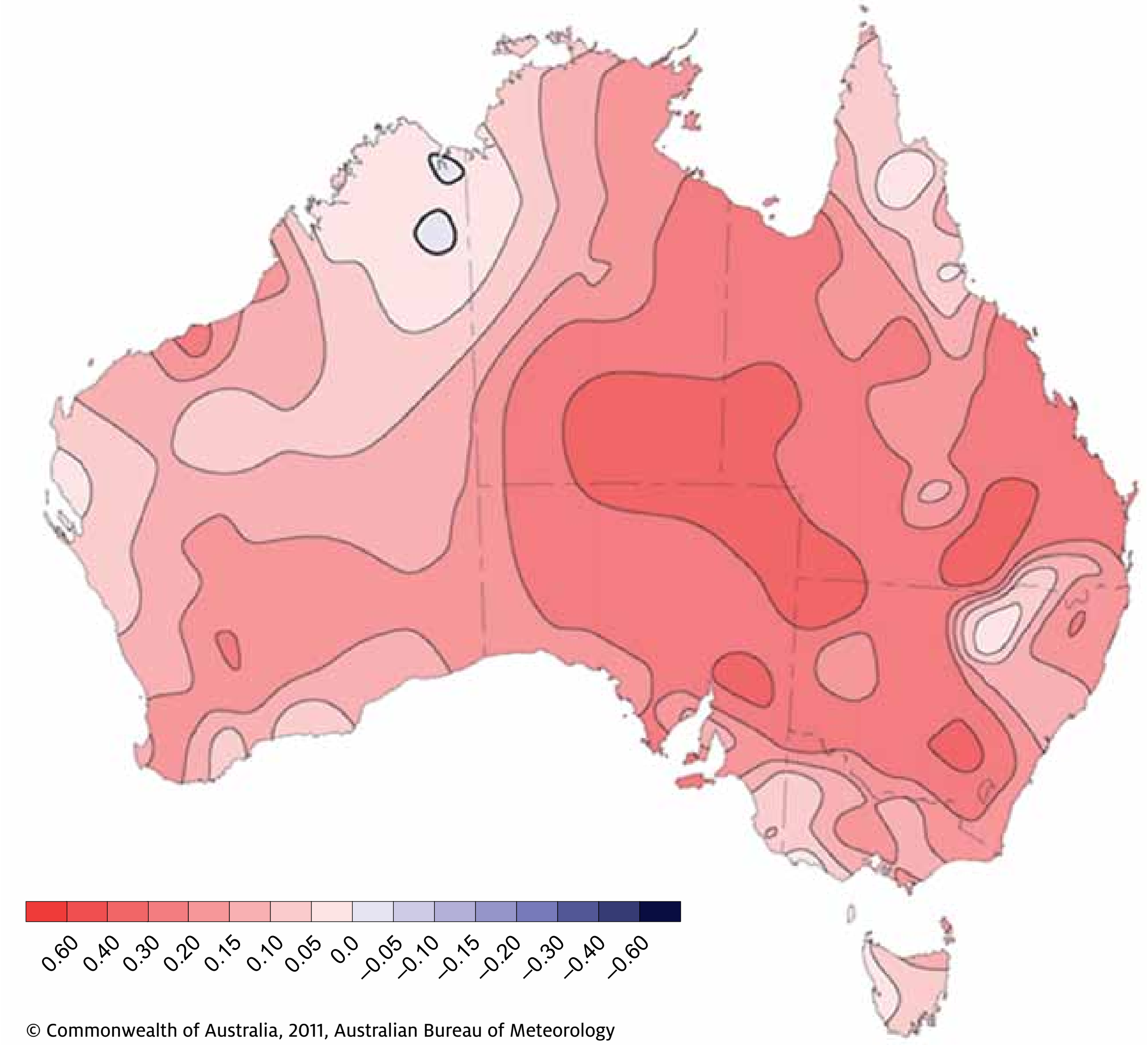
2.1 State and trends of Australia's climate

Perhaps the salient feature of the Australian environment over the past decade, at least for the majority of Australians, was an extended drought. This drought was characterised not only by low rainfall but also by higher than average temperatures. For many places, the severity and duration of drought were unprecedented, with profound environmental, social and economic implications. In southern Australia, the drought (sometimes known as the millennium drought) lasted from 2000 to 2010, although in some areas it began as early as 1997. For parts of the country, the drought broke in 2010 (in some cases, with extreme flooding); in other places, like the south-west of Western Australia, the extended drought deepened further.

2.1.1 Temperature

From 1970 to 2010, Australia's mean daily temperature rose in almost all parts of the country (Figure 3.2).

The increase in terrestrial temperatures over this period was consistent with a general warming of ocean surface temperatures around Australia (Figure 3.3). To the south-east of the continent, the southward extension of the East Australian Current has continued, with consequences for marine ecosystems and biodiversity in the ocean off the coast of eastern Tasmania.



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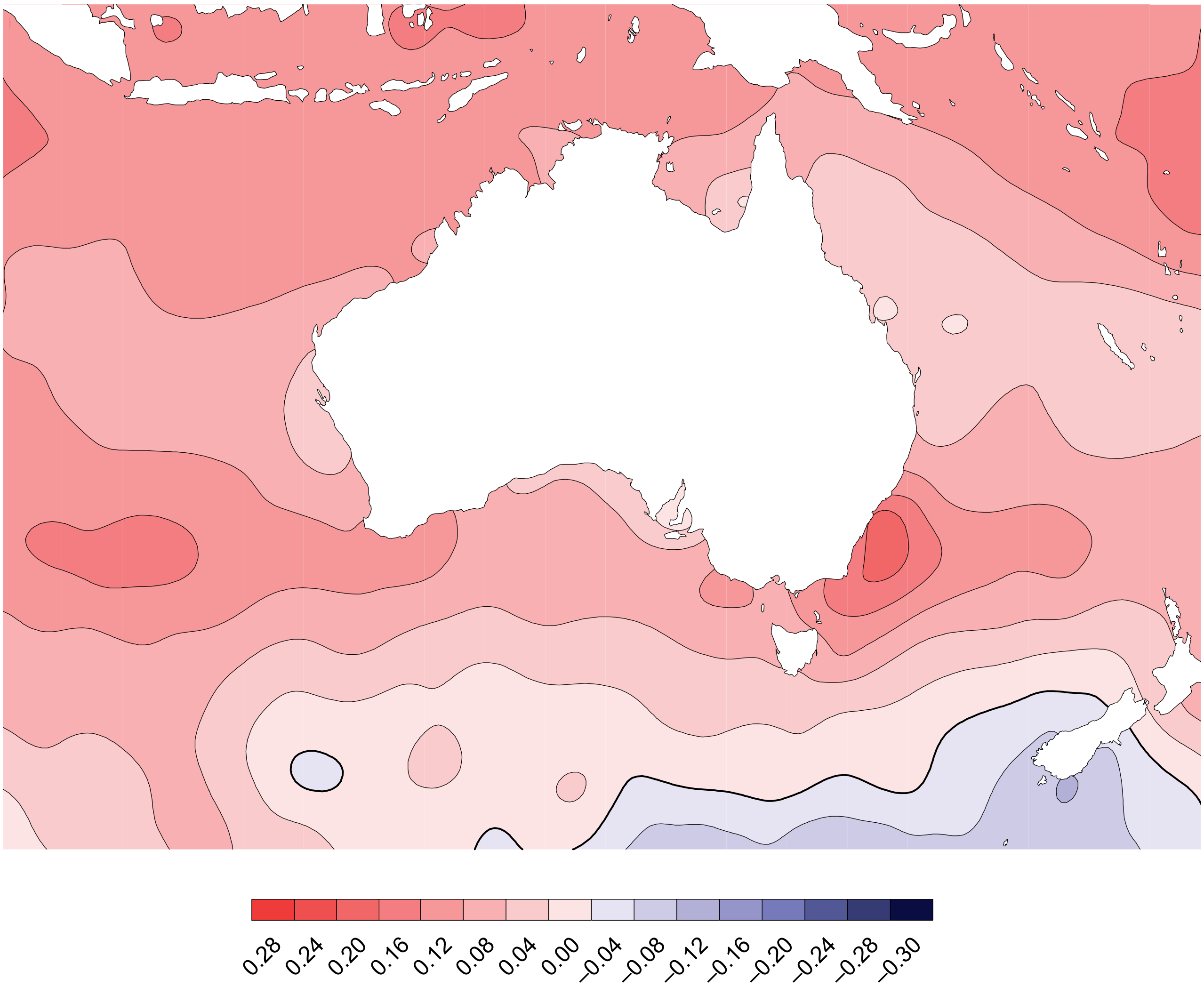
Source: Bureau of Meteorology[15]

Figure 3.2 Trend in mean temperature, 1970–2010 (°C per 10 years)



Source: Bureau of Meteorology[16]

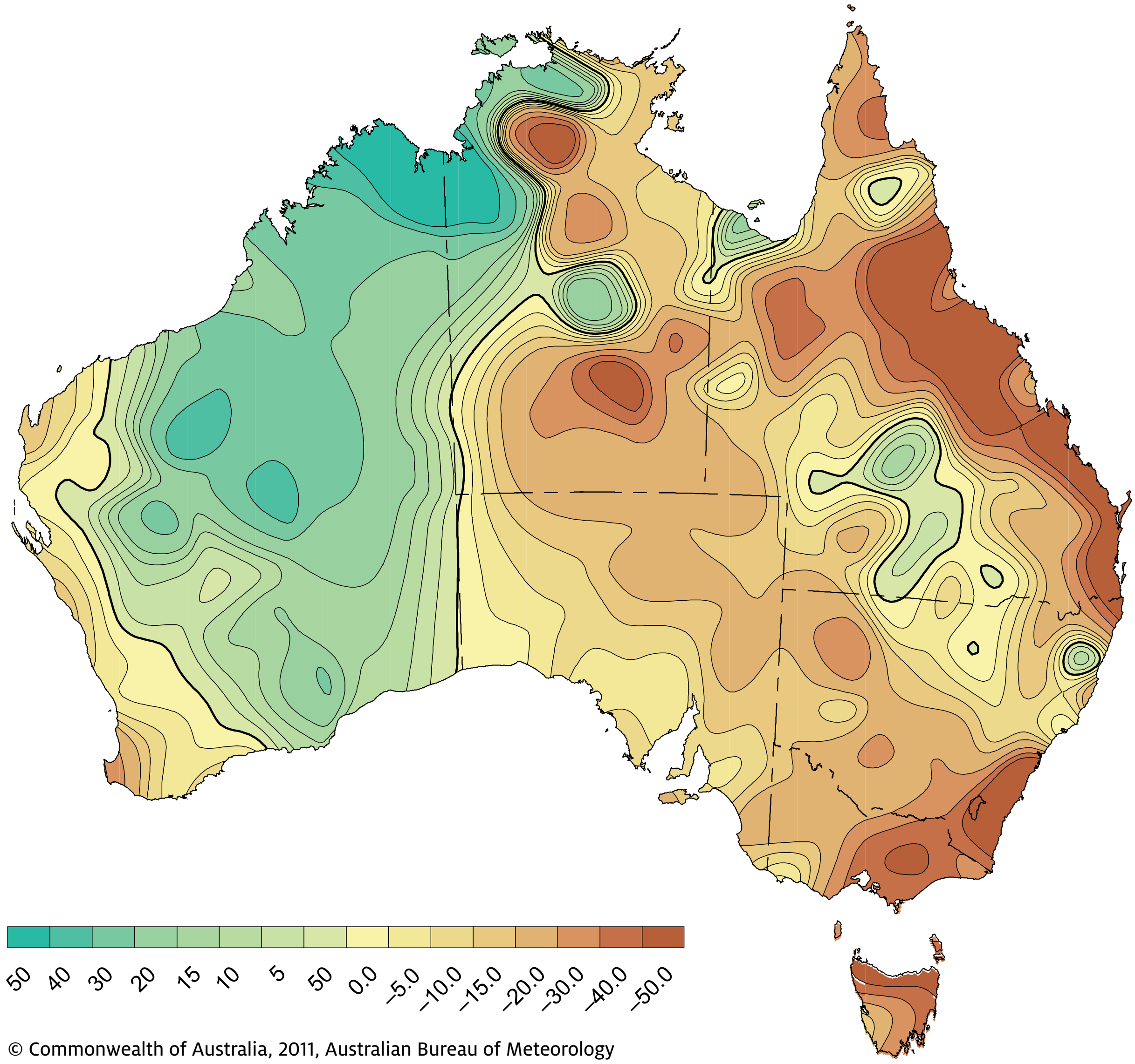
Figure 3.3 Trend in sea surface temperature for the Australian region, 1970–2010 (°C per 10 years)

2.1.2 Rainfall

From 1970 to 2010, total annual rainfall declined over much of eastern Australia and south-west Western Australia (Figure 3.4). This decline in rainfall affected all capital cities except Darwin. In contrast, rainfall increased over north-west and central Western Australia.

The 13-year period from April 1997 to March 2010 (156 months) shows rainfall deficiencies for much of south-western and south-eastern Australia, and south-eastern Queensland (Figure 3.5). Most notable are the large areas of lowest rainfall on record for this period: large parts of Western Australia's south-western coast, western Tasmania and large areas in Victoria received the lowest rainfall on record for the 13-year period.

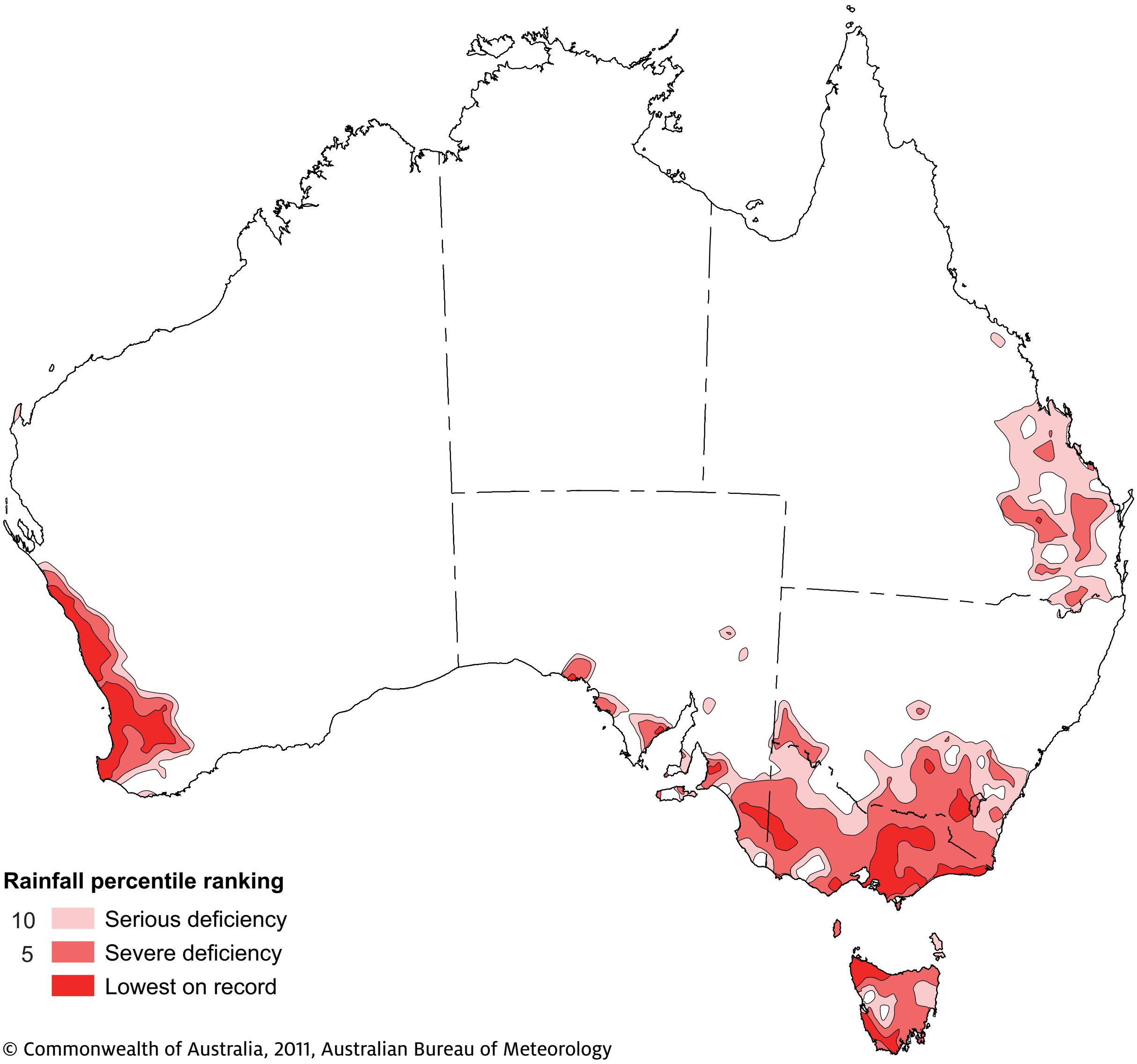
For the more recent eight-year period from April 2002 to March 2010 (96 months), much of south-eastern Australia still experienced severe, long-term rainfall deficiencies. Approximately 95% of Victoria received



Source: Bureau of Meteorology[17]

Figure 3.4 Trend in total annual rainfall, 1970–2010 (millimetres per 10 years) rainfall in the lowest 10% of historical totals when considered over such a period. The south-eastern corner of Queensland also had serious to severe rainfall deficiencies over this period. Serious to severe deficiencies also remained in central to eastern coastal districts of South Australia, large areas of Tasmania (especially in the north), and a large area covering the south-west coast and adjacent inland regions of Western Australia. Rainfall deficiencies across the south-western and south-eastern corners of the continent have been most severe in autumn and winter.

For the 12 months from April 2009 to March 2010 (Figure 3.6), serious to severe rainfall deficiencies remained evident over much of the central Western Australian coast, reaching inland to cover much of the Pilbara and Gascoyne districts, where they intensified to some extent. Serious to severe rainfall deficiencies also remain over the south-east coastal



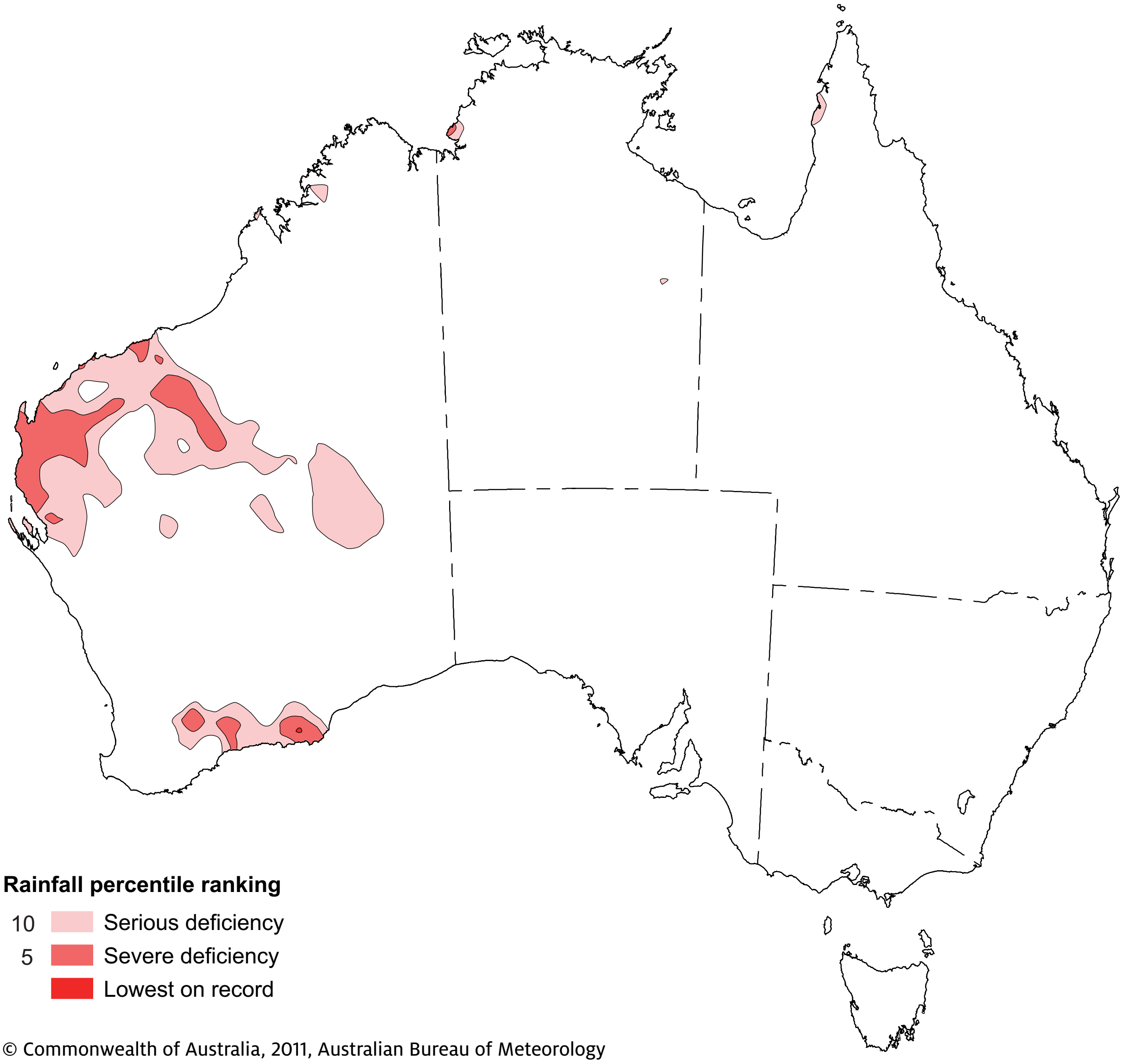
Source: Bureau of Meteorology[18]

Figure 3.5 Rainfall deficiencies over 156 months, 1 April 1997 – 31 March 2010

'Serious deficiency' refers to rainfalls in the lowest 10% of historical totals, but not in the lowest 5%; 'severe deficiency' refers to rainfalls in the lowest 5% of historical totals; and 'lowest on record' refers to the lowest rainfalls since at least 1900, when the data analysed begin.

and Great Southern districts of Western Australia, with a small area near Esperance reporting the lowest rainfall on record for the period.

However, from March 2010, large parts of the continent experienced above-average rainfall, associated with an extremely strong La Niña event (Figure 3.7). (A La Niña event refers to a periodic cooling of ocean surface waters off the western coast of South America. This leads to low rainfall in countries along that coast and in the south-west of the United States, and above-average rainfall in countries of the western Pacific, including the Philippines and northern and eastern Australia—

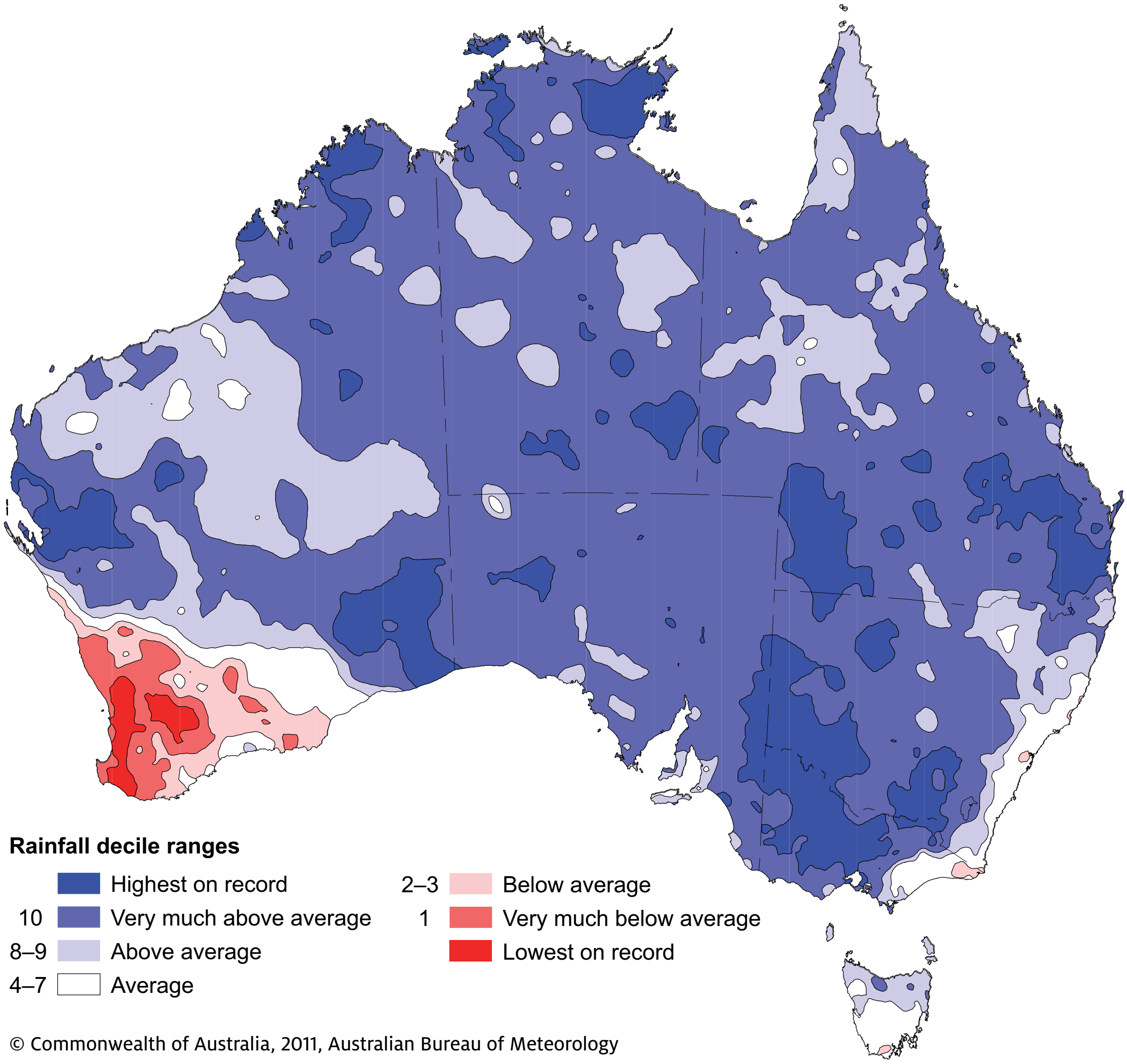


Source: Bureau of Meteorology[19]

Figure 3.6 Rainfall deficiencies over 12 months, 1 April 2009 – 31 March 2010

'Serious deficiency' refers to rainfalls in the lowest 10% of historical totals, but not in the lowest 5%; 'severe deficiency' refers to rainfalls in the lowest 5% of historical totals; and 'lowest on record' refers to the lowest rainfalls since at least 1900, when the data analysed begin.

outcomes that are the opposite of those associated with an El Niño event.) Most notably, eastern Australia received widespread record-breaking rains, with associated loss of life and massive damage to agriculture, homes and infrastructure. For the Murray–Darling Basin averaged as a whole, 2010 was the seventh wettest start to the year since records began in 1900. This rainfall has effectively ended a prolonged (decade or longer) sequence of very low rainfall years across parts of eastern Australia, most notably in the central and lower Murray–Darling Basin and south-east Queensland. Although Victoria experienced its wettest summer since 1974 in 2010–11, long-term rainfall deficiencies remained during autumn and winter.



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Source: Bureau of Meteorology[23]

Figure 3.7 Australian rainfall deciles, 1 March 2010 – 28 February 2011

‘Highest on record’ refers to the highest rainfalls since at least 1900 when the data analysed begin. ‘Very much above average’ refers to rainfalls in the highest 10% of historical totals; ‘above average’ to rainfalls in the highest 30% of historical totals, but not in the highest 10%; ‘average’ to rainfalls in the middle 40% of historical totals; ‘below average’ to rainfalls in the lowest 30% of historical totals, but not in the lowest 10%; ‘very much below average’ to rainfalls in the lowest 10% of historical totals; and ‘lowest on record’ to the lowest rainfalls since at least 1900, when the data analysed begin.

South-west Western Australia missed out on La Niña–driven rainfall for most of 2010, experiencing its lowest winter rainfall on record.[20-21] However, this situation changed markedly over the summer of 2010–11. Averaged across the state, summer rainfall was the second highest on record. In the north, this mainly reflected the influence of the monsoon that was active throughout the summer. Across the state more generally, it reflected the impact of the particularly strong La Niña. In much of the lower south-west, the Bureau of Meteorology characterised summer rainfall as 'very much above average', due mainly to rainfall in January.[22] Despite this, during the 12 months from March 2010, rainfall in the lower south-west ranged from below average to the lowest on record.

2.1.3 Climate research

Variability and extremes of weather are key characteristics of Australia's climate. Australian scientists are increasingly coming to understand the complex interplay of atmospheric and oceanic processes that shape our climate in both the short and the long term, and the processes that are responsible for cycles of drought and wet years in different parts of the country. These include natural events, such as fluctuations between El Niño and La Niña conditions in the Pacific, variations in the Indian Ocean Dipole, the southern annular mode and longer term features such as the Interdecadal Pacific Oscillation.

Against this background of natural variability, identifying a climate change 'signal' is often challenging. The Commonwealth Scientific and Industrial Research Organisation (CSIRO), in the phase 1 report on the South Eastern Australian Climate Initiative, contrasts the recently ended 13-year drought in the southern Murray–Darling Basin and Victoria with other droughts since 1900.[14] The report notes that:

- the most recent drought was generally limited to southern Australia (in comparison with previous droughts, including the severe Federation and World War 2 droughts)
- the recent period has experienced lower annual variability in rainfall, characterised by a complete absence of wet years
- a characteristic of recent rainfall across the southern Murray–Darling Basin, and the south-east of the continent in general, has been severe deficiencies (occurring as a step-change) in autumn and early winter rainfall
- the loss of early-season rainfall across both south-eastern and south-western parts of the continent has led to dramatically reduced streamflow and water storage in the past two decades.

The report concludes that, although natural variability is likely to have contributed to episodic drought (i.e. sequences of very dry years), the major and prolonged decline in rainfall is at least partly due to the effects of global warming on large-scale atmospheric circulation (specifically, the intensification of high-pressure cells across southern Australia—a phenomenon referred to as the 'subtropical ridge'). The report further suggests that the changes in rainfall and streamflow data during the drought may be indicative of a climatic shift in south-eastern Australia similar to that experienced in south-west Western Australia, where one study has suggested that half of the 10–15% decrease in winter rainfall experienced since around 1975 is attributable to climate change.[24]

Despite the uncertainties, there is an increasingly robust scientific consensus on the effects of climate change at a continental scale on temperature and on likely future impacts under the various climate change scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). With respect to temperature, the IPCC's fourth assessment concluded that Australian temperatures have increased and that most of the rise can be attributed to human-induced increases in emissions of GHGs.[25] In the case of rainfall, a longstanding result from climate modelling over the past two decades demonstrates that global warming leads to increased rainfall in the tropics and decreased rainfall in mid-latitude regions, including more prolonged drought. Rainfall intensity (periods of heavy rain) is expected to increase, including in regions where an overall decline in rainfall is projected.[25] However, determining the extent (if any) of the contribution of climate change to particular climatic events such as drought remains problematic and is an ongoing area of research.[14]

■ Sunshine over the landscape, Western Australia
Photo by Markus Gann

2.2 Pressures affecting Australia's climate

> Since the start of the industrial era (about 1750), the overall effect of human activities on climate has been a warming influence. The human impact on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions.
> *Intergovernmental Panel on Climate Change*[26]

The energy balance of Earth's atmosphere is influenced by the presence of trace levels of GHGs, the most important of which are carbon dioxide, methane, short-lived tropospheric ozone, nitrous oxide and the synthetic GHGs (e.g. chlorofluorocarbons [CFCs] and hydrofluorocarbons [HFCs]). Water vapour (a major GHG) and natural and industrial aerosols are also important in the atmospheric energy balance, as is natural variability in solar radiation. However, although the net effect of aerosols is known to be negative, there is considerable uncertainty about its magnitude. Similarly, there is uncertainty about the size of the effect of variations in solar radiation on Earth's energy balance since the start of the industrial era, although it is known to have been positive.[26]

The effect of factors such as solar radiation, GHGs and aerosols on the energy balance is termed 'radiative forcing' (Box 3.1).

Box 3.1 Radiative forcing

Radiative forcing is defined by the Intergovernmental Panel on Climate Change as ' ... a measure of the influence a factor [such as greenhouse gases] has in altering the balance of incoming and outgoing energy in the Earth–atmosphere system and is an index of the importance of the factor as a potential climate change mechanism'.

Warming of climate is a response to positive forcings, whereas cooling is a response to negative forcings. 'Radiative forcing is usually quantified as the rate of energy change per unit area of the globe as measured at the top of the atmosphere and is expressed in units of "watts per square metre".'

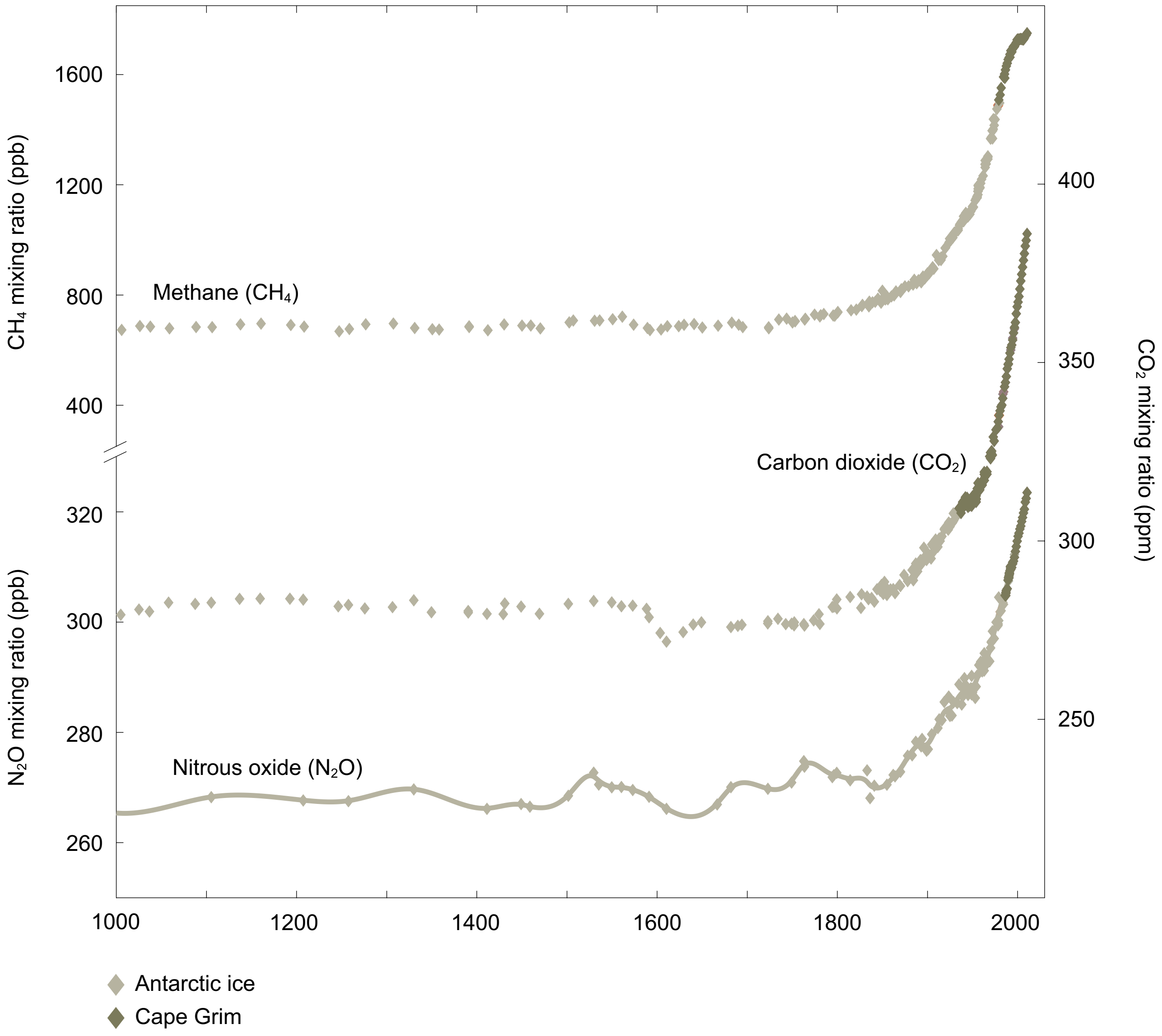
Source: Intergovernmental Panel on Climate Change[8]

At a glance

The energy balance of Earth's atmosphere is influenced by the presence of trace levels of greenhouse gases (GHGs), such as carbon dioxide, methane, nitrous oxide and water vapour (a major GHG), and natural and industrial aerosols. Since the start of the industrial era (around 1750), human activity (principally the burning of fossil fuels) has caused significant increases in the concentrations of these GHGs. Measurements at global background monitoring stations, such as the Cape Grim Baseline Air Pollution Station in Tasmania, show GHG concentrations continuing to increase in line with long-term trends and future projections. Per person, Australia's GHG emissions are the largest of any country in the Organisation for Economic Co-operation and Development (OECD) (26.8 tonnes in 2008—nearly twice the OECD average), reflecting Australia's heavy reliance on fossil fuels for our primary energy.

Under policy settings applicable before the release of the Australian Government's Securing a Clean Energy Future plan in July 2011, Australia's emissions were projected to grow by 113 megatonnes of carbon dioxide equivalents ($MtCO_2$-e), or 19.6%, between 2010 and 2020. This would have brought the nation's annual emissions to 690 $MtCO_2$-e in 2020, an increase of 23% from 2000 levels. The Securing a Clean Energy Future plan aims to achieve Australia's unconditional emissions reduction target—a reduction of 5% on 2000 levels by 2020. This will require abatement of at least 159 $MtCO_2$-e (23%) by 2020. To achieve Australia's 15% conditional target, a 31% reduction would be needed.

Over the past two and a half centuries, human activity (principally the burning of fossil fuels) has caused significant increases in the concentrations of GHGs (Figure 3.8). In the case of the principal GHG (carbon dioxide), the CSIRO global GHG-observing network recorded a preliminary global atmospheric concentration of 388 ppm (parts per million) for 2010 (Raupach & Fraser,[27] updated by CSIRO)—an increase of 39% from 280 ppm, the IPCC's estimate of pre-industrial levels.[28] CSIRO observations show that the preliminary global average methane concentration in 2010 was 1796 ppb (parts per billion)—an increase of 157% above estimated pre-industrial levels of 700 ppb. CSIRO observations also show that global nitrous oxide levels in 2010 were 324 ppb, a rise of 20% from pre-industrial levels of 270 ppb.[27]



ppb = parts per billion; ppm = parts per million

Source: MacFarling Meure et al.[29] updated by P Krummell, the Centre for Australian Weather and Climate Research and the Commonwealth Scientific and Industrial Research Organisation, unpublished data

Figure 3.8 Major greenhouse gas levels over the past 1000 years

In addition to the three main GHGs, there is a number of fluorinated gases—such as CFCs, HFCs, perfluorocarbons (PFCs) and sulfur hexafluoride—sourced from a range of industrial processes and from business and home use.[27] Although these gases are present in the atmosphere in only trace amounts, they are long lived and have global warming potentials thousands of times that of an equivalent concentration of carbon dioxide when assessed on a 100-year timescale.[30] They can therefore contribute significantly to global warming in the medium to long term and are included in the set of gases (HFCs, PFCs, sulfur hexafluoride) covered by Annex A of the Kyoto Protocol (an international agreement aimed at stabilising GHG concentrations in the atmosphere). The production and consumption of CFCs and other ozone depleting substances (ODSs) are covered by the Montreal Protocol on Substances that Deplete the Ozone Layer (see Sections 3.2.1 and 3.3.1).

Fluorinated gases made up around 12% of total global radiative forcing due to GHGs in 2010, similar to the situation in 1995 (13%). Under scenario A1B of the IPCC *Special report on emissions scenarios*, their contribution to global radiative forcing will decrease to 6% by 2100 (Raupach & Fraser,[27] updated by CSIRO), reflecting the gradual decline in CFCs in the atmosphere and increasing levels of HFCs.

The increased concentrations of human-generated GHGs have resulted in an increased absorption in the lower atmosphere of the heat radiated from Earth's surface, causing a rise in the global mean surface temperature of 0.74 ± 0.18 °C over the century from 1906 to 2005.[31] However, this rise did not occur uniformly across the century, as average global temperatures did not increase between the 1940s and the 1970s.[32] More recently, the 1998–2008 decade was characterised by little warming overall and a decrease of 0.2 °C between 2005 and 2008 (followed by an increase in 2009 and 2010, the most recent years for which data are available).[33]

Based on their analysis of this recent hiatus in warming, Kaufman et al.[33] concluded that the warming

Emissions from the steel works at Port Kembla, New South Wales

Photo by Ashley Cooper

Box 3.2 Carbon dioxide equivalent emissions

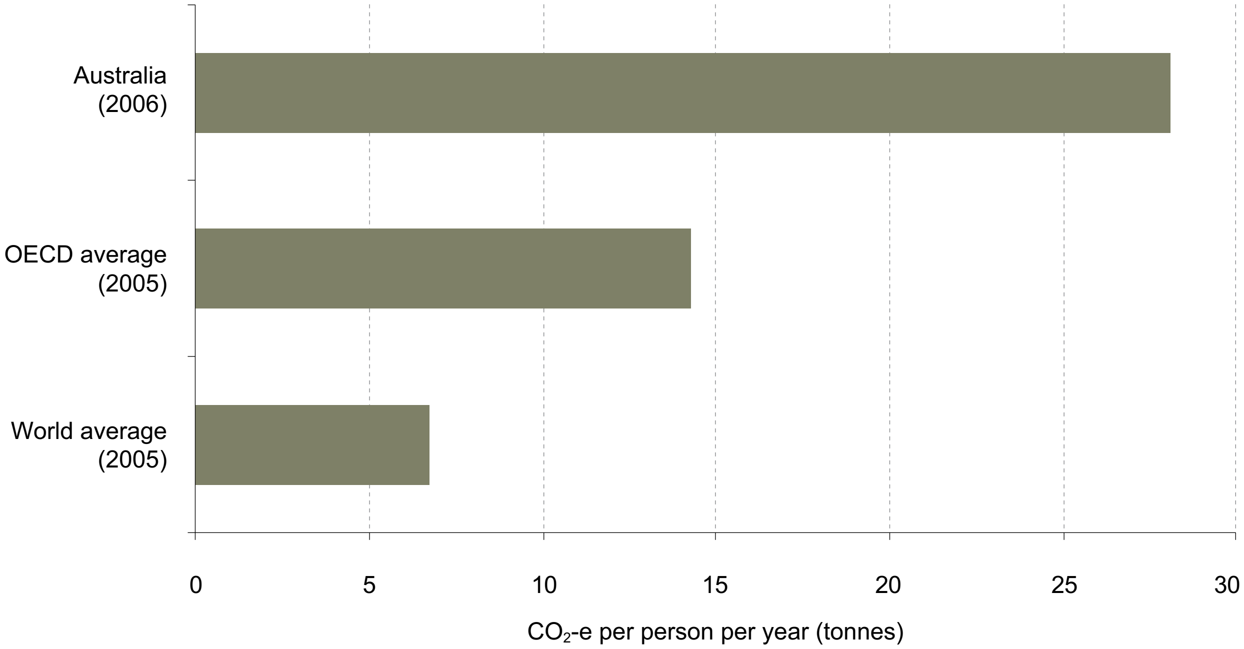
Each of the six greenhouse gases listed under Annex A of the Kyoto Protocol has a different greenhouse warming potential. The term 'carbon dioxide equivalent' (CO_2-e) refers to a single measure that combines the global warming effect of all the Annex A gases into a single meaningful number. Specifically, CO_2-e is the emissions of carbon dioxide that would cause the same heating of the atmosphere as a particular mass of Annex A greenhouse gases. The Annex A greenhouse gases are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.[35-36]

effects of GHG emissions during 1998–2008 have been partially offset by a combination of natural and anthropogenic (human-generated) factors. The natural factors (which were largely responsible for the offset) were a decline in solar insolation (a measure of the solar radiation energy received by Earth in a given time) as part of a normal 11-year cycle, and a cyclical shift from El Niño to La Niña conditions. These were supplemented by the anthropogenic factor—a rapid rise in short-lived emissions of sulfur due to large increases in coal use across Asia, particularly China. The sulfate aerosols formed by these emissions absorb solar radiation and reflect sunlight back into space (resulting in a negative radiative forcing). Sulfate aerosols, together with other pollutants, are thought to be largely responsible for the lack of increase in average global temperature over the 1940s to 1970s.[34]

Although Kaufman et al.[33] concluded that the recent hiatus in warming resulted principally from natural factors, they stressed that this does not contradict the IPCC's statement that 'most of the global average warming over the past 50 years is *very likely* due to anthropogenic GHG increases …'.[8]

Measurements at global background monitoring stations, such as the Cape Grim Baseline Air Pollution Station in Tasmania, show carbon dioxide and nitrous oxide concentrations continuing to increase, in line with long-term trends and future projections, whereas methane levels, after a decade-long pause, have resumed rising since 2007. The reasons for this variability in the growth rate of methane concentrations are complex, but the period of stability in the late 1990s and early years of this century was probably due to a reduction in the rate of growth of emissions from the oil and gas industry and an approach to equilibrium, where anthropogenic methane releases are matched by the atmosphere's ability to remove methane. Growth in emissions since 2007, which has occurred in the Arctic and in the tropics, may be caused by increased releases from wetlands due to unusually high temperatures (Arctic) and precipitation (tropics).[37]

In absolute terms, Australia's emissions of GHGs (558 megatonnes of carbon dioxide equivalents [MtCO$_2$-e]) appear small alongside major emitters such as China and the United States (7233 MtCO$_2$-e and 6914 MtCO$_2$-e, respectively), but they are not insignificant, being on a par with countries such as France, Italy and the Republic of Korea (550–570 MtCO$_2$-e per year; all data are for 2005).[38] Per person, Australia's emissions are the largest of any Organisation for Economic Co-operation and Development (OECD) country—26.8 tonnes in 2008, nearly twice the OECD average (Figure 3.9).[12-13]



CO$_2$-e = carbon dioxide equivalents; OECD = Organisation for Economic Co-operation and Development

Sources: Garnaut[13] and DCC 2008, National Greenhouse Gas Inventory 2006, International Energy Agency

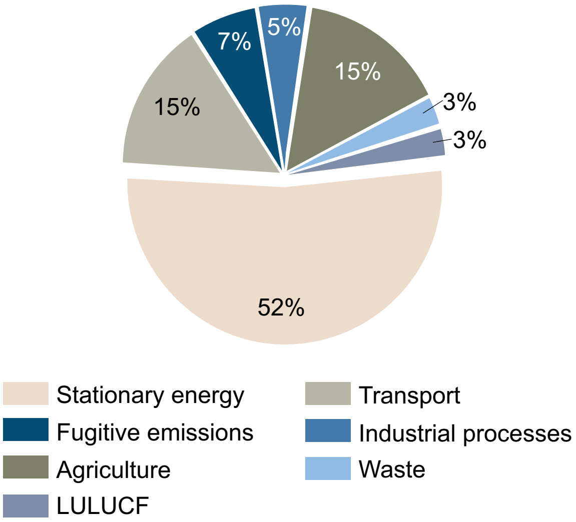
Figure 3.9 Greenhouse gas emissions per person

2.2.1 Emissions sources

The energy sector (comprising stationary energy, transport and fugitive emissions from fuels) continues to be the dominant source of Australia's GHG emissions, accounting for 74% of net emissions, including those associated with land use, land-use change and forestry (LULUCF) (Figure 3.10). Within this sector, stationary energy accounts for 52%, comprising electricity (37%) and fuel combustion (15%).

Australia's very high level of emissions per person reflects the nation's heavy reliance on fossil fuels as a primary energy source and, in particular, the dominant role of coal (an emissions-intensive fuel) in the production of electricity (Figure 3.11).

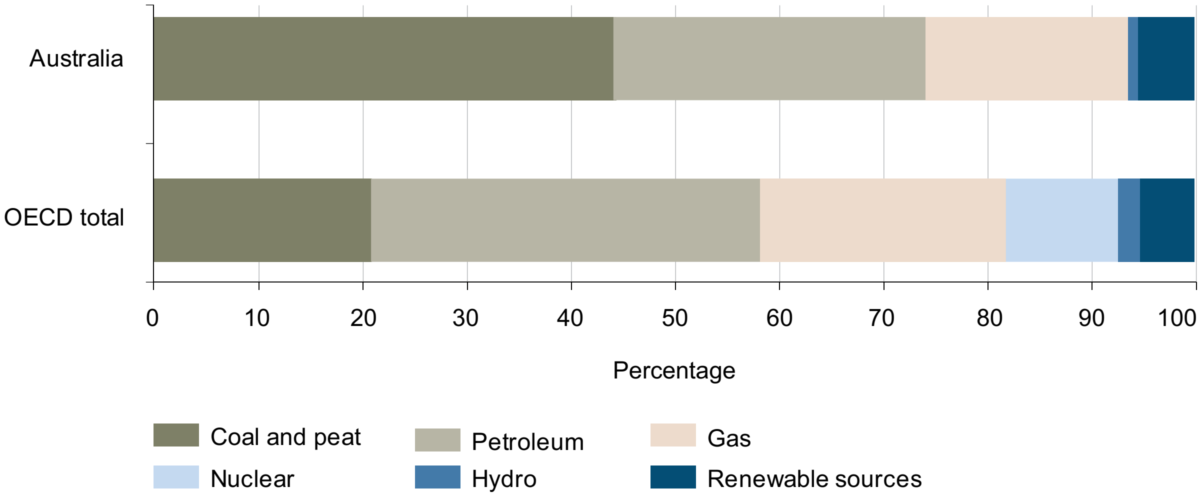
Although the transport and agricultural sectors both contribute around a sixth of Australia's net GHG emissions, transport's contribution is almost entirely through emissions of carbon dioxide, whereas agriculture's contribution is through methane and nitrous oxide—gases with global warming potentials many times that of carbon dioxide (Figure 3.12). (The 100-year warming potential of methane is 21 times that of carbon dioxide; the figure for nitrous oxide is 310.)[41]



LULUCF = land use, land-use change and forestry

Source: Australian Government Department of Climate Change and Energy Efficiency[39]

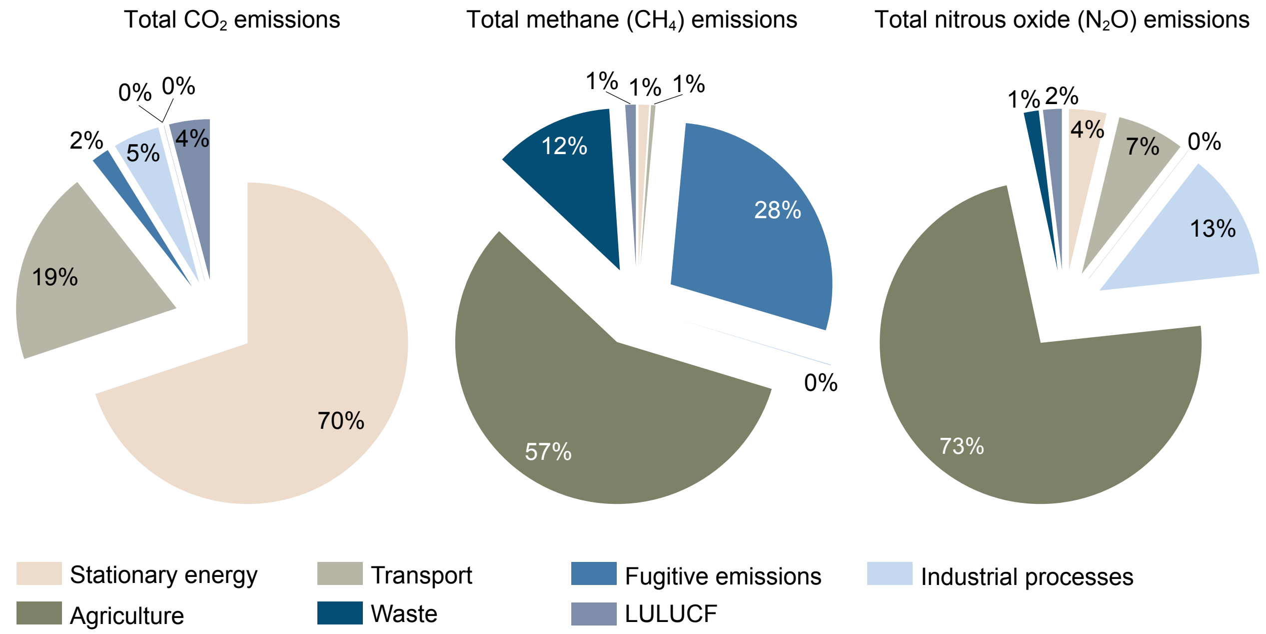
Figure 3.10 Greenhouse emissions by sector, Kyoto accounting, 2009



OECD = Organisation for Economic Co-operation and Development

Source: International Energy Agency[40]

Figure 3.11 Fuel mix contributing to total primary energy supply, 2008



LULUCF = land use, land-use change and forestry

Source: Australian Government Department of Climate Change and Energy Efficiency[39]

Figure 3.12 Carbon dioxide, methane and nitrous oxide emissions by sector, Kyoto accounting, 2009

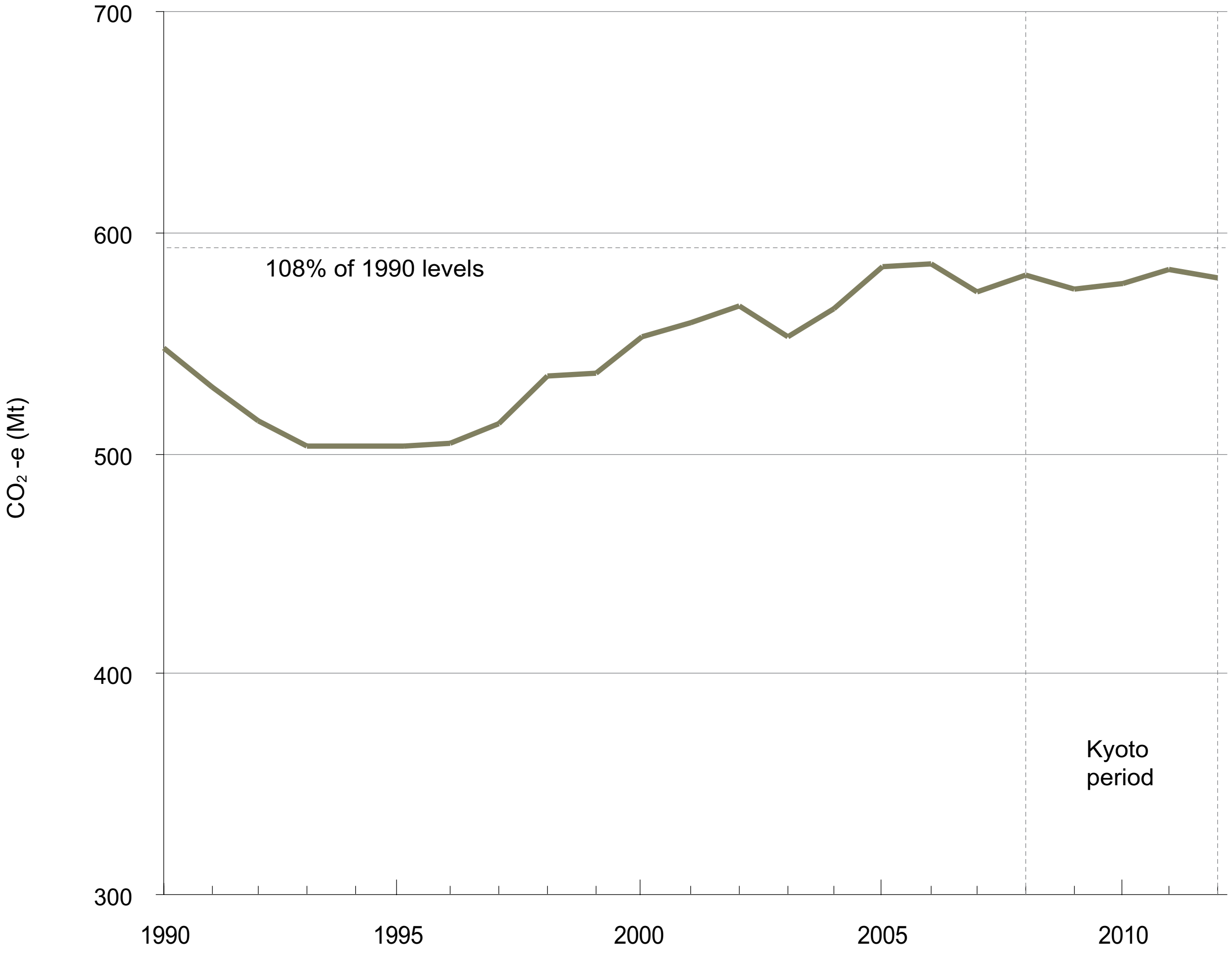
Under Article 3.3 of the Kyoto Protocol, parties can use net changes in GHG emissions associated with direct human-induced LULUCF activities that occurred since 1990 to meet their emission reduction commitments. Australia, in meeting its obligations to account for its GHG emissions under the protocol, includes net emissions associated with LULUCF. However, these tend to vary significantly from year to year, reflecting variability in climate; peaks (such as in 2007) are associated with extreme events such as bushfires and drought, which lead to major loss of carbon from vegetative and soil sinks.

2.2.2 Emissions trends

As a signatory to the Kyoto Protocol (ratified in 2007), Australia is committed to limiting increases in net GHG emissions to 108% of its 1990 levels by 2008–2012 (the ‘Kyoto commitment period’). As reported in 2010 in its *Fifth national communication on climate change* (under the United Nations Framework Convention on Climate Change),[42] Australia remains on track to meet this commitment, largely due to a major reduction in emissions associated with LULUCF (80% from 1990 to 2008) and, more particularly, to less land clearing over the same period (Figure 3.13).[42]

In contrast, from 1990 to 2009, emissions (excluding LULUCF) grew by 30.5% (Figure 3.14). The largest increase was in the stationary energy sector, which includes emissions from fuel consumption for electricity generation; fuels consumed in the manufacturing, construction and commercial sectors; and other sources such as domestic heating. This sector grew by 51%, driven by a mix of factors, notably rising population and household incomes, and growth in demand for energy associated with substantial increases in the export of resources. In the same period, transport grew by 35% in response to increases in the number of vehicles. Fugitive emissions (which typically result from leaks during the production, processing, transport, storage and distribution of raw fossil fuels) increased by 23%, chiefly because of increased emissions from coal mines. Emissions due to industrial processes rose by 21%, principally associated with increased production of HFCs as substitutes for ozone depleting CFCs, and substantial (220%) growth in emissions from the chemical industry.[39,42-43]

The waste and agricultural sectors are the only ones to have recorded a decline in emissions from 1990 to 2009 (22% and 2%, respectively). In the waste sector, this reflected the increasing capture of methane from landfill in response to a combination of regulatory pressure



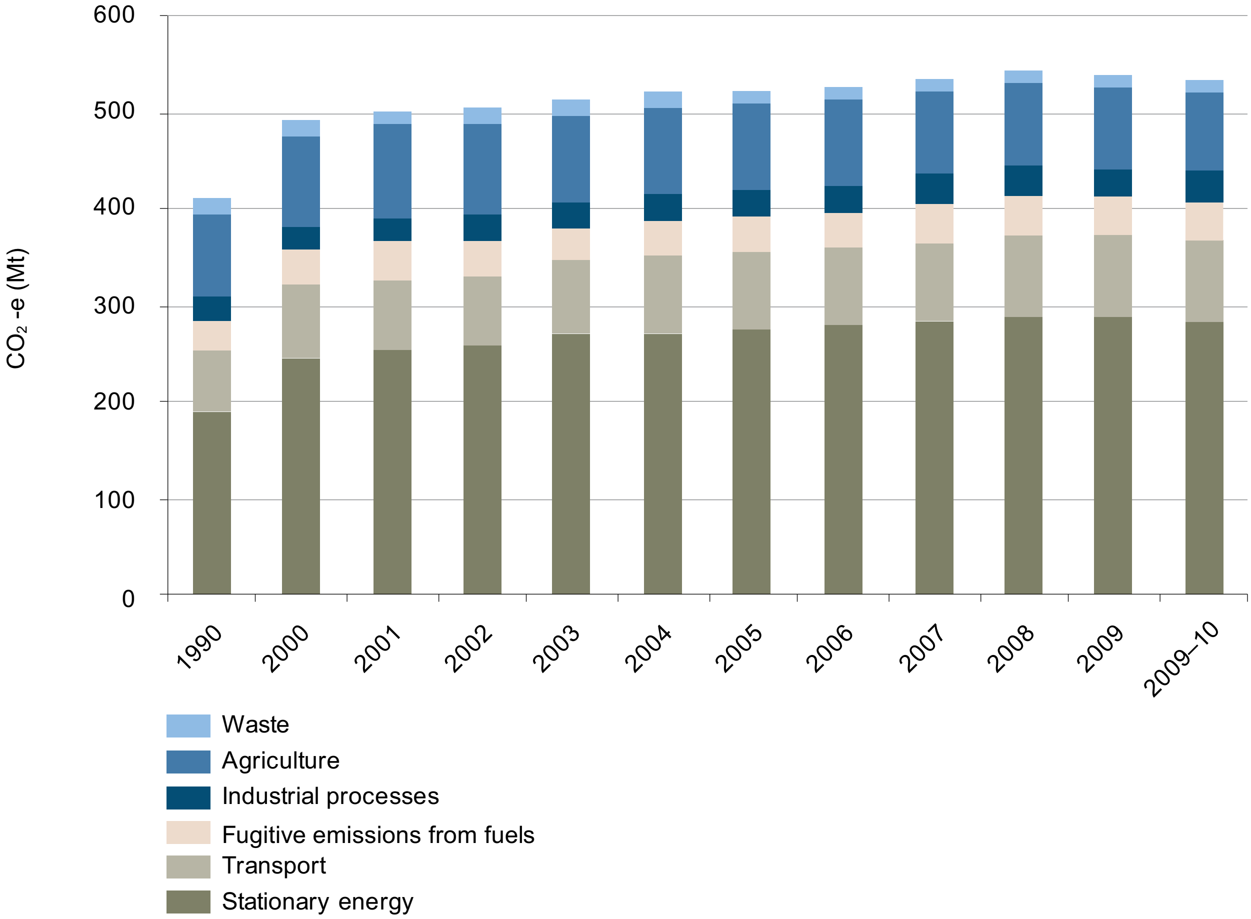
CO_2-e = carbon dioxide equivalents; Mt = megatonne

Source: Adapted from Australian Government Department of Climate Change and Energy Efficiency,[42] with permission

Figure 3.13 Australian greenhouse gas emissions, 1990–2012 (projected), including emissions associated with land use, land-use change and forestry and commercial gain (through use of the emissions as a source of energy). In agriculture, increases in emissions during the 1990s due to rising fertiliser use and savanna burning have been reversed since 2002, reflecting reduced fertiliser use and a significant drop in crop and animal production due to drought.[39,42-43]

Since 2000, Australia's emissions of GHGs (excluding LULUCF) have grown by an average of 1.1% per year. This compares with average annual growth of 1.9% from 1990 to 2000. The difference is principally attributable to a slower rate of growth of emissions from stationary sources and transport, as well as a decrease in emissions from agriculture. Like most OECD countries, Australia experienced a reduction in annual GHG emissions during the global financial crisis. However, the reduction was only marginal, with emissions (excluding LULUCF) falling from 551 $MtCO_2$-e in 2008 to 546 $MtCO_2$-e in 2009—a fall of 0.9%.[39] By comparison, the United States and the European Union experienced reductions in emissions growth of approximately 7% during the same timeframe.[44]

This marginal decline in Australia's emissions is only a minor and temporary divergence from the continuing longer term growth trend (Figure 3.15).



CO_2-e = carbon dioxide equivalents; Mt = megatonne

Note: Figures for 2009–10 are preliminary estimates.

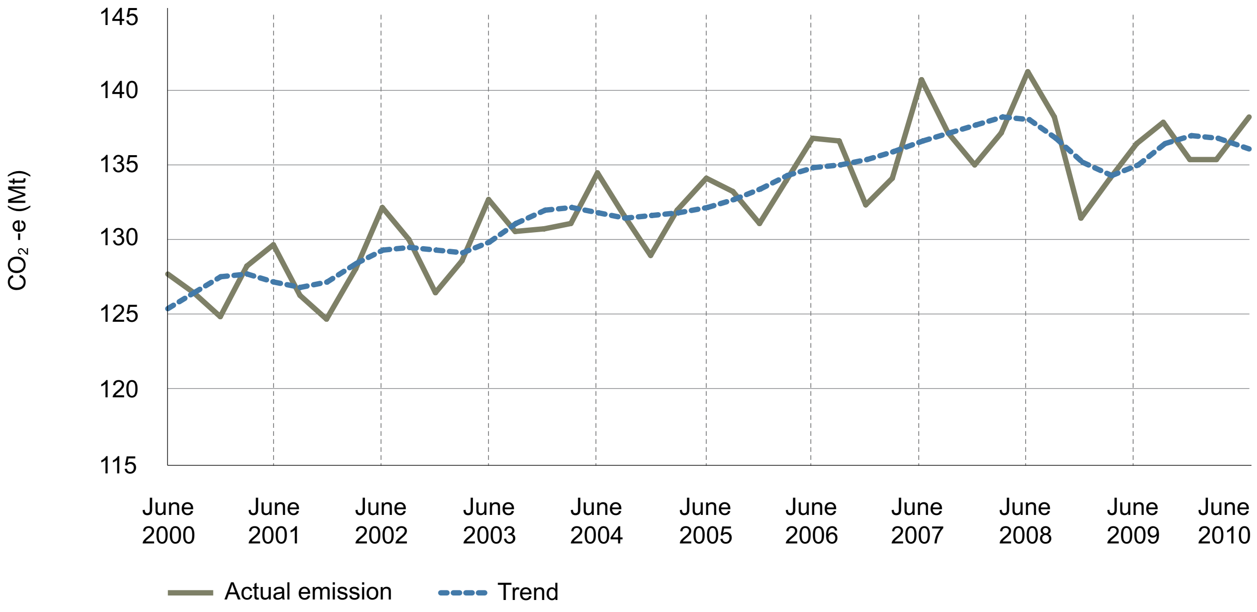
Source: Australian Government Department of Climate Change and Energy Efficiency,[39] with permission

Figure 3.14 Net greenhouse gas emissions by sector, excluding land use, land-use change and forestry

Under policy settings applying before the release of the Australian Government's Securing a Clean Energy Future plan, Australia's emissions were projected to grow by some 113 $MtCO_2$-e (19.6%) from 2010 to 2020. This would have brought Australia's annual emissions (including LULUCF) to 690 $MtCO_2$-e in 2020, an increase of 23% from 2000 levels. The projected growth was mainly due to anticipated emissions from the extraction and processing of energy resources to meet expected continued strong export demand. This contrasted with previous decades, when most emissions growth related to electricity generation. From 2010 to 2020, emissions from electricity generation were projected to grow much more slowly than in the past, increasing by only 6% (12 $MtCO_2$-e). This reflected the factoring into the projection of a significant increase in the use of renewable energy sources for generation of electricity, in response to the Renewable Energy Target. The target, which was established by the Australian Government in 2009, aims to ensure that 20% of Australia's electricity supply comes from renewable sources by 2020.[46] The Securing a Clean Energy Future plan aims to achieve Australia's unconditional emissions reduction target—a reduction of 5% on 2000 levels by 2020. This will require abatement of at least 159 $MtCO_2$-e (23%) in 2020.[47] (See Section 2.3.2 for details of the plan.)

2.2.3 Direct (primary) effects of pressures on climate

CSIRO and the Bureau of Meteorology's latest *State of the climate* report[48] concludes that, in the



CO_2-e = carbon dioxide equivalents; Mt = megatonne

Source: Australian Government Department of Climate Change and Energy Efficiency[45]

Figure 3.15 National Greenhouse Gas Inventory, actual quarterly emissions estimate and trend emission estimate, June quarter 2000 – June quarter 2010

The national inventory does not include estimates of net emissions from Article 3.3 of the Kyoto Protocol (land use, land-use change and forestry activities), which are estimated on an annual basis only. Emission estimates have been compiled by the Australian Government Department of Climate Change and Energy Efficiency using the methods incorporated in the Australian Greenhouse Emissions Information System, preliminary activity data obtained under the National Greenhouse and Energy Reporting System and from a range of publicly available sources—principally the Australian Bureau of Agricultural and Resource Economics and Sciences, the Australian Bureau of Statistics, the Australian Energy Market Operator and the Australian Government Department of Resources, Energy and Tourism. As more data become available from these sources—in particular the National Greenhouse and Energy Reporting System—these preliminary activity data will be replaced and the estimates of emissions revised before submission to the United Nations. The department's assessment is that the 90% confidence interval for the national inventory (before taking account of Article 3.3 activities) is ± 1% (i.e. there is a 90% probability that future revisions will be limited to ± 1% of the current estimate).

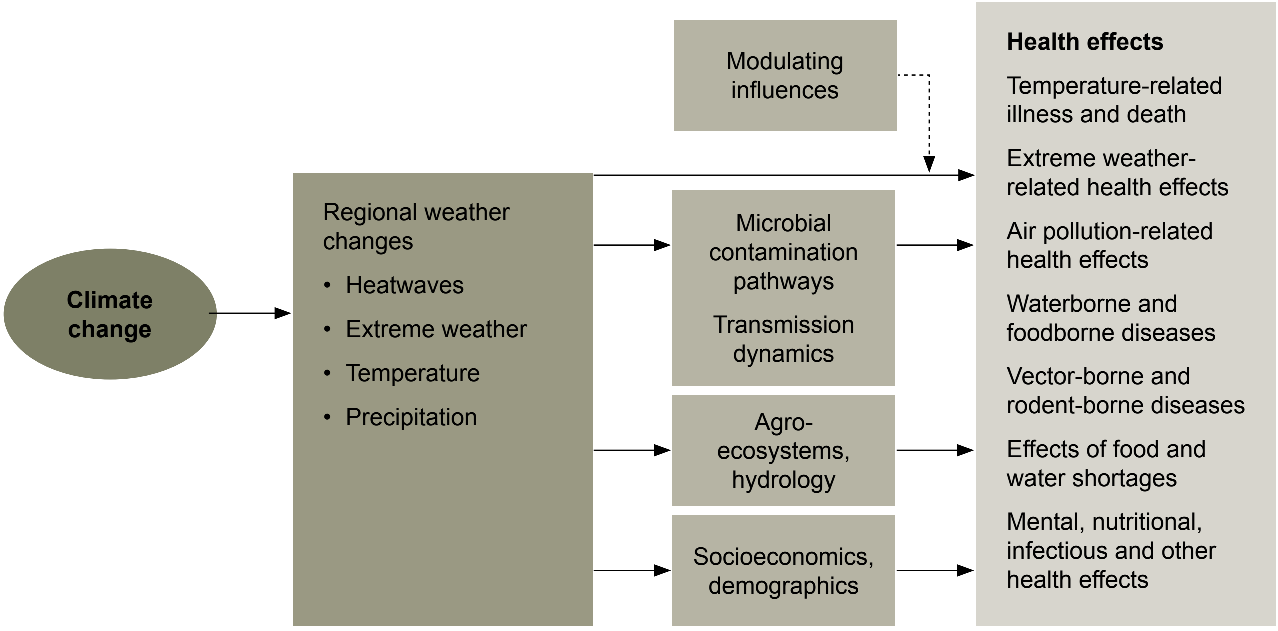
coming decades, Australia will be hotter and much of the continent will be drier. More specifically, the report summarises the main direct effects of climate change as follows:

- By 2030, projections show average temperatures rising by 0.6–1.5 °C, in addition to an existing rise of around 0.7 °C since 1960.
- By 2070, if growth in GHG emissions continues in line with past trends, projected warming will be in the range of 2.2–5.0 °C. Even at the lower end of this range, the projected increase is near or above the level regarded by many climate scientists as likely to trigger 'dangerous climate change'. (See Schneider and Lane[49] for a discussion of the complexities of the concept of dangerous climate change.)
- Compared with the last two decades of the 20th century, southern Australia is likely to experience reduced winter rain, and spring rainfall declines are expected in southern and eastern areas. In south-west Western Australia, reductions in autumn rainfall are likely to add to pressures associated with the existing decades-long decline in winter rain. Northern Australia is likely to experience an increase in annual and summer rainfall.[50]

In addition to directly affecting large-scale aspects of climate, such as average temperature and precipitation, human-induced climate change has the potential to alter the frequency and severity of extreme events, such as storms, floods, droughts and heatwaves.[50-53] As noted above, separating the effect of climate change from that of natural processes can be difficult, and this uncertainty greatly complicates efforts to characterise likely changes in these extreme events. Nevertheless, improving our understanding of the vulnerabilities associated with such changes is an essential step in planning our adaptation to climate change.[54]

2.2.4 Indirect (secondary and tertiary) effects of pressures on climate

Direct effects on climate, such as those outlined in Section 2.2.3, trigger indirect effects further down a complex chain of cause and effect. These are products of the profound and pervasive influence of climate, both on a host of natural processes that underpin the condition and trend of ecosystems, and on a range of demographic, economic and social processes and systems. The complex nature of the effects of changes in climate is illustrated in Figure 3.16 in relation to human health.



Source: Redrawn from McMichael et al.,[55] with permission

Figure 3.16 Pathways by which climate change affects human health, including local modulating influences and the feedback influence of adaptation measures

Australia's *Fifth national communication on climate change* (under the United Nations Framework Convention on Climate Change)[42] draws on the work of the IPCC[25] to outline a wide range of indirect effects of climate change:

- decreased water availability and water security, due to
  - reduced rainfall in southern Australia and south-west Western Australia
  - increased evaporation, which reduces run-off to streams and recharge of groundwater systems
- coastal zone impacts, such as inundation from sea level rise
- damage to energy, water, communications and built infrastructure
- a decline in agricultural productivity due to increased drought and fire
- damage to iconic natural ecosystems, such as the Great Barrier Reef and Kakadu National Park
- a decline in biodiversity.

Other sources identify additional indirect effects of climate change, such as:

- likely increases in the frequency of days of extreme bushfire risk,[56-58] and of dust storms, linked to widespread reductions in levels of soil moisture[25]
- changes to human health, including
  - some positive, particularly in the first part of the century, when some areas will benefit from a reduction in cold weather
  - some negative, resulting from factors such as more frequent and intense heatwaves, particularly later in the century (Table 3.1), and possible extension in the range of various disease vectors (notably mosquitoes).[13,25,59]

Table 3.1 Change in likely temperate-related deaths due to climate change

In the baseline case, any increase in number of deaths is due to the expanding and ageing of the population. The next three cases are best-estimate cases and use the 50th percentile rainfall and relative humidity and 50th percentile temperature for Australia. The final case (right-hand side) is an illustrative 'bad-end story' that uses the 10th percentile rainfall and relative humidity and 90th percentile temperature for Australia (a hot, dry extreme).

	Baseline—no human-induced climate change		No-mitigation case		Global mitigation with CO_2-e stabilisation at 550 ppm by 2100		Global mitigation with CO_2-e stabilisation at 450 ppm by 2100		Hot, dry extreme case	
	Number of temperature-related deaths in 2030 and 2100									
Region	**2030**	**2100**	**2030**	**2100**	**2030**	**2100**	**2030**	**2100**	**2030**	**2100**
ACT	300	333	280	250	278	285	276	295	275	262
NSW	2 552	2 754	2 316	1 906	2 290	2 224	2 268	2 334	2 255	2 040
NT	63	61	63	407	63	93	64	76	64	768
Qld	1 399	1 747	1 276	5 878	1 274	1 825	1 278	1 664	1 286	11 322
SA	806	811	770	704	766	735	762	750	758	740
Tas	390	375	360	240	357	313	354	327	352	211
Vic	1 788	1 966	1 632	1 164	1 614	1 586	1 599	1 673	1 589	1 021
WA	419	515	418	685	419	529	419	519	420	835
Australia	7 717	8 562	7 115	11 234	7 061	7 590	7 020	7 638	6 999	17 199

ACT = Australian Capital Territory; CO_2-e = carbon dioxide equivalent; NSW = New South Wales; NT = Northern Territory; ppm = parts per million; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

Source: Garnaut[13]

■ Partial solar eclipse through a thick plume of bushfire smoke, 4 December 2002, Broken Bay, New South Wales

Photo by Manfred Gottschalk

Box 3.3 Victorian heatwave, January 2009

During the second half of January 2009, Victoria experienced an unprecedented heatwave. Maximum day-time and night-time temperature records were broken by significant margins, and new records were set for the duration of extreme heat. From 27 to 31 January, much of Victoria experienced maximum temperatures 12–15 °C above normal. For three of these days (28–30 January), the maximum was above 43 °C, peaking at 45.1 °C on 30 January (Table A).

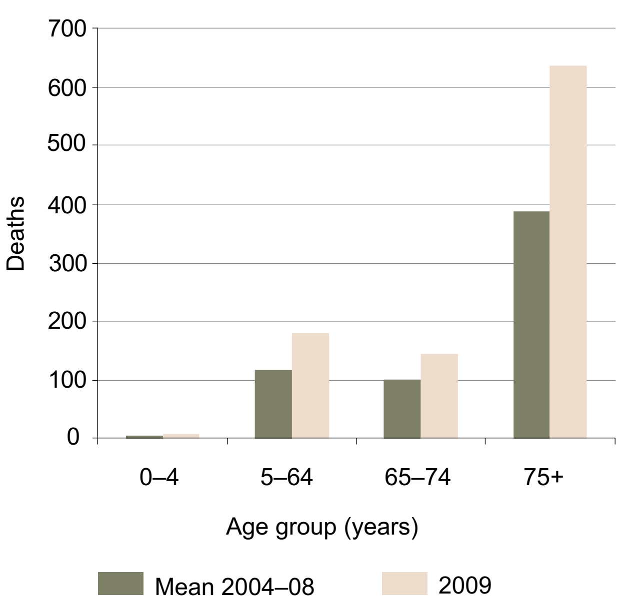
Table A Temperatures in Victoria, 26 January – 1 February 2009

	Maximum day-time temperature (°C)	Minimum night-time temperature (°C)	Mean temperature (°C)
Monday 26 January	25.5	14.4	19.9
Tuesday 27 January	36.4	16.6	26.5
Wednesday 28 January	43.4	18.8	31.1
Thursday 29 January	44.3	25.7	35.0
Friday 30 January	45.1	25.7	35.4
Saturday 31 January	30.5	22.5	26.5
Sunday 1 February	33.8	20.3	27.0

The impact of the heatwave on public health was clearly identifiable and substantial. The effects were similar to those of the catastrophic 2003 European heatwave, which had an estimated total excess mortality of 70 000. In Victoria, the Department of Health calculated a figure of 374 excess deaths over the average number in the same weeks of the preceding five years (an increase of 62% in all-cause mortality).

In addition to this marked spike in mortality, there was a pronounced impact on morbidity, which was reflected in increases in ambulance emergency case load (46% over the three hottest days), locum general practitioner visits (almost four-fold increase in heat-related attendances), and emergency room attendances (eight-fold increase in heat-related presentations). Not surprisingly, as shown in Figure A, the elderly were the group most affected, with people over 75 years of age being disproportionately represented in both mortality and morbidity.

As with any extreme climatic event, estimating the extent to which climate change played a role over and above natural variability is problematic. Nevertheless, an increase in the frequency of such extreme temperature–driven events is entirely consistent with the now decades-long upward trend of average temperatures and with the results from studies modelling a broad range of climate change scenarios.



These data from the Registrar and the State Coroner's Office are provisional and, although these are expected to account for the vast majority of deaths, may be revised over time. it is possible that deaths relating to the heatwave occurred or were reported outside the period of analysis, thereby underestimating the impact. Certainly, the vast majority of short-term mortality is expected to have been captured.

Figure A Deaths in Victoria by age group between 26 January and 1 February, 2004–08 and 2009

Source: Department of Human Services Victoria,[60] using data from the Bureau of Meteorology and the Victorian Registry of Births, Deaths and Marriages

3.1 Assessment summary

Pressures affecting Australia's climate

Component	Summary	Assessment grade				Confidence	
		Very high impact	High impact	Low impact	Very low impact	In grade	In trend
Greenhouse gases	Under policy settings applying before the release of the Australian Government's Securing a Clean Energy Future plan, Australia's emissions were projected to grow by 113 MtCO$_2$-e (19.6%) between 2010 and 2020. This would have brought Australia's annual emissions (including emissions from land use, land-use change and forestry) to 690 MtCO$_2$-e in 2020, an increase of 23% from 2000 levels. To achieve the nation's minimum target of a 5% cut on 2000 levels by 2020 will require a reduction of 159 MtCO$_2$-e (23% compared with the projected 2020 level). The Securing a Clean Energy Future plan aims to achieve this reduction by 2020. To achieve Australia's 15% conditional target, a 31% reduction would be needed Climate change modelling indicates that average temperatures will rise, the number of dry days will increase, and intense rainfall events will increase in many areas. More frequent bushfires, dust storms and heatwaves, and attendant impacts on human health, can all be expected		 ↙			◒	●

Recent trends	↗	Improving	—	Stable	
	↙	Deteriorating	?	Unclear	

Confidence	●	Adequate high-quality evidence and high level of consensus
	◒	Limited evidence or limited consensus
	○	Evidence and consensus too low to make an assessment

Grades	🟩	Very low impact	Few or no impacts have been observed, and accepted predictions indicate that future effects are likely to be minor
	🟫	Low impact	Current pressures have been observed to have had a limited impact on some aspects of climate, and there is concern that, based on accepted predictions, these may worsen
	🟧	High impact	Current pressures are probably already having serious impacts on important aspects of climate and are expected to worsen, with serious implications for a broad range of areas
	🟥	Very high impact	Current pressures are already having very serious impacts on important aspects of climate (such as temperature, rainfall and extreme events) with very serious flow-on effects in a broad range of areas

MtCO$_2$-e = megatonnes of carbon dioxide equivalents

2.3 Effectiveness of management

As a developed country that is a signatory to the United Nation's Framework Convention on Climate Change, every four years Australia submits a national communication on climate change that sets out the national strategy to address climate change and reports on progress made over the reporting period. In Australia's most recent national communication (the fifth), which was submitted in 2010, the government describes its climate change strategy as comprising 'three pillars': mitigating emissions, adapting to unavoidable climate change and helping to shape a global solution (Figure 3.17). As the communication notes, the strategy and key policies and measures it encompasses have been informed by:

- a significant improvement in the national climate science research effort
- a comprehensive, in-depth analysis to identify the best mix of approaches to deal with climate change (the Garnaut Climate Change Review)
- extensive consultation with business and the community.[42]

At a glance

If Australia is to achieve the national 2020 target of a 5% reduction in greenhouse gas emissions below 2000 levels, the range and effectiveness of abatement measures being applied in both the public and private sectors will need to be greatly increased. This is the key aim of Securing a Clean Energy Future, the Australian Government's climate change plan released in July 2011, which sets out details of a mechanism to establish a price on carbon and drive reductions in emissions via least-cost means. The plan also builds on existing measures, such as the legislated 20% Renewable Energy Target and the Carbon Farming Initiative, to promote development of renewable energy sources, energy efficiency and action to sequester carbon. At the time of writing (July 2011), the Australian Government proposes to introduce the necessary supporting legislation to parliament before the end of the year.

Current governance is complex, because three tiers of government need to be involved in working with the private sector and the community to plan for and implement effective mitigation and adaptation measures. Coordination of federal and state programs has improved via actions by the Council of Australian Governments (COAG). Understanding of the science of climate change as it relates to Australia is continuing to improve, as is confidence in modelling projections at both national and regional scales. There is extensive support for policy and priority setting at a national level through the initial Garnaut Climate Change Review (2008) and subsequent review update (2011) and through an improved national greenhouse gas emissions reporting system. The Australian Government has established a broad ('three-pillars') strategy, underpinned by the Renewable Energy Target, an energy efficiency strategy and a national adaptation framework that was adopted by COAG in 2007.

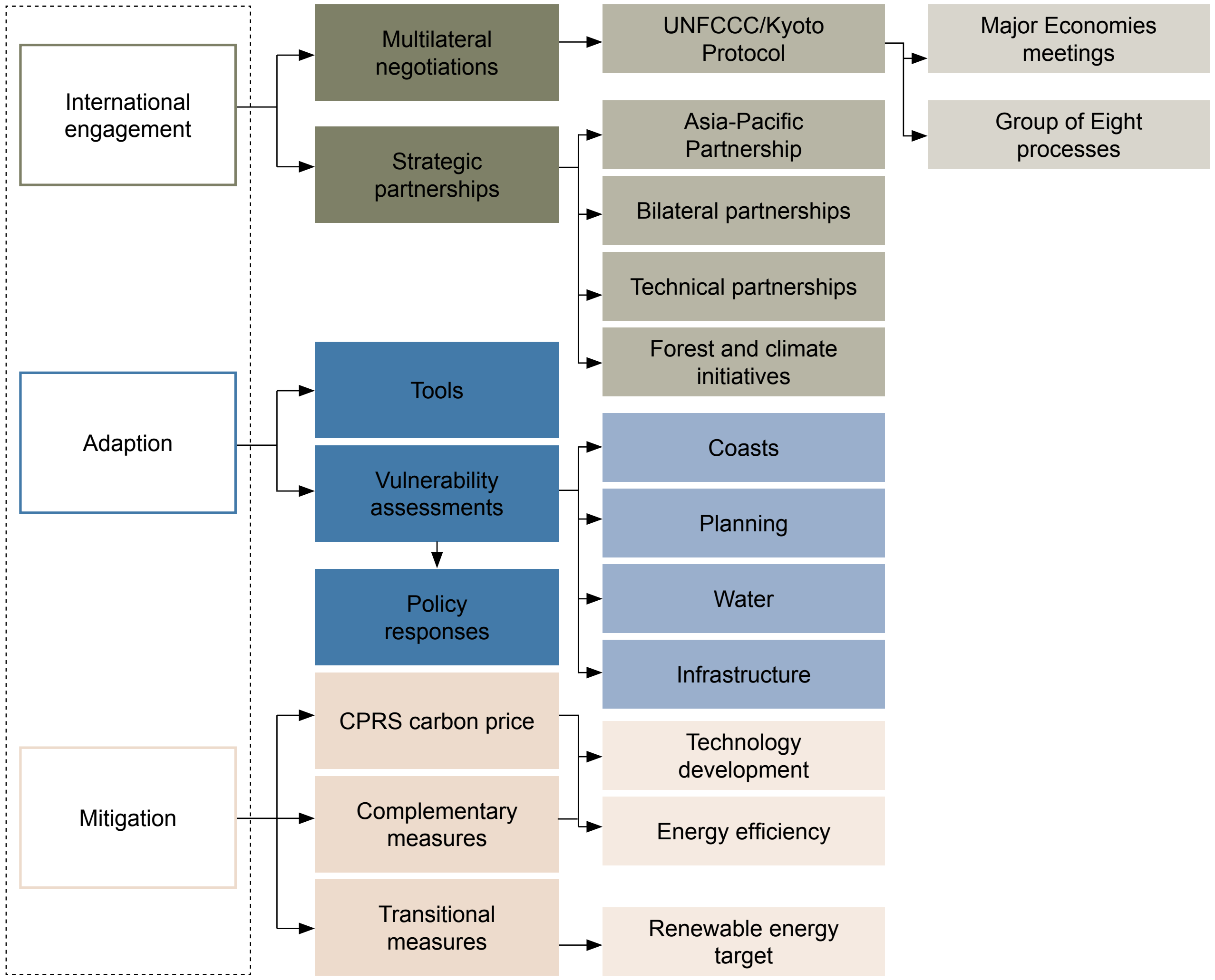
The Australian Government has committed around $15 billion to climate change initiatives. States and territories are also applying significant resources to mitigation and adaptation programs.

2.3.1 Understanding and research

> Information about climate change and its likely impacts is the first requirement of good adaptation and mitigation policies. This requires strengthening of the climate-related research effort in Australia. *Garnaut*,[13] *p. xli*

In the six years since the fourth national communication, international climate change science has advanced significantly, through many hundreds of studies of the complex, interacting processes driving change in the atmosphere, oceans and terrestrial systems. The base of empirical evidence has greatly expanded, as have the power and sophistication of climate change modelling at global, continental and regional scales. This has enabled better informed and more precise understanding of risks, and analysis of opportunities to mitigate and adapt to future change.[9,61-62]

Australia is recognised as being particularly vulnerable to the effects of climate change.[25,63] Acting on the need to improve our understanding of the risks to the environmental systems that support our economy and to identify opportunities to manage such risks via mitigation and adaptation, the Australian Government established the National Climate Change



CPRS = Carbon Pollution Reduction Scheme; UNFCCC = United Nations Framework Convention on Climate Change

Source: Australian Government Department of Climate Change and Energy Efficiency[42]

Figure 3.17 Australia's three-pillar climate change strategy

Adaptation Research Facility in 2007 and the National Framework for Climate Change Science in 2009. It also committed to substantial investments in climate science: $31.2 million over four years from 2009 for the Australian Climate Change Science Program (with matching contributions from CSIRO and the Bureau of Meteorology); $387.7 million in research infrastructure over four years to increase Australia's capacity to respond to climate change and improve protection of Australia's marine territory; and a number of scientific partnerships between CSIRO, the Bureau of Meteorology, and state and territory governments.[42,64] (Details of grants made under the Australian Climate Change Science Program can be accessed at the Department of Climate Change and Energy Efficiency website.[a])

In December 2007, Australia ratified the Kyoto Protocol and established a new Department of Climate Change (now Climate Change and Energy Efficiency) to take the lead across government on climate change, providing a focus for policy development and advice, both domestically and internationally. Since then, Australia's system for measuring and reporting on GHG emissions and energy use by major industry sectors and for estimating losses and gains from vegetation and soil sinks (the National Greenhouse Gas Inventory) has substantially improved. This reporting system underpins Australia's commitment under the protocol to a GHG emissions target of 108% above 1990 levels for the first commitment period (2008–12). The statutory framework for this system was established in 2007 with the introduction of the *National Greenhouse and Energy Reporting Act 2007*. The Act streamlines reporting with the establishment of a single reporting point for emissions and energy data and, since 2008, mandates reporting by companies exceeding thresholds for emissions and energy production. The framework also enables Australia to meet its reporting requirements under the Kyoto Protocol through the establishment of a national registry of emissions units. Planning and quality control systems associated with the national inventory have also been strengthened.[42]

2.3.2 Planning and strategy

Governments have a key role to play in mitigation of, and adaptation to, climate change, including:

- supporting scientific studies that are unlikely to be undertaken by the private sector (particularly relevant to the Australian Government)
- providing information to the private sector and the community to encourage and assist adaptation (relevant to all tiers of government, but of particular importance to state, territory and local governments)
- adopting policy settings that facilitate adaptation and a regulatory framework that supports, rather than distorts, effective market signals (a critical role for the Australian Government, but one that state and territory governments can significantly reinforce)
- employing policy mechanisms such as land-use planning, building codes and product standards to deal with situations where short-term market responses may act to restrict longer term adaptive action (primarily relevant to state and territory governments, but also to the Australian Government for setting minimum energy performance standards and the Building Code of Australia, and to local governments, which play an important role in on-ground implementation)
- fully factoring climate change into planning, resourcing and managing the provision of public goods and services such as public health and safety, emergency services, flood and coastal protection, water supply, drainage and sewerage services, protection of public lands, parks and reserves, fisheries and other natural resources (relevant to all three tiers of government, but especially to state, territory and local governments).

A key part of the Australian Government's three-pillars strategy has been the introduction of a price on carbon to drive reductions in emissions via least-cost means. An initial attempt in 2008–10 to do this by means of an emissions trading scheme (the Carbon Pollution Reduction Scheme) failed to gain bipartisan support in parliament and did not proceed.

■ Tropical Cyclone Billy over Western Australia, December 2008

Photo by Fotosearch/SuperStock

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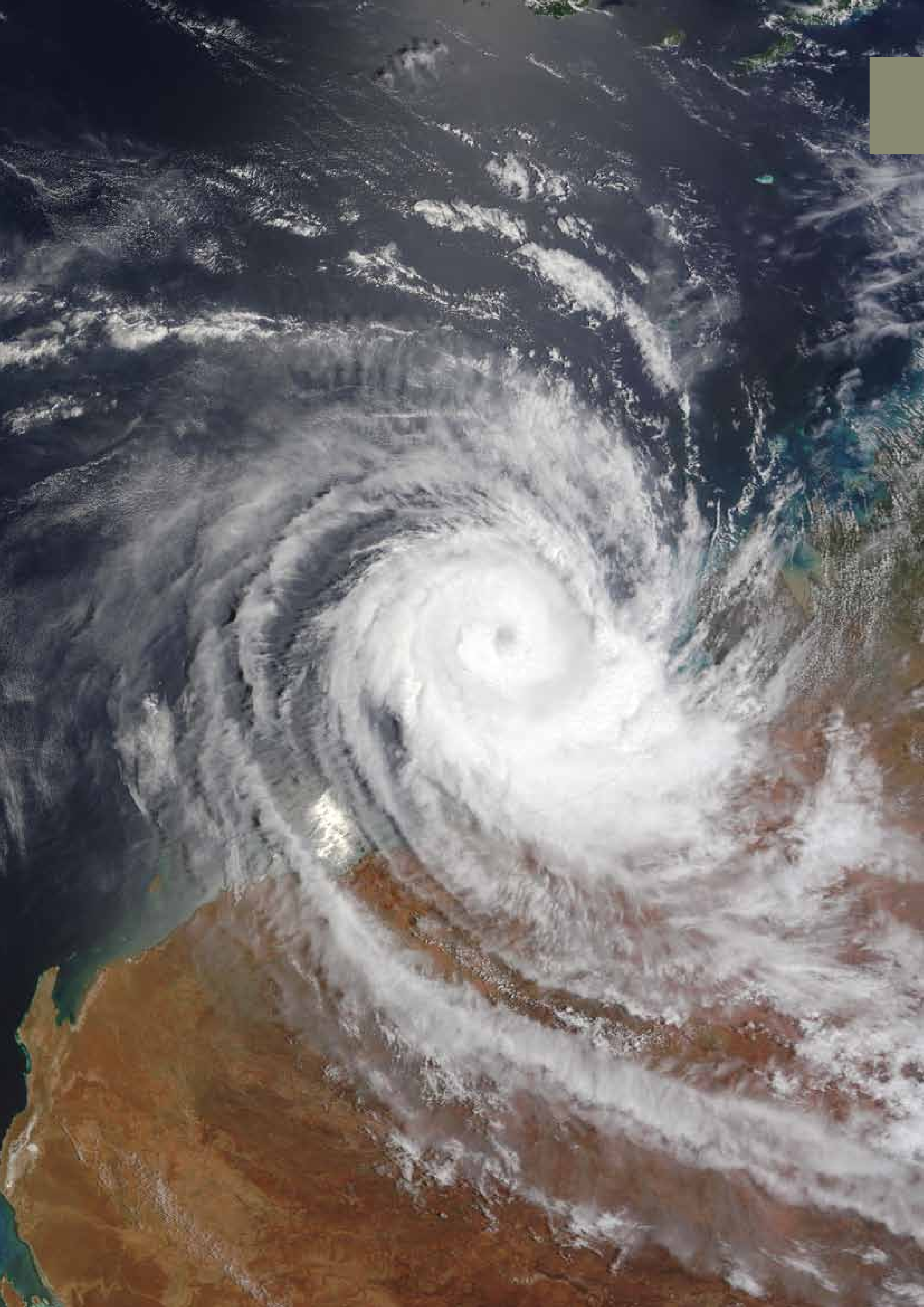
[a] www.climatechange.gov.au/about/grants.aspx



In July 2011, the Australian Government released its new plan for the introduction of a price on carbon (titled Securing a Clean Energy Future). Although the plan has four components (a carbon price, renewable energy, energy efficiency and land-based action to sequester carbon), the critical element is a mechanism to put a price on carbon and thereby stimulate least-cost abatement measures.[47]

Unlike the earlier failed attempt to move directly to a carbon emissions trading scheme, the plan involves moving to a trading scheme via a three-year transitional period. During this period, starting from 1 July 2012, facilities directly emitting 25 000 tonnes or more of CO_2-e per year (excluding transport fuel emissions) and large suppliers of natural gas will have to buy and surrender to the Australian Government a carbon permit for each tonne of GHG they emit. The government will issue as many permits as businesses need to cover their emissions. The starting price will be fixed at $23 per tonne, increasing by 2.5% per year in real terms. GHGs for which permits will have to be purchased are carbon dioxide, methane and nitrous oxide, and PFC emissions from the aluminium sector. Existing legislation relating to synthetic GHGs will be used to apply an equivalent tax on manufacturing and import of all the synthetic GHGs covered by the Kyoto Protocol—HFCs, PFCs and sulfur hexafluoride. In combination, this will cover around 60% of Australia's emissions, including emissions from electricity generation, stationary energy, some business transport, nonlegacy waste, industrial processes and fugitive emissions. (Emissions from agriculture will not be covered.)

On 1 July 2015, the fixed price (or carbon tax) period will be replaced by an emissions trading scheme (ETS). Under the ETS, the government will set an annual carbon pollution cap that will determine the number of permits issued. Market forces will then act to influence the price of a permit at any time. However, for the first three years of the scheme, a ceiling and floor price will be in place to limit extreme price volatility. The ceiling will be set at $20 per tonne above the anticipated international price, rising by 5% per year in real terms. The floor price will start at $15 per tonne and increase by 4% per year in real terms. The role of the ceiling and floor price will be reviewed in the third year of operation of the ETS. From the outset of the ETS, businesses will be able to purchase international permits from credible carbon markets. Until 2020, businesses will be able use international permits to meet up to 50% of their required permits each year. (This restriction will be reviewed in 2016.)

Fifty per cent of the revenue from the carbon pricing mechanism will be used to assist households to deal with price impacts. The balance will be divided between supporting a range of industries directly or indirectly affected by the introduction of a carbon price (including energy-intensive, trade-exposed industries) and expanding existing funding for clean energy and energy efficiency programs.

The plan provides for a legislated independent expert body (the Climate Change Authority) to advise government on matters such as future pollution caps, indicative national emissions trajectories and long-term emissions budgets, and the progress made towards national reduction targets. Legislation will also establish a clean-energy regulator to administer the carbon pricing mechanism.

Although a carbon price will not apply to agriculture, the plan will continue the existing Carbon Farming Initiative to encourage and support farmers and land managers to reduce emissions and store carbon in soil and vegetation. Funding for such actions will be available through an ongoing Biodiversity Fund ($946 million over the first six years) and an ongoing Carbon Farming Futures program ($429 million over the first six years).

Under the plan, the existing Renewable Energy Target will be complemented by the establishment of a new statutory authority, the Australian Renewable Energy Agency, which will provide funding for projects through a range of competitive grants programs. The agency will consolidate existing funding of $3.2 billion over nine years to support innovation in renewable energy and will make additional funds available. In addition, a Clean Energy Finance Corporation will be established to invest in the commercialisation and deployment of renewable energy and in enabling technologies, energy efficiency and low-emissions technologies.

Emissions reduction targets for 2020, to which the Australian Government had already committed, have been maintained, and the long-term target (2050) has increased from 60% to 80% of 2000 levels (Box 3.4). To meet the government's minimum emissions reduction target (a 5% reduction from 2000 levels by 2020) in the face of projected continuing growth in emissions will require abatement of at least 159 $MtCO_2$-e (23%) by 2020.

At the time of writing (July 2011), the Australian Government proposes to introduce the necessary supporting legislation to parliament before the end of the year.

Box 3.4 Australia's climate change targets

Emissions

Kyoto target: to limit net increases in greenhouse gas emissions to an average of 108% of 1990 levels across 2008–12. Australia is on track to meet this target, largely due to a significant reduction in land clearing during the late 1990s, which was achieved via controls at state level.

2020 target range: to achieve emissions reductions of between 5% and 25% below 2000 levels by 2020:

- 5%—an unconditional commitment even in the absence of an international commitment
- 15%—a target Australia is prepared to adopt if there is a global agreement that falls short of securing atmospheric stabilisation at 450 parts per million (ppm) CO_2-e (carbon dioxide equivalents), but under which all major economies commit to significant emissions reductions and advanced economies accept reductions comparable with Australia's
- 25%—agreed by Australia in Appendix 1 to the Copenhagen Accord, provided the world agrees to an ambitious global deal capable of stabilising levels of greenhouse gases in the atmosphere at 450 ppm CO_2-e or lower.

2050 target: In July 2011 (as part of its Securing a Clean Energy Future plan) the Australian Government increased the national 2050 emissions reduction target from a 60% reduction on 2000 levels to an 80% reduction. Developed countries need to achieve a 60% reduction to stabilise global greenhouse gas levels in the range 450–550 ppm by 2050. At 450 ppm, the estimated likelihood of limiting global mean temperature rise to 2 °C above pre-industrial levels is around 50%. At 550 ppm, a rise of 3 °C is likely. The Commonwealth Scientific and Industrial Research Organisation estimates that around 97% of the Great Barrier Reef will be bleached each year if temperatures rise to within this range.

Energy efficiency

Renewable Energy Target: to source 20% of Australia's electricity supply from renewable resources by 2020.

Sources: Australian Government;[65] Australian Government Department of Climate Change and Energy Efficiency;[66] United Nations Framework Convention on Climate Change;[67] Garnaut;[13] Preston & Jones[68]

Hermannsburg solar array providing electricity to local communities, near Alice Springs, Northern Territory

Photo by Steven David Miller

2.3.3 The role and coordination of different levels of government

An overarching Australian Government strategy—implemented via a range of policies, plans and programs—is essential if Australia is to succeed in mitigating climate change and addressing key areas of vulnerability through adaptation. However, in Australia's federal system, it is also imperative that other Australian governments play their part in the national initiative and that their actions are coordinated effectively with those of the Australian Government.

Table 3.2 lists examples of key climate change policies and strategies established at state and territory level. In addition to seeking to mitigate climate change through means such as renewable energy targets, electricity feedback tariffs and energy efficiency programs, each jurisdiction's policies and strategies focus on the need to identify vulnerabilities and opportunities associated with climate change and to implement appropriate adaptive actions.

Table 3.2 Examples of key state and territory climate change policies and strategies

State/territory	Policy response or strategy	Comment
Australian Capital Territory (ACT)	Weathering the Change—the ACT Climate Strategy 2007–2025	
	Electricity Feed-in (Renewable Energy Premium) Act 2008	
New South Wales	Greenhouse Plan	
	Draft Climate Change Action Plan	To replace Greenhouse Plan
	Greenhouse Gas Reduction Scheme (formerly the Greenhouse Gas Abatement Scheme)	Trading aspects to cease when a national emissions trading scheme commences
	Renewable energy target	
	Promotion of energy-efficient buildings	Encourages adoption of National Australian Built Environment Rating System
Northern Territory (NT)	Climate Change Policy	A $34-million action plan that commits NT to becoming carbon neutral by 2018 Provides a plan for lowering land clearing rate and protecting coastal wetlands
Queensland	ClimateSmart 2050	State climate change strategy
	ClimateSmart Adaptation 2007–2012	Action plan for managing effects of climate change
	Smart Energy Policy	
	Renewable Energy Fund	
South Australia	Tackling Climate Change—South Australia's Greenhouse Strategy 2007–2020	Deals with a range of mitigation and adaptation actions
	Electricity (Feed-in Schemes—Solar Systems) Amendment Act 2008	Bill to amend 2008 Act introduced in April 2011 to increase benefits while limiting total cost of scheme
	Residential Energy Efficiency Scheme	
	Draft Adaptation Framework	A guide to government agencies, local government, nongovernment organisations, business and the community

Table 3.2 *continued*

State/territory	Policy response or strategy	Comment
Tasmania	Framework for Action on Climate Change	
	Community Grants Programs	Micro-grants (up to $3000) and ClimateConnect grants (up to $30 000)
Victoria	Taking Action for Victoria's Future—Victorian Climate Change White Paper, 2010	Comprehensive framework that addresses mitigation and adaptation
	Climate Change Act 2010	Deals with a range of matters, including providing for an emissions reduction target of 20% by 2020; establishing property rights in forestry, carbon sequestration and soil carbon; empowering the Environment Protection Authority to regulate emissions
	Climate Change Adaptation Plan and community-based climate change preparedness programs	Key adaptation actions under the white paper
	Victorian Renewable Energy Target Scheme	Sets annual statutory targets and issues renewable energy certificates
Western Australia	Climate Change Adaptation and Mitigation Strategy	Under development
	Low Emissions Energy Development Fund	$30 million available to support development of technologies
	Residential feed-in tariff scheme	Provides eligible residential system owners with a subsidy rate of 40 cents per kilowatt hour for energy exported to the electricity grid

Sources: Parliament of Australia,[35] state and territory agency websites

In February 2008, the Australian Government commissioned a strategic review of all climate change programs (the Wilkins review[69]) 'to determine whether existing climate change programs are efficient, effective and complementary to the Carbon Pollution Reduction Scheme (CPRS)—so that climate change can be addressed at least cost to the economy'.[70] The review recommended, among other things, a reduction in the number of federal programs and a clarification of roles of the Australian and state and territory governments. More specifically, it suggested a rationalisation of activities, with the Australian Government to focus on mitigation measures and the states and territories to concentrate on adaptation via the Council of Australian Governments (COAG) National Adaptation Framework, which aims to build our capacity to manage climate change impacts and reduce vulnerability in key sectors and regions.

However, in the three years since the release of the Wilkins review, it has become clear that a thorough rationalisation of activities along these lines is unlikely to be practicable, given the important role of state and territory governments in areas such as promotion of energy efficiency and renewable energy sources, land-use planning and public transport.

In responding to this element of the Wilkins review, the Australian Government emphasised the importance of COAG in engaging the states and territories. Examples of cooperation and coordination cited included finalising the expanded national Renewable Energy Target scheme, developing the COAG Energy Efficiency Strategy, adopting the National Adaptation Framework in 2007, reviewing existing climate change programs and developing new initiatives.[70]

Local government, as the tier of government closest to the community, has a particularly important role in engaging businesses and community groups in identifying key vulnerabilities to climate change (and potential opportunities); setting priorities; and developing and implementing adaptation strategies that take full account of local conditions, resource availability and community capacity to deal with change. As Professor Garnaut notes:

> The appropriate adaptation response will always depend on a range of local circumstances. Therefore, unlike the mitigation effort, adaptation is best seen as a local, bottom-up response. *Garnaut,*[13] *p. 363*

Local government actions to mitigate and adapt to climate change have been assisted in Australia and internationally by Cities for Climate Protection® (CCP®)—an international campaign initiated by the International Council for Local Environmental Initiatives (ICLEI), which 'provides a framework for local governments to integrate climate protection policies with actions that address immediate municipal concerns'.[71] Between 1998–99 and 2007–08, Australian councils participating in the CCP Australia campaign reported a total abatement of 18 million tonnes of CO_2-e.[72] In 2009, as part of the rationalisation of programs following the Wilkins review, Australian Government funding of around $1.5 million per year for the CCP® program was halted on the basis that it was not complementary to the CPRS. The decision, which was strongly criticised by local government and the Australian Greens party, attracted limited media attention (e.g. see Cubby[73]). Under its present title, CCP—Integrated Action®, the campaign continues to assist local governments and their communities with action to mitigate climate change (CCP-Mitigate®) and to adapt to climate change (CCP-Adapt®).

In the final analysis, although action by all tiers of government will be needed to adapt to climate change, 'adaptation is a shared responsibility—governments, business and the community all have a stake and a role in responding to climate change impacts'.[74]

2.3.4 Management outputs and outcomes

Efforts by government, the business sector and the broader community to reduce GHG emissions are essential to minimise the degree of climate change and associated consequences. Table 3.3 summarises the projected reductions in emissions from major abatement policies and measures put in place by the Australian and state and territory governments. The projected reduction averaged across each year during the Kyoto commitment period (2008–12) is 56 $MtCO_2$-e, and the projected reduction in 2020 is 109 $MtCO_2$-e.

Revegetation work at Curragh Mine, near Blackwater, central Queensland
Photo by Tim Acker

Table 3.3 Projected annual reductions in greenhouse gas emissions from government policies and programs[a]

Scheme[b]	Kyoto commitment period (2008–12) average (MtCO$_2$-e)	2020 (MtCO$_2$-e)
Renewable Energy Target	8.8[c]	29.9[c]
• Large-scale Renewable Energy Target	8.6	26.3
• Small-scale Renewable Energy Scheme	0.2	3.7
National Strategy on Energy Efficiency	14.3[c]	42.6[c]
• Equipment Energy Efficiency Program	6.3	20.3
• Energy efficiency requirements: building codes	4.2	11.8
• Mandatory disclosure requirements: buildings	<0.1	<0.1
• Framework Cool Efficiency Program	0.1	0.4
• Phase-out of incandescent lighting	1.0	1.9
• Phase-out of inefficient water heaters	0.1	4.1
• Energy Efficiency Opportunities Program	2.7	4.2
Queensland Gas Scheme	2.2	4.3
Victorian Energy Efficiency Target and Energy Saver Incentive Scheme	0.2	1.6
Greenhouse Gas Abatement Program	3.4	3.6
Greenhouse Challenge Plus	5.3	2.6
Biofuel Act 2007 (New South Wales)	0.1	0.3
New South Wales and Queensland land clearing legislation	18.0	18.4
Other measures	3.8	5.7
Total	**56**	**109**

MtCO$_2$-e = megatonnes of carbon dioxide equivalent

a These estimates do not attempt to indicate the economic efficiency of programs or to calculate the cost per tonne of abatement.

b Only a selection of policies and measures are presented here. Overlap between policies and measures has been deducted from these estimates. Therefore, each estimate reflects the net abatement attributed to that policy or measure.

c Figures may not total to the number shown due to rounding.

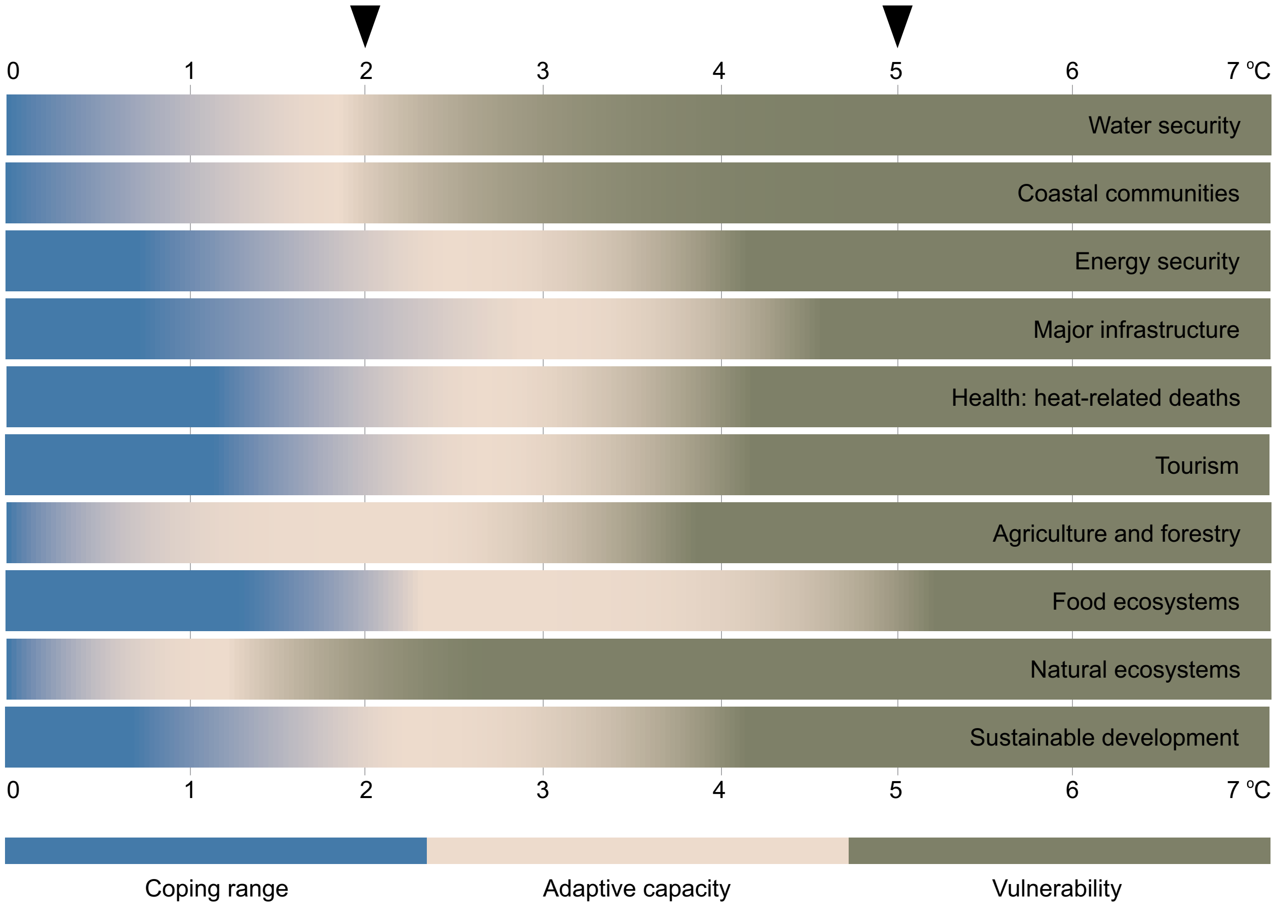
Source: Australian Government Department of Climate Change and Energy Efficiency[46]

However, due to the long lifetimes (decades or centuries) of most GHGs[30] and the length of time for oceans to adjust to changes in the temperature of the atmosphere, even if emissions were to cease completely, the world's climate will continue to change for centuries. Under realistic scenarios involving the cessation of carbon dioxide emissions, the elevated global surface temperature and thermal expansion of the oceans associated with carbon dioxide will persist for more than 1000 years.[75] As there will be some unavoidable consequences of climate change, it is critical that strategies to adapt to inevitable climate change are developed and implemented, particularly in areas of greatest vulnerability to change. In Australia, our natural ecosystems, coastal communities and water security are particularly vulnerable, having a limited range of ability to cope with climate change (Figure 3.18).[25]

Commenting on Australia's vulnerability, the IPCC noted in 2007:

> … even if adaptive capacity is realized, vulnerability becomes significant for 1–2 °C of global warming. Energy security, health (heat-related deaths), agriculture and tourism have larger coping ranges and adaptive capacity [than natural ecosystems, coastal communities and water security], but they may become vulnerable if global warming exceeded 3 °C. *Intergovernmental Panel on Climate Change*[25]

Since then, further studies suggest that the risks may be more immediate than indicated by the IPCC.[9]



Source: Intergovernmental Panel on Climate Change[25] (Figure 11.4, p. 529, as modified in CSIRO[63])

Figure 3.18 Vulnerability to climate change aggregated for key sectors in the Australia and New Zealand region, allowing for current coping range and adaptive capacity

Scale refers to increase in global average temperature. The temperature range of 2–5 °C indicates the range of warming that would result if the world's current emissions path is projected to 2070.

3.2 Assessment summary

Effectiveness of climate change management

Summary	Assessment grade: Ineffective	Partially effective	Effective	Very effective	Confidence: In grade	In trend
Greenhouse gases and climate change						
Understanding: Good understanding of broad processes and improving confidence in modelling projections at both national and regional scales. Extensive support for policy and priority setting at national level through initial Garnaut Climate Change Review (2008) and subsequent review update (2011) and through an improved national greenhouse emissions reporting system			↗		◒	●
Planning: Australian Government has established a broad ('three-pillars') strategy underpinned by a legislated 20% Renewable Energy Target and Energy Efficiency Strategy. In July 2011, the government released a plan to establish a price on carbon and encourage least-cost abatement measures. Legislation to give effect to this is expected to be introduced to parliament in the latter half of 2011. A National Adaptation Framework was adopted by COAG in 2007. Level of strategic planning to mitigate and adapt to climate change varies considerably from state to state (e.g. in relation to adaptation to potential impacts of sea level rise)		↗			◒	◒
Inputs: Around $15 billion committed to climate change initiatives by the Australian Government. Significant funds are available to support climate science at both national and state levels. Significant resources are also being applied by states and territories to mitigation and adaptation programs		↗			◒	●
Processes: Governance is complex, with three tiers of government needing to be involved. Coordination of federal and state and territory programs has been improved via COAG actions		↗			◒	◒
Outputs and outcomes: Current and projected levels of success of federal and state and territory abatement programs are limited. To achieve the national 2020 target of a 5% reduction in greenhouse gas emissions below 2000 levels, abatement measures will need to be greatly increased	?				◒	◒

Recent trends
↗ Improving
— Stable
↙ Deteriorating
? Unclear

Confidence
● Adequate high-quality evidence and high level of consensus
◒ Limited evidence or limited consensus
○ Evidence and consensus too low to make an assessment

Grades
🟩 Very effective
🟫 Effective
🟧 Partially effective
🟥 Ineffective

COAG = Council of Australian Governments

2.4 Resilience of Australia's climate

Earth's atmosphere and oceans form a complex, coupled system, characterised at a global scale by a high level of short-term resilience. In general, significant global climate change has typically occurred over thousands of years in the geological record, rather than over decades or centuries. This is because changes to climate forcing (such as changes to incoming solar energy or atmospheric chemistry) typically occur over very long timescales. Only in the past few decades have the cumulative effects of human activities reached a scale that threatens to challenge Earth's short-term resilience and drive change in the global climate at rates unprecedented in recent geological history.[8,76]

2.4.1 Resilience of our climate

To date, the apparent resilience of the atmospheric–oceanic system has been a major factor limiting the rate and extent of change in climate (largely due to the capacity of the oceans to absorb carbon dioxide and heat). However, there is rising concern among climate scientists that, unless the growth in GHG emissions is soon slowed and reversed, continued increase in water temperature will reduce the oceans' capacity to remove carbon dioxide from the atmosphere.[77-78]

At present, the oceans remove about a quarter of human-produced carbon dioxide emissions. As a result, the oceans have gradually become more acidic (with a reduction in the pH of surface waters of about 0.1 during the past 250 years). This trend is generally expected to continue, with a further reduction of 0.2–0.3 pH units occurring by 2100. Should this happen, it could have a major impact on the wide variety of marine organisms with carbonate skeletons, notably corals and plankton, thus potentially affecting the entire marine food chain (see Chapter 6: Marine environment).[10]

However, this remains an area of considerable uncertainty, as evidenced by the work of Law and her colleagues,[79] whose modelling did not find a saturating Southern Ocean carbon sink due to recent climate change. Rather, they concluded that, although carbon uptake was reduced by wind forcing, forcing due to heat and freshwater flow resulted in an increased uptake. Debate on this issue is continuing in the scientific literature (e.g. see Zickfeld et al.[80] and Le Quéré et al.[81]).

At a glance

There is abundant evidence to show that significant global climate change has typically occurred over thousands of years, rather than over decades or centuries. However, in the past few decades, the cumulative effects of human activities (principally the burning of fossil fuels) have reached a scale that is challenging Earth's resilience and driving unprecedented rates of change in the global climate.

Regardless of the effectiveness of future abatement strategies at international and national levels, increased temperatures associated with carbon dioxide emissions will be 'largely irreversible for 1000 years after emissions stop'. So while efforts to mitigate climate change remain fundamentally important, human communities must plan for and adapt to climate change.

When viewed in the context of its highly developed economy and robust system of governance, Australia is well placed to adapt to climate change. However, Australia is also the driest inhabited continent and characterised by a high degree of climate variability. Australia is therefore significantly vulnerable at relatively low levels of temperature rise in key areas, such as water security, natural ecosystems and coastal communities, even if our adaptive capacity is realised.

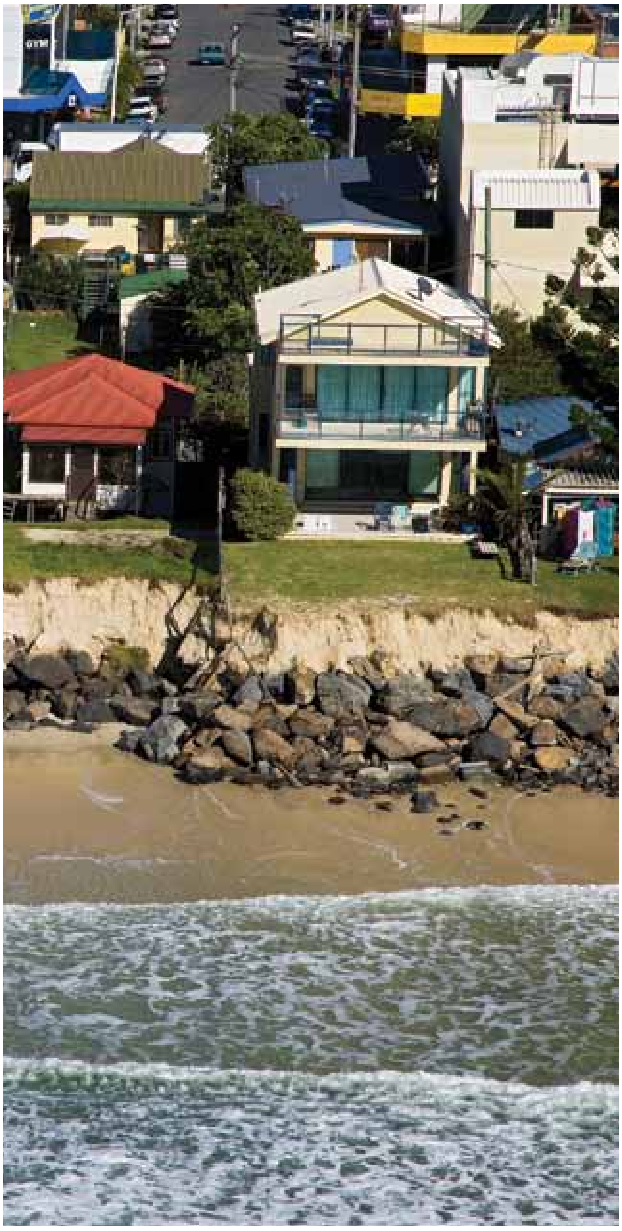
2.4.2 Resilience of our environment and society

Although the changing physical resilience of the atmospheric–oceanic system is a critically important focus of concern, so too is the resilience of different human and animal populations to the changes in climate that are already occurring and will continue for the foreseeable future. The degree to which any population is resilient will depend on its sensitivity to specific elements of climate change and its capacity to adapt. Sensitivity will be influenced by factors such as location and the level of security of food and water supplies. In human populations and in the ecosystems of which they are part, adaptive capacity is strongly influenced by the rate at which change occurs. In the case of humans, this markedly affects our ability to anticipate change, develop adaptive strategies and marshal resources to adjust to change in a way that minimises harm and takes advantage of opportunities.

Resilience of human populations to climate change will vary between and within nations. As a general rule, within any society, the most marginal groups in terms of income, health and education are likely to be the most sensitive to climate change and the least well equipped to adapt without assistance from those better off. At the international scale, this generalisation holds true, as evidenced by many small island states that are highly sensitive to climate change–induced sea level rise and have inherently limited scope for adaptation. A critical role for policy makers at both national and international levels is therefore to recognise and reflect these variations in ‘social resilience’ when framing measures to adapt to climate change.

In the Australian context, a significant number of coastal communities are sensitive to sea level rise, particularly the Indigenous communities of Torres Strait, a number of which face inundation from rising sea levels. Across the nation, 160 000–250 000 homes are estimated to be potentially at risk of inundation from a 1.1-metre rise in sea level.[82] By comparison with most small island states, the great majority of Australia’s coastal communities have considerable scope and resources to plan for and adapt to such change. However, without effectively coordinated planning and action at national, state and local levels, the potential resilience of these communities may not be realised.

For many of Australia’s Indigenous communities, climate change represents a major threat. In addition to sea level rise, increasing temperatures and likely (but less certain) changes in seasonal rainfall will impact these communities in many ways, including through changes to plant and animal populations.[83] This is not to suggest that these communities lack resilience or a willingness and capacity to identify and seize opportunities that are likely to accompany change. As Professor Marcia Langton noted in an address to the National Indigenous Land and Sea Management Conference held in Broken Hill in November 2010, ‘… opportunities emerging from climate change includ[e] a growing industry in which Indigenous land and sea managers can be involved, such as carbon abatement and sequestration, solar and wind farms, biodiesel, and tidal energy. Green collar jobs should be black collar jobs. Indigenous rangers can provide very good environmental management services that can be marketed’.[84]



Beach erosion following storms in May 2009, Palm Beach, Queensland

Photo by Skyepics

2.5 Risks to Australia's climate

> Observations and research outcomes since 2008 have confirmed and strengthened the position that the mainstream science then held with a high level of certainty, that the Earth is warming and that human emissions of greenhouse gases are the primary cause. *Garnaut*[85]

As noted in Chapter 2: Drivers, global GHG emissions have (since 2005) continued to track above the middle of the IPCC's scenario range—between A1B (economic growth based on a balance between resource-efficient and fossil fuel–intensive industries) and A1F1 (fossil fuel–intensive growth).[86-87] Given the longevity of most GHGs in the atmosphere and the slow rate at which the temperature of the oceans changes, we know that the lower atmosphere and oceans will continue to warm for centuries after emissions are stabilised.[88] Even if the most optimistic scenarios for carbon dioxide reductions were to be realised, increased temperatures associated with carbon dioxide emissions will be 'largely irreversible for 1000 years after emissions stop'.[75]

In addition to the risks of increasing temperatures and changes in rainfall amount and seasonality, a key risk associated with climate change is the likelihood of more frequent and/or severe extreme weather events, such as floods, droughts and heatwaves, and an increase in bushfires. However, although the number of intense cyclones may increase, the total number of cyclones is likely to decline.[50] Such primary 'atmospheric' risks generate a broad series of secondary and tertiary risks, many of which are explored elsewhere in this report. These include increased mortality and morbidity due to heatwaves and spread of disease vectors, reduced streamflows and groundwater recharge, reduced soil moisture, and changes in habitat with attendant risk to biodiversity. The summary of risks below assumes a timeframe of 30–40 years.

At a glance

For Australia, as the driest inhabitable continent and with a climate characterised by high levels of variability, climate change poses a clear and present threat. At national and regional scales, although there is inevitable uncertainty associated with projections of future climate, the most recent comprehensive review of modelling outcomes shows that a continuing, spatially variable rise in temperatures across the continent is highly likely. By 2030, annual average warming (above 1990 levels) is estimated to be approximately 1.0 °C, varying from an increase of 0.7–0.9 °C in coastal areas to 1–1.2 °C inland. Projections of rainfall are more variable, but half of the 23 models considered by the Commonwealth Scientific and Industrial Research Organisation and the Bureau of Meteorology show an increase in annual and summer rainfall in northern Australia, while nearly all show a decrease in winter rainfall in the south-west and along the south coast. Warmer and drier conditions over much of southern Australia are likely to lead to reduced soil moisture. Intense rainfall events are likely to become more extreme in response to a warmer, wetter atmosphere. Extreme events, such as floods, droughts, heatwaves and fires, are likely to increase in frequency and/or severity. However, although the number of intense cyclones may increase, the total number of cyclones is likely to decline. Such primary 'atmospheric' risks generate a broad series of secondary and tertiary risks, many of which are explored elsewhere in this report.

3.3 Assessment summary

Current and emerging risks to Australia's climate

	Catastrophic	Major	Moderate	Minor	Insignificant
Almost certain		🟧 Continuing spatially variable rise in temperatures across the continent			
Likely		🟧 Reduced rainfall in southern areas, especially in winter, and in southern and eastern areas in spring 🟧 Increased evaporation and reduced soil moisture 🟧 Increased frequency and severity of wildfires 🟧 Increased frequency of heatwaves	🟧 Increased geographic range of disease vectors (e.g. mosquitoes)		
Possible	🟥 One or more climate change tipping points are passed, triggering abrupt, nonlinear and irreversible changes in the climate system	🟧 Increased severity of extreme weather events such as cyclones			
Unlikely					
Rare					

☐ Not considered

Explanation of terms:

Almost certain: >90% probability of occurring during the specified timeframe

Likely: >66% – ≤90% probability of occurring during the specified timeframe

Possible: >33% – ≤66% probability of occurring during the specified timeframe

Unlikely: >10% – ≤33% probability of occurring during the specified timeframe

2.6 Outlook for Australia's climate

> The weight of scientific opinion [is] that developed countries need to reduce their greenhouse gas emissions by 60% by 2050 against 2000 emission levels, if global greenhouse gas concentrations in the atmosphere are to be stabilised to between 450 and 550 ppm by mid century. *Garnaut,*[13] *p. xvi*

The IPCC uses the term ‘equilibrium climate sensitivity’ to refer to ‘the global average surface warming following a doubling of carbon dioxide concentrations [from pre-industrial levels of 280 ppm]. This is likely [i.e. more than 66% probable] to be in the range of between 2 °C and 4.5 °C with a best estimate of about 3 °C’.[61] This best estimate has been generated from geological evidence, climate modelling and 20th century observations. Based on the estimate, stabilisation at 450 ppm CO_2-e would provide a 50% probability that global mean temperature increase could be limited to 2 °C, while stabilisation at 550 ppm would likely result in a rise of at least 3 °C.[89] Although the magnitude of future changes in global temperatures is important, it is the rate of change that will cause the biggest impacts. A rise of around 2 °C over just two centuries is expected to lead to widespread and significant risks to Australia’s natural ecosystems, water security and coastal communities.[25]

Unfortunately, the prospects of an international agreement on a framework to stabilise global emissions at either 450 ppm or 550 pm appear to be limited. Analysing developed nations’ pledges to reduce emissions made under the Copenhagen Accord of December 2009, the World Resources Institute concluded that, collectively, they could by 2020 achieve a reduction of 12–19% below 1990 levels. However, the institute noted that this was well below the 25–40% reductions that the IPCC indicated were needed to achieve stabilisation at 450 ppm and thereby reduce the risk of overshooting the goal of limiting global mean temperature rise to 2 °C (agreed under the accord and by the Major Economies Forum and the G8).[90] Even at 450 ppm, the risk of overshooting is still considerable (in the range 26–78%).[89]

At a glance

The latest *State of the climate* report notes that, by 2070, if growth in global emissions of greenhouse gases (GHGs) continues in line with past trends, Australia will warm by 2.2–5.0 °C. A rise of around 2 °C over just two centuries is expected to lead to widespread and significant risks to Australian natural ecosystems, water security and coastal communities. The prospects of an international agreement on a framework to stabilise global emissions at either 450 parts per million (with a likely rise of 2 °C in global average temperature) or 550 parts per million (with a likely rise of 3 °C) appear to be limited. Many climate scientists feel that a 2 °C increase is near to or above the level that is likely to trigger ‘dangerous climate change’.

Projections of Australia’s growth in GHG emissions to 2020 based on policy settings applying before the release of the Australian Government’s Securing a Clean Energy Future plan showed an increase of 23% above 2000 levels. The Securing a Clean Energy Future plan aims to prompt a move away from ‘business as usual’, achieving the nation’s minimum 2020 target of a 5% cut on 2000 levels by reducing emissions by at least 159 megatonnes of carbon dioxide equivalent (23%) in 2020. However, even if national and international mitigation efforts were to increase dramatically over the next decade or two and emissions were stabilised, temperatures will remain at elevated levels for centuries to come, making adaptation to change essential.

Australia, with its highly developed economy and physical, human and social capital, is better placed than many nations to anticipate the threats and opportunities associated with climate change and to take adaptive action in the short to medium term. However, this is no reason for complacency or for delaying urgent action, particularly given the potential for feedback mechanisms to amplify or accelerate climate change and cause large step-changes in regional and global climate. Should such changes occur, adaptive strategies framed around incremental change are unlikely to be adequate to prevent major harmful impacts on key sectors.

Against a background of global emissions continuing to track between the IPCC's A1F1 scenario (fossil fuel–intensive growth) and the A1B scenario (economic growth based on a balance between resource-efficient and fossil fuel–intensive industries), projections of Australia's growth in GHG emissions to 2020, based on policy settings applying before the release of the Australian Government's Securing a Clean Energy Future plan, showed an increase of 23% above 2000 levels (taking emissions to 690 $MtCO_2$-e).[46,62] The Securing a Clean Energy Future plan aims to prompt a move away from 'business as usual', achieving the nation's minimum 2020 target of a 5% cut on 2000 levels by reducing emissions by at least 159 $MtCO_2$-e (23%) in 2020.[47] To achieve Australia's 15% conditional target, a 31% (216 $MtCO_2$-e) reduction from the projected 2020 level would be needed.

Although mitigation is central to Australia's broad climate change strategy, at the time of writing (July 2011), there is still no bipartisan support at the federal level for a key element of that strategy—establishing a price on carbon. This is despite the view of widely respected economists such as Lord Nicholas Stern and Professor Ross Garnaut on the central importance of pricing carbon to mitigating carbon emissions, and the conclusion of the recent Productivity Commission's research report, *Carbon emission policies in key economies*:[93]

> The basic theory of externalities identifies the source of the economic problem in untaxed or unpriced emissions of GHGs. The externality requires a price for emissions: that is the first task of mitigation policy. *Stern*,[91] *p. 40*

> Economy-wide pricing of carbon is the centre piece of any policy designed to reduce emissions at the lowest possible costs. *Garnaut*,[92] *p. 2*

> … the consistent finding from this study is that much lower-cost abatement could be achieved through broad, explicit carbon pricing approaches [than from existing policies] irrespective of the policy settings in competitor economies. *Productivity Commission*,[93] *p. 155*

Despite the lack of bipartisan agreement on the need to put a price on carbon, legislation needed to give effect to key elements of the government's Securing a Clean Energy Future plan is expected to come into effect before the end of 2011, with the anticipated support of three independent members of the House of Representatives and of the Greens in the Senate. As described in Section 2.3.2, the central element of this plan is a mechanism to establish a price on carbon and drive reductions in emissions via least-cost means.

However, even if national and international mitigation efforts increase dramatically over the next decade or two, temperatures will remain at elevated levels for centuries to come.[75] Mitigation of future GHG emissions is therefore aimed at limiting future climate change and avoiding catastrophic climate change tipping points, rather than returning the climate system to a pre-industrial state. Beyond mitigation, our most important strategy will be adaptation. Our capacity as a society to adapt to a changing climate will depend on many factors, in particular:

- the rate of change
- the degree of exposure to the effects of change, which will vary not only geographically and from sector to sector, but also between different groups in society
- the strength and diversity of the economy
- our capacity to innovate
- our capacity for behavioural change
- our ability to expand our knowledge base and apply that knowledge in planning and decision-making
- a willingness to accept uncertainty and not to use it as a reason for postponing necessary action.

Australia, with its highly developed economy and physical, human and social capital, is better placed than many nations to anticipate the threats and opportunities associated with climate change and to take adaptive action in the short to medium term. Areas of opportunity include sequestering carbon in the soil and via large-scale landscape revegetation programs, supporting innovation in renewable energy and energy-saving technologies, and developing highly resilient systems of agricultural production. Although it is critical that these and other opportunities are identified and seized, in some key sectors—such as natural ecosystems, coastal communities and water security—our scope for adaptation through incremental change is limited and our exposure to risk is high. This combination makes us vulnerable to a temperature rise of even 1–2 °C.

Even sectors with greater scope for adaptation (such as energy security, health, agriculture and tourism) are likely to be vulnerable if, in the absence of highly effective global mitigation efforts, temperatures rise by 2–5 °C.[25] A temperature rise of this magnitude is not just a remote possibility. If the world continues along its present emissions track, Australia's average temperature is projected to rise 2.2–5.0 °C by 2070.[63]

It should be noted that smooth changes are the exception rather than the norm in the climate system, which is nonlinear in nature. This means that a number of feedback mechanisms exist that can amplify or accelerate climate change, with the potential to cause large step-changes in regional and global climate. Such mechanisms include rapid melting of terrestrial ice caps and changes to the large-scale circulation of the oceans. Rapid changes in climate forcing mechanisms in the geological history of the planet have been associated with sudden climate shifts; hence, failure to mitigate GHG emissions increases the likelihood of precipitating such events. In general, dramatic climate shifts have not been factored into future climate scenarios that policy makers and economists have worked with, and our ability to adapt to such changes is largely unknown.[94-96]

Should such changes occur, adaptive strategies framed around incremental change are unlikely to be adequate to prevent major harmful impacts on key sectors. Instead, what CSIRO describes as 'transformational' change will be needed, and 'a major scientific and societal challenge [will be] to understand and decide how, where, and when this transformational change is required'.[63]

Aftermath of Cyclone Larry: damaged trees in ruined banana plantation, near Innisfail, Queensland

Photo by Fred Kamphues

3

Ambient air quality and other atmospheric issues

This section describes aspects of the atmosphere other than the effects of atmospheric composition on climate.

3.1 State and trends of Australia's atmosphere

Assessing the state of Australia's atmosphere in essence involves assessing the impact of a number of contaminants on three main areas: the stratospheric ozone layer, ambient (outdoor) air and indoor air.

3.1.1 Stratospheric ozone

The stratosphere is the layer of the atmosphere that begins at an altitude of around 10 kilometres above Earth's surface and extends to approximately 50 kilometres. It is situated between the troposphere (near Earth's surface) and the mesosphere.[97] Stratospheric ozone limits the amount of harmful ultraviolet B (UVB) light (UVB wavelengths are 280–315 nanometres) passing through to lower layers of the atmosphere. The ozone layer, therefore, has a vital role in protecting life on Earth, as increased levels of UVB may result in damage to a range of biological systems, including human health. In humans, UVB—although necessary for the production of vitamin B—causes nonmelanoma skin cancer and is a significant factor in the development of malignant melanoma. In addition, it is associated with the development of cataracts.[98-100] (However, it should be noted that, whereas ozone in the stratosphere is protective of human health, ozone near the ground, where it can be breathed in, is a pollutant and harmful to health. Section 3.1.2 further discusses ozone as a pollutant.)

At a glance

Global observations of atmospheric levels of the major ozone depleting substances (ODSs)—principally chlorofluorocarbons and halons (used as refrigerants, industrial solvents, flame retardants and propellants in aerosol spray cans)—show them reaching a peak in the mid-1990s and declining since then. As a result, stratospheric levels of the breakdown products of ODSs (such as chlorine and bromine), which react with and destroy ozone, have also begun to decline. This drop is expected to continue with the ongoing phase-out of these ODSs under the Montreal Protocol. However, the stability of these substances will result in the continued depletion of stratospheric ozone for many decades.

Ambient air quality in Australia's major urban centres is generally good. National health-based standards are rarely exceeded for prolonged periods, and very high levels of pollution are usually associated with short-lived extreme events, such as bushfires and dust storms, that generate very high levels of particulate pollution. Despite substantial population growth, industry expansion and greatly increased motor vehicle use, levels of carbon monoxide, nitrogen dioxide, sulfur dioxide and lead have declined in urban areas over the past two decades.

However, this overall favourable situation should not be taken to imply that air quality in our major cities does not impact on human health. Levels of particles and of the secondary pollutant ozone have not decreased. Both these pollutants are known to impact on cardiovascular and respiratory health. Research into the health effects of particles and ozone, along with pollutants such as sulfur dioxide, indicates that there is no threshold level below which they have no health effect. This means that sensitive individuals—such as asthmatics and people with respiratory or cardiovascular disease—may be affected even when air quality standards are met. By one estimate, there were close to 3000 deaths due to urban air pollution in 2003—nearly twice the national road toll.

Most Australians spend more than 90% of their time indoors, leading to concern over the possible impacts of indoor air quality on our health. Symptoms associated with poor indoor air quality can range from acute to chronic, and from mild and generally nonspecific (eyes, nose and throat irritation, and headaches and dizziness) to severe (asthma, allergic responses and increased cancer risk). Despite the potentially significant health effects of indoor air, data on indoor air quality in Australia are limited, and Australia has no specific guidelines for indoor air quality to provide a firm basis for forming assessments of overall status and trend.

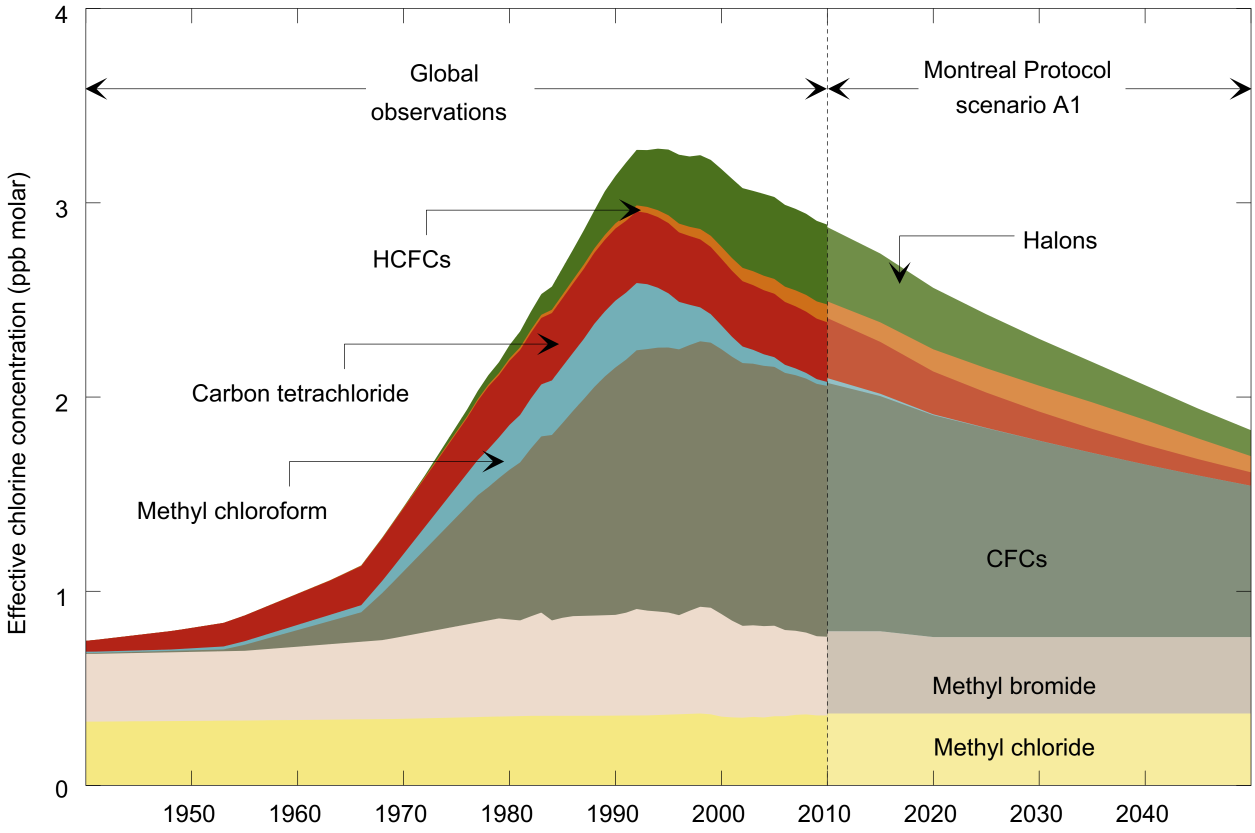
Photosynthesis in many species of plants is impaired by UVB radiation, and overexposure can reduce yield and quality in some crop species, including varieties of rice, winter wheat, soybeans, corn and cotton. UVB radiation may also change the susceptibility of plants to insect and pathogen attack. In aquatic systems, photosynthesis in phytoplankton is more sensitive to UVB than in terrestrial plants, and short-term exposure to increased UVB levels can reduce productivity in such systems.[101-103]

The ozone layer was threatened by human-produced ozone depleting substances (ODSs), principally chlorofluorocarbons (CFCs) and halons, which were widely used in refrigerators, air conditioners, fire extinguishers and electronic equipment, as solvents for cleaning (including dry cleaning) and as agricultural fumigants. These substances are stable and long lived in the lower atmosphere, but slowly drift up to the stratosphere, where they are subject to breakdown through the action of UV radiation. This releases highly reactive molecules (chlorine and bromine) that react with ozone molecules and break them apart.

Since peaking in the mid-1990s, levels of stratospheric chlorine and bromine from CFCs and other ODSs have declined. The latest World Meteorological Organization (WMO) *Scientific assessment of ozone depletion*[104] concludes that:

> … the atmospheric abundances of nearly all major ODSs that were initially controlled [under the Montreal Protocol] are declining [Figure 3.19]. Nevertheless, ozone depletion will continue for many more decades because several key ODSs last a long time in the atmosphere after emissions end.

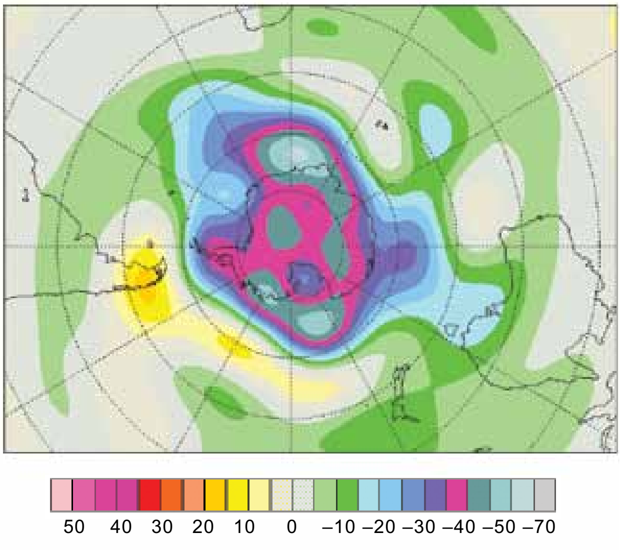
This has important implications for climate, since all ODSs (except methyl bromide) are powerful GHGs, and the gradual recovery of the ozone layer is expected to interact with climate change through a complex series of linkages. These relationships may, for example, reduce the capacity of the oceans to absorb carbon dioxide and delay the recovery of stratospheric ozone.[105]



CFC = chlorofluorocarbon; HCFC = hydrochlorofluorocarbon; ppb = parts per billion

Source: Krummel & Fraser,[106] updated by P Krummel, Centre for Australian Weather and Climate Research, and Commonwealth Scientific and Industrial Research Organisation, unpublished data

Figure 3.19 Effect of the Montreal Protocol on levels of ozone depleting substances in the atmosphere



Source: Environment Canada[110]

Figure 3.20 Example of the dispersal of the depleted ozone layer over areas surrounding Antarctica, 11 September 2006

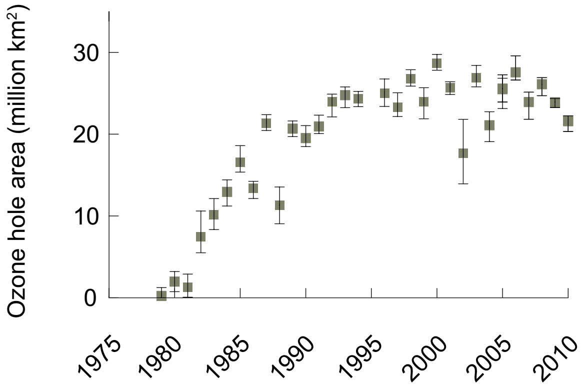
This map represents total ozone deviations from the 1978–88 level estimated using total ozone mapping spectrometer data for all areas, except the Antarctic, and from the pre-1980 level estimated using Dobson data over the Antarctic. Although the map shows some reduction in ozone levels over parts of Australia relative to the base period, in absolute terms ozone levels would still be very high south of Australia.

The ozone hole

The impact of ODSs on the stratospheric ozone layer has been observed at all latitudes, except in the tropics (i.e. 20°N and 20°S), where ozone depletion is negligible.[104] However, by far the most pronounced ozone losses are associated with the Antarctic ozone hole, which occurs each year over Antarctica between August and December. The ozone hole reaches its maximum extent in spring, when 60% of the total ozone in the vertical air column is lost. The depleted ozone layer then breaks up and disperses over the areas surrounding Antarctica during the summer and autumn months (see also Chapter 7: Antarctic environment). The break-up of the ozone hole during summer is the cause of reductions in stratospheric ozone in the Southern Hemisphere, as parcels of ozone-depleted polar air move north and mix with mid-latitude air.[107-109] There is also increased evidence that the Antarctic ozone hole affects the Southern Hemisphere's climate, acting as the driver of changes in pressure, surface winds and rainfall at mid-to-high latitudes during summer.[104]

Images available from Environment Canada illustrate the break-up of the ozone hole and the dispersal of the depleted ozone layer across Tasmania and southern Australia (Figure 3.20).

Following a period of rapid growth from the late 1970s to the mid-1990s, the area of the ozone hole has remained relatively stable over the past 15 or so years (Figure 3.21), with October mean column ozone levels within the polar stratospheric vortex approximately 40% of 1980 values.[104] The ozone holes of 2000 and 2006 were the most severe on record; the 2006 hole was the deepest and the 2000 hole the largest (in area). However, the hole can fluctuate markedly from year to year, with 2010 being one of the smallest on record in the past two decades.[111-112]



km^2 = square kilometre

Source: Tully et al.,[111] updated by P Krummel, Centre for Australian Weather and Climate Research, and Commonwealth Scientific and Industrial Research Organisation, unpublished data

Figure 3.21 Maximum 15-day average ozone hole area (million km^2), 1979–2010

The figure is based on Total Ozone Mapping Spectrometer/Ozone Monitoring Instrument data. The error bars represent the range of the ozone hole area in the 15-day average window.

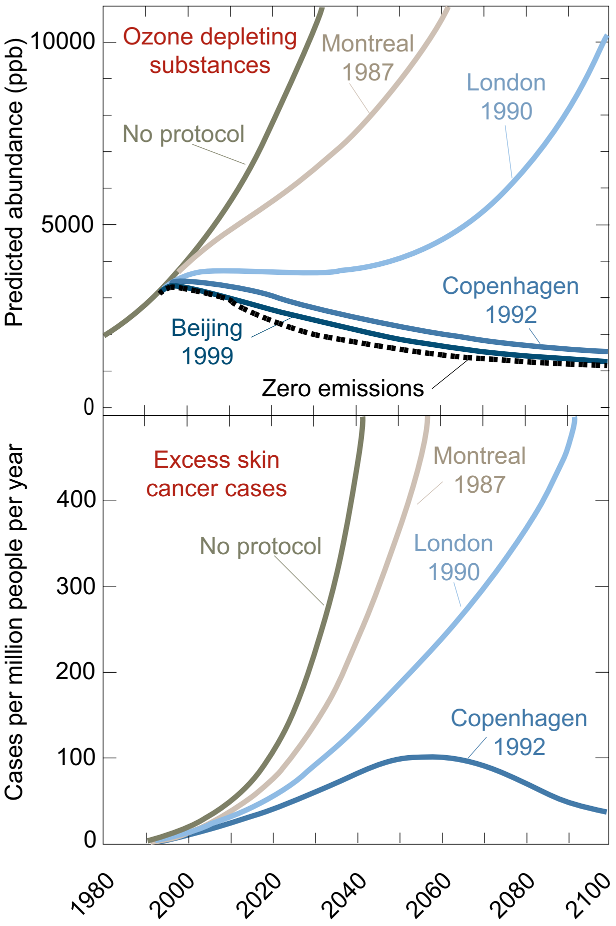
The relative stability of the ozone hole reflects the fact that there have been only moderate decreases in stratospheric chlorine and bromine in the past few years. Since around 1997, ODS levels have been nearly constant, and the depth and magnitude of the ozone hole have been controlled by variations in temperature and climate dynamics. Although summer ozone levels over Antarctica have yet to show any statistically significant increasing trend, recent simulations of the effect of reductions in ODSs that are projected to continue to flow from controls under the Montreal Protocol indicate a return to pre-1980 benchmark values late this century.[104,113] Modelling results suggest that this recovery may be accelerated by climate change in the form of stratospheric cooling, linked to increases in GHGs.[104]

Ozone hole impacts

As noted above, the most recent WMO *Scientific assessment of ozone depletion*[104] comments on the importance of the ozone hole as a driver of changes in Southern Hemisphere seasonal surface winds at mid-to-high latitudes. However, the influence of the hole extends to the whole of the hemisphere.[114] Modelling by Son et al.,[115] which incorporates stratospheric chemical interactions and takes into account the likely influence of recovering ozone levels, indicates that the anticipated recovery of the hole may result in a reversal of the current acceleration of these seasonal surface winds (summer tropospheric westerlies) on the poleward side. The authors concluded:

> … our analyses suggest that stratospheric processes, and ozone recovery in particular, may be able to affect SH [Southern Hemisphere] climate in major ways and thus should be included in predictions of SH climate in the 21st century.

In addition to its influence on climate, the ozone hole has been of concern in relation to UVB effects on health. The progressively more rigorous controls established under the Montreal Protocol during the 1990s are expected to lead to the avoidance of a significant increase in cases of skin cancer that would otherwise have been associated with large reductions in global stratospheric ozone (Figure 3.22). This is of particular importance in Australia, where high levels of UVB radiation combine with outdoor lifestyles to produce one of the highest incidence rates of skin cancer in the world.[116-117]



ppb = parts per billions

Source: Climate Change Science Program[118]

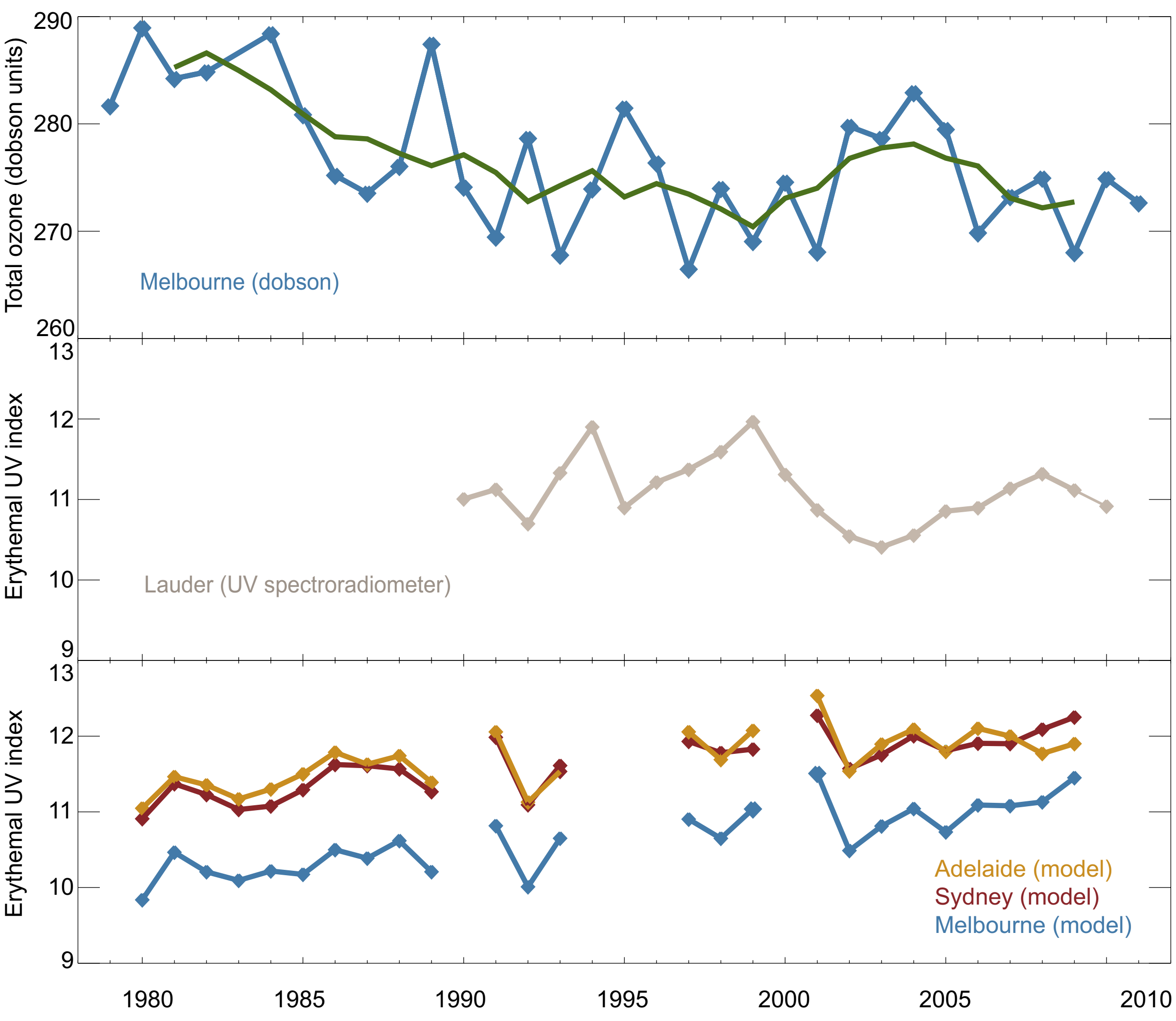
Figure 3.22 Effect of the Montreal Protocol and its amendments on ozone depleting substances and excess skin cancer cases

The top panel gives a measure of the projected future abundance of ozone depleting substances in the stratosphere, without and with the Montreal Protocol and its various amendments. The bottom panel shows similar projections for how excess skin cancer cases might have increased.

Box 3.5 Ozone and UV radiation

Ultraviolet (UV) radiation levels at ground level are principally an inverse function of the amounts of ozone in the upper atmosphere, the concentration of aerosols and water vapour in the atmosphere, and the extent of cloud cover. Long-term trends in UV radiation levels are measured at Lauder in New Zealand's South Island and are modelled at a number of sites in Australia. UV is expressed as an erythemal UV index—a measure that describes the strength of the skin-burning component of UV radiation.

Figure A shows total column ozone levels over Melbourne and erythemal index values for Lauder and three Australian capital cities. The top panel shows January mean total ozone values, measured by the Bureau of Meteorology's Dobson network at locations around greater Melbourne from 1979 to 2011. The green line shows a five-year running mean. Although year-to-year variability is evident—as is a clear signal of the 11-year solar cycle (which peaked around 1980, 1991 and 2002)—the underlying negative trend in ozone ceased in the mid-1990s. The long-term ozone behaviour closely follows the concentration of ODSs measured in the global atmosphere, which peaked in the mid-1990s (see Figure 3.19)



Source: M Tully, Leader Ozone Science Team, Bureau of Meteorology, pers. comm., August 2011; R McKenzie, Principal Scientist—Radiation, National Institute of Water and Atmospheric Research, Central Otago, New Zealand, pers. comm., July 2011; McKenzie et al.;[119] Lemus-Deschamps et al.;[120] Lemus-Deschamps & Makin[121]

Figure A Total column ozone for Melbourne, surface-measured erythemal index for Lauder (New Zealand) and satellite-derived clear-sky erythemal index for three Australian cities

Continued next page

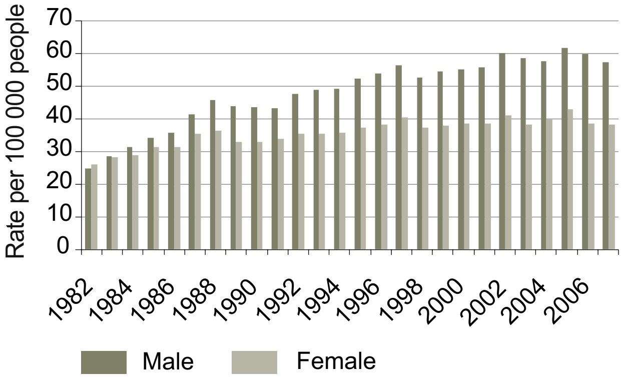
Box 3.5 *continued*

The middle panel shows summer-time peak UV index values in 1990–2010, as measured by UV spectroradiometer at Lauder by New Zealand's National Institute of Water and Atmospheric Research. Although UV radiation values are affected by factors other than just ozone, the underlying trend quite closely follows the expected inverse relation to the ozone timeseries, with highest UV index values in the late 1990s when ozone was lowest.

The bottom panel shows modelled clear-sky UV index values for three Australian cities (Sydney, Adelaide and Melbourne), illustrating the effect of location on the amount of UV radiation received. The values were calculated using summer satellite measurements of ozone and meteorological fields from the Bureau of Meteorology forecast model, as input to the UV radiation code.

Some differences in the detail of panels 1 and 3 are evident. However, the overall pattern of rising UV through the 1980s and 1990s, followed by a stabilisation, corresponds to the decline and subsequent stabilisation of ozone during the same period. The differences are primarily due to the use of satellite-measured ozone values rather than ground-based values, a slightly different averaging period (all of summer in panel 3 compared with just January in panel 1) and some missing periods of satellite data in the late 1990s, when ozone values were low.

From the early 1980s to the early 2000s, Australian skin cancer rates for both sexes showed a generally increasing trend, after which rates appear to have stabilised (Figure 3.23). Most recent data for melanoma show a decline in both male (7.1%) and female (10.7%) rates from 2005 to 2007.[122-123] However, the period involved is too short to tell whether the reduction indicates a genuine decline or is the result of fluctuations in the data.



Source: Australian Institute of Health and Welfare[122]

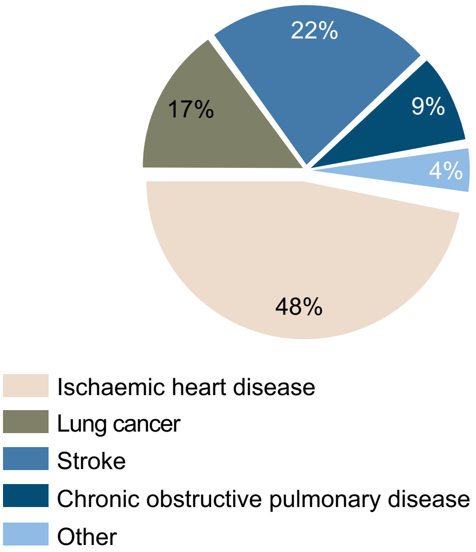
Figure 3.23 Australian skin melanoma rates by gender, 1982–2007

3.1.2 Ambient air quality

Ambient air quality and health

Although air pollution can harm vegetation, erode the facades of historic stone buildings and limit visibility, the main focus of public concern over air pollution is its short-term and long-term effects on human health. Over the past decade, scientific studies have greatly expanded our understanding of the nature and extent of the effects of major air pollutants in our cities (e.g. Environment Protection Authority Victoria,[124-125] Environment Protection and Heritage Council,[126-127] Simpson et al.[128-129]). On the basis of these and related studies, it is clear that urban air pollution is a significant cause of death and illness in the community. By one estimate,[7] there were close to 3000 deaths due to urban air pollution in 2003. This was 2.3 % of all deaths and nearly twice the national road toll. Two-thirds of these deaths were attributable to long-term exposure to air pollutants, with the elderly most affected. The health burden associated with urban air pollution was shared about equally between males and females (53% to 47%). Such deaths occur from a range of medical causes (Figure 3.24).

As shown in Table 3.4, a range of adverse health effects is associated with air pollution. The nature and severity of the effect are a function of the type and concentration of pollutant, the duration of exposure and the sensitivity of the individual. Individual sensitivity is influenced by factors such as age, general state of health and fitness, and prior illnesses.



Source: Begg et al.[7]

Figure 3.24 Deaths attributed to long-term exposure to urban air pollution, 2003

Table 3.4 Health effects and populations at risk from certain air pollutants

Pollutant	Health effects	Population at risk
Carbon monoxide	Mortality and increased hospital admission due to heart disease	People with ischaemic heart conditions
Nitrogen dioxide	Hospital admissions for respiratory diseases, decreases in lung function, cardiovascular disease	Sufferers of respiratory disease, such as children with asthma; those with cardiovascular disease
Particulates	Mortality due to cardiovascular and respiratory diseases; hospital admissions due to respiratory and cardiovascular disease; decreases in lung function	Elderly people with respiratory and cardiovascular diseases; people with respiratory diseases, such as children with asthma
Ozone	Mortality due to respiratory and cardiovascular diseases; hospital admissions due to respiratory diseases; decreases in lung function	Elderly people; people with respiratory diseases

Source: Adapted from Environment Protection and Heritage Council[127]

National air quality standards

In 1998, the Australian and state and territory governments adopted a set of national air quality standards—the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM). The standards covered the six most common air pollutants (also referred to as 'criteria pollutants')—carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, lead and particulate matter smaller than 10 micrometres (PM_{10}), which can be inhaled directly into the lungs (Table 3.5).

In 2003, the standards were amended to include advisory reporting standards for fine particulate matter smaller than 2.5 micrometres ($PM_{2.5}$), reflecting growing concern over links between increases in $PM_{2.5}$ levels and mortality and morbidity associated with respiratory and cardiovascular disease (Table 3.6). A number of studies have suggested that the impact of the $PM_{2.5}$ size fraction may be most pronounced in relation to cardiovascular illness and mortality, whereas the coarse (PM_{10}) fraction may be more important in worsening asthma and upper respiratory illnesses. The health effects of short-term exposure to elevated levels of $PM_{2.5}$ is an important area for further research.[6,135]

Table 3.5 Standards and goals for pollutants other than $PM_{2.5}$ particles

Pollutant	Averaging period	Maximum concentration	Goal (within 10 years) for maximum allowable exceedences
Carbon monoxide	8 hours	9.0 ppm	1 day per year
Nitrogen dioxide	1 hour	0.12 ppm	1 day per year
	1 year	0.03 ppm	None
Sulfur dioxide	1 hour	0.20 ppm	1 day per year
	1 day	0.08 ppm	1 day per year
	1 year	0.02 ppm	None
Photochemical oxidants (as ozone)	1 hour	0.10 ppm	1 day per year
	4 hours	0.08 ppm	1 day per year
Lead	1 year	0.50 $\mu g/m^3$	None
Particles (PM_{10})	1 day	50 $\mu g/m^3$	5 days per year

PM_{10} = particulate matter smaller than 10 micrometres; ppm = parts per million; $\mu g/m^3$ = micrograms per cubic metre

Source: Office of Legislative Drafting[134]

Box 3.6 Pollens—the forgotten air pollutants

Many types of flowering plant depend on the wind to distribute their pollen, and the small, light, dry pollen grains that these plants produce are easily breathed in by humans. When inhaled, proteins and glycoproteins associated with these pollens can interact with the immune systems of sensitive individuals to produce an allergic response in the form of hayfever or allergic asthma.[130] Acting on its own or in combination with fine particles, airborne pollen is known to influence the incidence and severity of hayfever and asthma in a population.[131] Traidl-Hoffman et al.[130] report that the incidence of hayfever and allergic asthma in the community has more than doubled over the past 30 years, with 10–25% of the population experiencing symptoms.

Although intact pollen grains (with a diameter of around 10 micrometres) are too large to penetrate to the lower airways, research has shown that pollens can rupture under wet conditions and during thunderstorms, releasing allergen-carrying starch granules small enough to reach these airways. This can trigger severe asthma attacks in hayfever sufferers.[132] In addition to the well-publicised links between pollen, hayfever and allergic asthma, a timeseries study in the Netherlands found a strong association between daily pollen levels and mortality due to cardiovascular disease, chronic obstructive pulmonary disease and pneumonia.[133]

Silver wattle (*Acacia dealbata*) flowers loaded with pollen, Victoria

Photo by Philippe Giraud

The standards are measured at locations that are generally representative of the level of exposure of the broad population, rather than at 'hot spots' (such as near major point sources or roads). Authorities have agreed on standardised monitoring methods, to ensure national comparability of results.[136]

The standards are set at levels intended to protect human health. They reflect the evidence available in the mid-to-late 1990s on links between the various pollutants and human health. The AAQ NEPM is currently being reviewed in light of new evidence on health effects and international trends in air quality standards. Analysis of such evidence confirms that a number of the criteria pollutants (e.g. ozone and particles) do not have a threshold level below which there is no health effect. This means that sensitive individuals, such as asthmatics and people with respiratory or cardiovascular disease, may be affected even when air quality standards are met.[6]

As well as setting standards for the criteria pollutants, the AAQ NEPM established goals, expressed in terms of 'maximum allowable exceedences', to be achieved within 10 years (i.e. by 2008). These goals reflected a broadly based consensus on the extent of improvements in air quality that would be practicable over the period.

Table 3.6 Advisory reporting standards and goal for $PM_{2.5}$ particles

Pollutant	Averaging period	Maximum concentration (µg/m³)	Goal
Particles ($PM_{2.5}$)	1 day	25	To gather sufficient national data to facilitate a review of the advisory reporting standards
	1 year	8	

$PM_{2.5}$ = particulate matter smaller than 2.5 micrometres; µg/m³ = microgram per cubic metre

Source: Office of Legislative Drafting[134]

Box 3.7 The air quality index

In a number of states, the agency responsible for monitoring air quality reports results at each station in its network in terms of an air quality index (AQI) for all or a subset of the pollutants covered by the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM), apart from $PM_{2.5}$, which is not regularly reported. Often, the highest AQI is reported for each location. The AQI relates the observed level of a pollutant to the AAQ NEPM standard, expressed as a percentage. A given index level reflects the residual risks to public health.

$$\mathit{Index} = \frac{\text{Pollutant concentration}}{\text{Pollutant standard level}} \times 100$$

Five qualitative categories are used in public reporting of air quality. The categories and the AQI ranges that they represent are listed in Table A, together with a qualitative description of the associated health effects.

Table A Air quality index

Very poor	150+	Air quality is unhealthy, and everyone may begin to experience health effects. People in sensitive groups may experience more serious health effects.
Poor	100–149	Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range.
Fair	67–99	Air quality is acceptable. However, there may be a health concern for very sensitive people.
Good	66–34	Air quality is considered good, and air pollution poses little or no risk.
Very good	0–33	Air quality is considered very good, and air pollution poses little or no risk.

Each category in the AQI corresponds to a different level of air quality and associated health risk.

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities[6]

Pollutant sources

Most pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide and $PM_{2.5}$ particles) result from combustion (primary pollutants) (Table 3.7). Major sources include motor vehicles, industrial processes and domestic heating. Coarse particles (the PM_{10} fraction)—which include mineral dust, salt and soot—are also a form of primary pollutant, originating from both natural and human sources. Secondary pollutants (such as ozone) result from the action of complex photochemical processes on primary pollutants (oxides of nitrogen and volatile organic compounds), predominantly in the warmer months, forming photochemical smog.

Table 3.7 Major sources of criteria pollutants and fine particles ($PM_{2.5}$)

Pollutant	Major sources
Primary pollutants	
Nitrogen dioxide (NO_2), together with nitric oxide (NO), generalised as NO_x	Combination of nitrogen and oxygen during high-temperature combustion of fossil fuels Around 80% of urban NO_2 is from motor vehicle exhaust Other sources are petrol and metal refining, electricity generation from coal-fired power stations, other manufacturing industries and food processing
Sulfur dioxide	Electricity generation from fossil fuels, metal smelting of sulfurous ores, including aluminium, copper, lead, zinc and iron
Carbon monoxide	Combustion, including vegetation burning and wildfires, motor vehicles and metal manufacturing
Lead	Road dust, metal manufacturing and metal ore mining
PM_{10}	In nonurban areas: vegetation burning, wildfires, soot, windblown dust from agriculture and other land uses, road dust In urban areas: predominantly motor vehicles and secondary particles Other sources are solid (domestic) fuel burning in winter and mining
$PM_{2.5}$	Combustion sources, secondary nitrates and sulfates, secondary organic aerosol and natural-origin dust
Secondary pollutants	
Ozone	Atmospheric photochemical reactions of primary pollutants, NO_x and hydrocarbons (volatile organic carbons) from motor vehicles and industry Naturally occurring ozone

$PM_{2.5/10}$ = particulate matter smaller than 2.5 or 10 micrometres

Sources: Australian Government Department of Sustainability, Environment, Water, Population and Communities;[6] Environment Protection and Heritage Council;[127] Goldstein & Galbally;[137] Oltmans et al.[138]

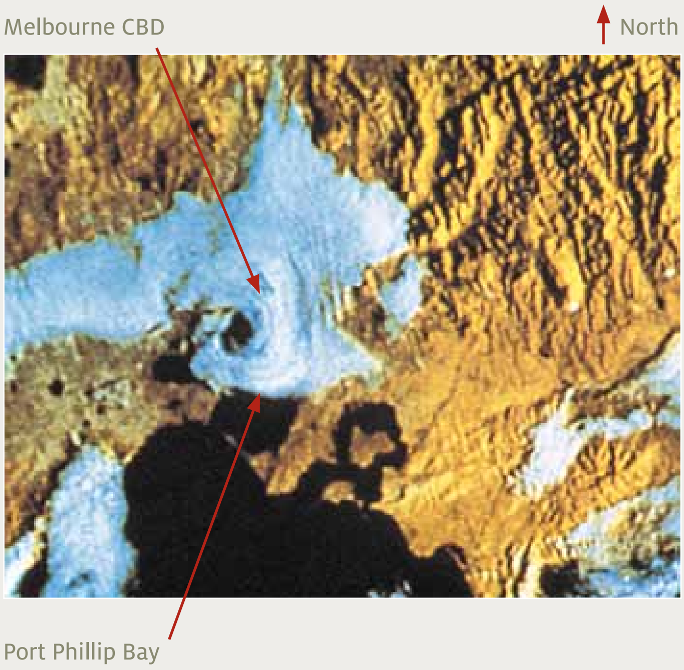
Although standards and monitoring strategies necessarily focus on individual pollutants, it is becoming increasingly clear that many of the health effects of air pollution are not due to single pollutants acting in isolation. This is hardly surprising, given that most major sources of urban air pollution (such as motor vehicle exhausts and domestic combustion heaters) emit a complex mix of gaseous and solid pollutants, some of which act as the building blocks for secondary pollutants such as ozone and some forms of fine particulate pollution.

Ambient air quality trends

Air quality in Australia's urban centres is generally good, with levels of all the criteria pollutants usually falling well below the national standards. The latest national state of the air report[6] showed that the levels of these pollutants (other than ozone and particles) declined or remained stable from 1999 to 2008. In some cities, peak ozone levels occasionally approached or exceeded the NEPM standard, whereas peak particle levels in nearly all regions exceeded the standard on a number of days. If, as seems likely, the yet-to-be-released review of the AAQ NEPM leads to a tightening of the current four-hour ozone standard (readings averaged over four hours) and to the establishment of an eight-hour standard (readings averaged over eight hours), the frequency of ozone exceedences is likely to increase significantly, particularly in Sydney.

Urban air quality varies both with short-term meteorological conditions—such as temperature inversions, which can trap pollutants near ground level—and seasonally, with summer temperatures promoting the formation of ozone and other photochemical pollutants. Extreme weather events are often associated with 'peak' pollution levels in Australian cities, where peak refers to the top 5% of measurements—this is distinct from the maximum (or highest) measurement. In addition, the frequency and severity of pollution events are strongly influenced in centres such as Sydney and Melbourne (Box 3.8) by the regional topography and the presence of the sea, which affect the circulation of air in those airsheds, recirculating polluted air and promoting the formation of photochemical smog. (An airshed is a body of air, bounded by meteorology and topography, in which substance emissions are contained. For example, the Bunbury Regional Airshed study area in Western Australia covers an area of 165 kilometres [east to west] by 234 kilometres [north to south] and contains a population of 270 000 people.)[139]

Box 3.8 The Melbourne eddy recorded by a weather satellite in February 1985 (the eddy is made visible by low cloud)



Under a special set of meteorological conditions, air flowing from the north-east is funnelled by mountains to the north and east of Port Phillip Bay, creating a circular (clockwise), horizontal motion of air (about 100 kilometres in diameter). The eddy pushes air pollution out over the bay, initially taking it away from Melbourne before returning it in reacted form as photochemical smog.

Source: Satellite image originally processed by the Bureau of Meteorology from the polar-orbiting satellite NOAA-6, operated by the National Oceanographic and Atmospheric Administration (NOAA)

Ozone

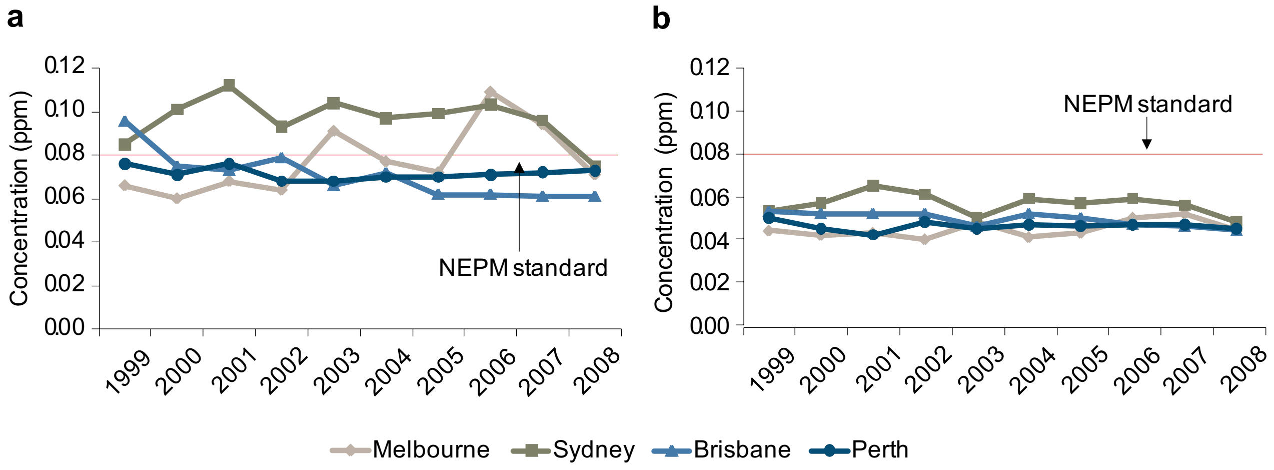
The state of the air report shows ozone levels in the Sydney and the Illawarra regions to have been generally higher than in other Australian metropolitan and industrial regions, exceeding the one-hour and four-hour ozone standards in most years from 1999 to 2008. Expressed in terms of the air quality index (AQI), Sydney's annual maximum four-hour ozone levels were generally classed as poor, whereas the 95th percentile levels were in the fair range. By comparison, annual maximum ozone levels in Melbourne, Brisbane, Perth, Adelaide and Canberra occasionally exceeded the standards, but generally rated as fair. Among these five cities, Melbourne's annual peak ozone levels were the highest, exceeding the four-hour standard in some years, with a consequent AQI rating of poor (Figure 3.25). Median (50th percentile) levels in all regions were around 40% of the four-hour standard (in AQI terms, rating as good). Overall, across the 44 NEPM monitoring sites, the report discerned no trends in ozone levels.[6]

Particles (PM_{10})

Peak PM_{10} levels in both urban and nonurban areas tend to be seasonal. In summer, wildfires and dust storms associated with occasional extreme weather can lead to very high levels of particle pollution. In areas with a high dependence on solid fuel burning for domestic heating, the seasonal peak in particle levels usually occurs in winter. This is particularly the case in centres such as Launceston, where local topography can lead to a layer of cold polluted air being trapped near the ground by an overlying layer of warmer air (a situation referred to as a temperature inversion). In autumn, when most forest fuel-reduction burns occur, some areas, including metropolitan centres, can experience significant particulate pollution.

From 1999 to 2008, maximum PM_{10} levels in Australian capitals and in some regional centres often exceeded the AAQ NEPM 24-hour standard, with levels up to 4 times the standard in the capitals and up to 14 times in some regional centres. However, annual state and territory reports on NEPM implementation reveal that in the capital cities such exceedences were generally limited in number and mainly related to extreme events, on which government air quality improvement programs have very limited effect.

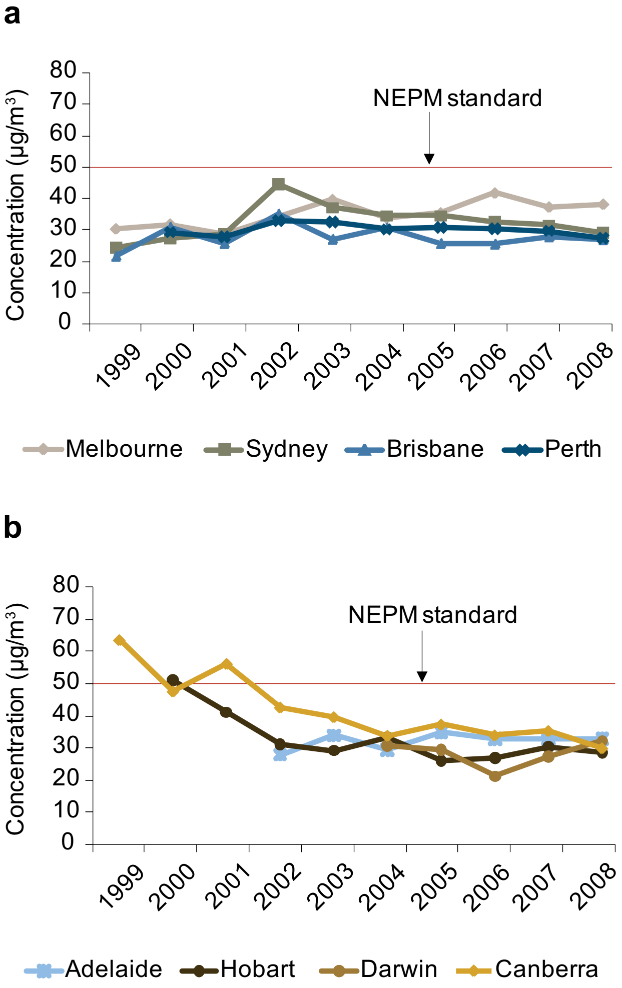
In all capitals (other than Canberra and Hobart), 95th percentile PM_{10} levels met the 24-hour standard (with levels falling in the fair or good AQI categories). In both Canberra and Hobart, the 95th percentile values exceeded the standard on one or two occasions early in the decade, subsequently declining and stabilising at levels comparable with the other capitals (Figure 3.26). These declines (along with a similar reduction in Launceston) largely reflect the success of programs to reduce wood smoke from domestic heaters. Setting aside these reductions, no trend is clear in the data for the other major cities.[6]



µg/m^3 = microgram per cubic metre; NEPM = National Environment Protection Measure; ppm = parts per million

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities[6]

Figure 3.25 For four major cities, the (a) average maximum four-hour average ozone concentrations and (b) average 95th percentile four-hour average ozone concentrations, 1999–2008

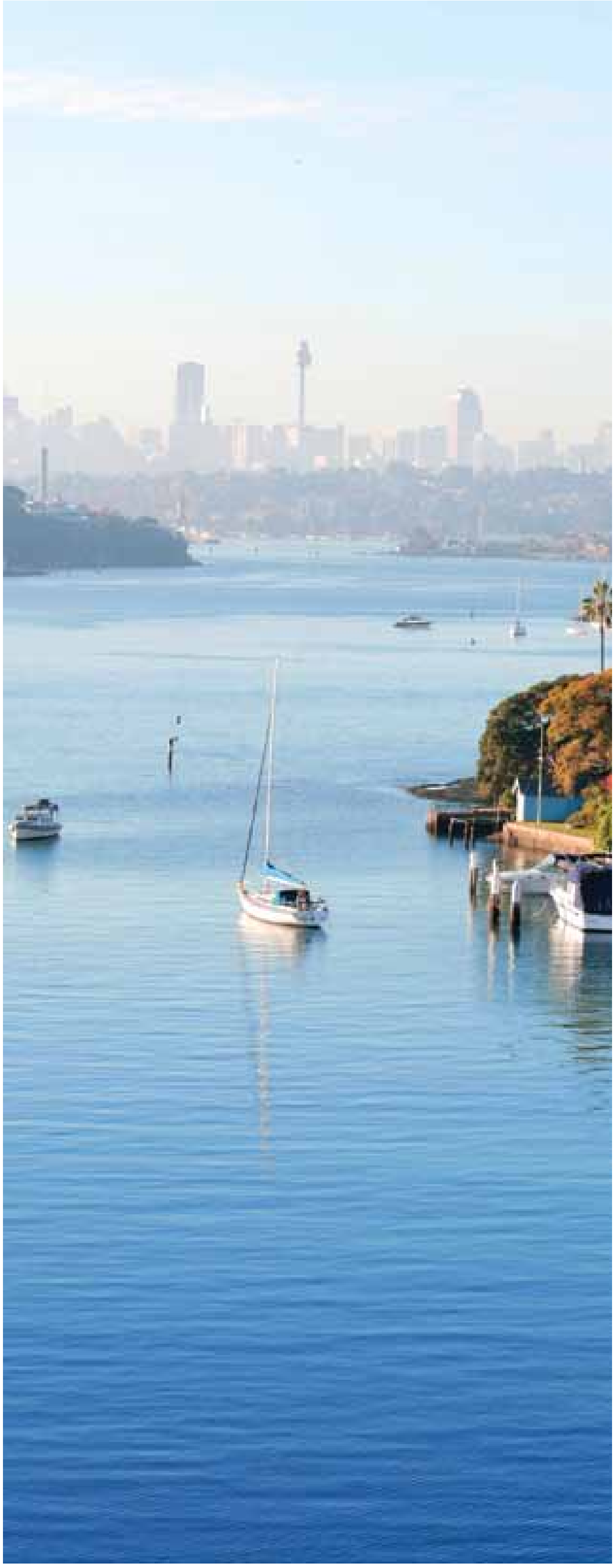


µg/m^3 = microgram per cubic metre; NEPM = National Environment Protection Measure; PM$_{10}$ = particulate matter smaller than 10 micrometres

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities[6]

Figure 3.26 Average 95th percentile 24-hour average PM$_{10}$ concentrations in (a) Melbourne, Sydney, Brisbane and Perth, and (b) Adelaide, Hobart, Darwin and Canberra, 1999–2008

As the state of the air report notes, particle levels tend to be slightly higher in regional cities in south-eastern Australia than in the capital cities. The most likely explanation is their greater seasonal exposure to the effects of bushfires, dust storms, planned burning and the use of wood for domestic heating.[6]



Early morning smog over Sydney, New South Wales

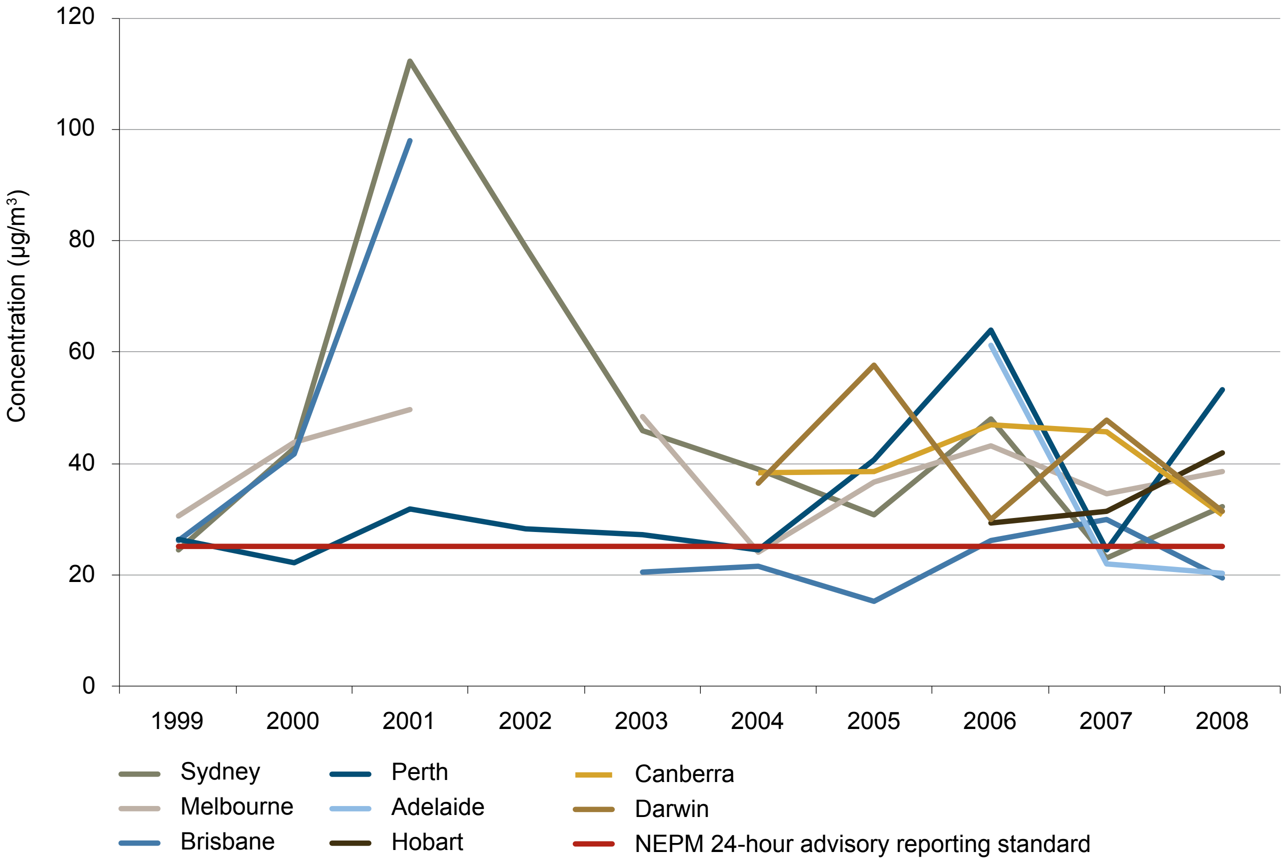
Photo by Barnaby Chambers

Fine particles ($PM_{2.5}$)

Fine particle levels are monitored at 18 sites around Australia, with Perth having the longest record, starting in 1994 (Figure 3.27). In 2008, the 24-hour advisory reporting standard (25 micrograms per cubic metre) was met at six sites (four in New South Wales, one in Queensland and one in South Australia). Peak levels are highly variable, being strongly influenced by extreme events such as bushfires and dust storms. This, together with a relatively short monitoring record at most sites, makes the identification of long-term trends problematic.[6]

Carbon monoxide

National Pollutant Inventory data show that, apart from vegetation burning and wildfires, motor vehicles are the main source of carbon monoxide. Over the past two decades, levels of carbon monoxide have declined significantly. This has been part of a broader improvement in air quality associated with strengthened vehicle standards that required the exhaust systems of new vehicles to be fitted with catalytic converters, and legislation requiring the phase-in of unleaded fuel. Current peak carbon monoxide levels fall into the very good AQI category in all regions and are less than one-third to one-fifth of the national standard.[6,140]



µg/m³ = microgram per cubic metre; NEPM = National Environment Protection Measure; $PM_{2.5}$ = particulate matter smaller than 2.5 micrometres

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities,[6] National Air Quality Database

Figure 3.27 Capital cities' highest daily average $PM_{2.5}$ concentrations

Nitrogen dioxide

Levels of nitrogen dioxide (both maximum and 95th percentile) are generally well below both the one-hour average and the annual average AAQ NEPM standards, rating good to very good (maximum) and very good (95th percentile) in terms of the AQI. Long-term records show a significant decline in maximum nitrogen dioxide levels, most notably in the 1990s. As is the case for carbon monoxide, the decrease was mainly driven by the introduction of tighter vehicle emission standards. During the past decade, although there has been a continued decline in nitrogen dioxide in some areas, levels have generally remained stable, despite an increase in vehicle numbers and distances travelled.[6,141]

Sulfur dioxide

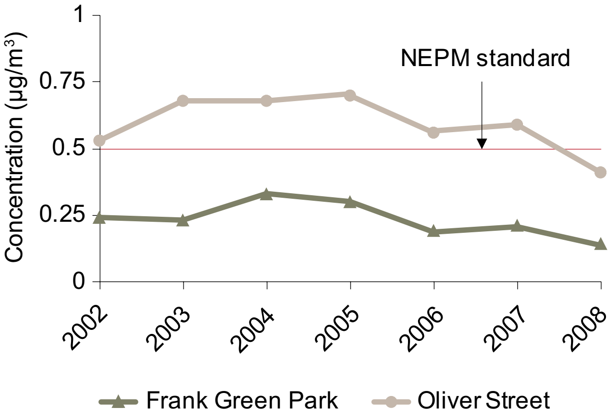
Sulfur dioxide levels remain low in the capitals and most other urban areas. Between 1995 and 2000, there was an overall reduction in Australian sulfur dioxide emissions of almost one-third, due mainly to recovery of sulfur dioxide to produce sulfuric acid. However, over the past decade, levels across Australian cities have been relatively stable, despite the progressive tightening of standards for sulfur dioxide in fuel.[6,142] Mount Isa and Port Pirie, with their large ore smelting operations, typically experience more than 20 exceedences of the one-hour sulfur dioxide NEPM standard, with Mount Isa recording more than three times and Port Pirie more than twice the standard—that is, in the very poor AQI category.[6,107]

Lead

Since the start of the national phase-out of leaded petrol in 1993, atmospheric lead levels in Australian cities have fallen markedly and are now below 10% of the national standard. The few exceptions are regional towns (such as Port Pirie) with large industrial point sources (Figure 3.28). This improvement is particularly welcome because lead (a persistent neurotoxin) is known to have adverse effects on children's development of memory and motor abilities, even at low levels.[143]

Volatile organic compounds

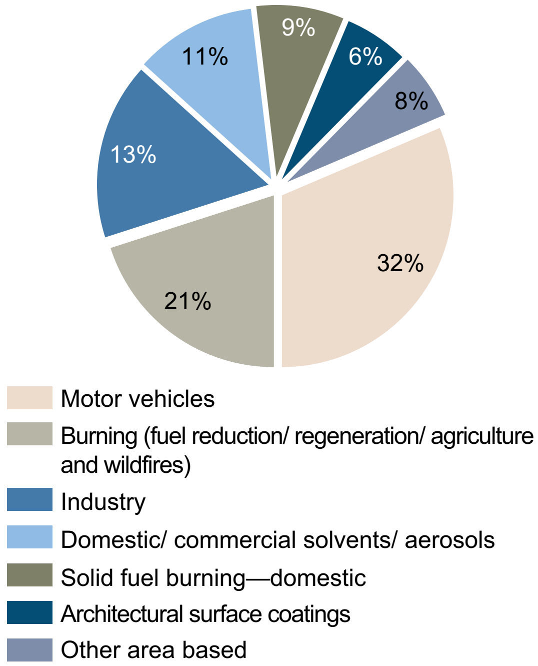
Volatile organic compounds (VOCs) are primary pollutants that react with nitrogen oxides in complex photochemical processes to generate a range of secondary pollutants (notably ozone). Biogenic sources (vegetation and soil) form about three-quarters of the total VOC emissions from natural and human sources.[144] Although emissions from biogenic sources are not hazardous themselves, they add to the background level of VOCs and thus can contribute to the formation of ozone. Figure 3.29 shows the main sources of VOCs other than vegetation and soil.



$\mu g/m^3$ = microgram per cubic metre

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities[6]

Figure 3.28 Lead levels at two locations in Port Pirie, South Australia



Source: National Pollutant Inventory[145]

Figure 3.29 Total volatile organic compounds by source, excluding biogenics, 2009–10

Air toxics

Air toxics (also called hazardous air pollutants) are a broad group of pollutants found in ambient air, usually at relatively low levels. These hazardous air pollutants include known or suspected carcinogens and pollutants linked to other serious health impacts, including birth defects and developmental, respiratory and immune system problems.[146] They include heavy metals and many types of volatile and semivolatile organic compounds. Some of these compounds (such as dioxins and furans) are highly persistent, tend to accumulate through food chains (bioaccumulation) and can be transported long distances through the atmosphere. These persistent organic pollutants are a focus of significant international concern and are controlled under the United Nations Stockholm Convention on Persistent Organic Pollutants, to which Australia is a signatory.[147] Air toxics are formed as products of combustion (motor vehicles are a significant source), as volatile emissions from paints and adhesives, and from various industrial processes.

In 2004, the National Environment Protection Council agreed on an additional air quality NEPM to address air toxics. This measure deals with five priority air toxics: benzene, toluene, xylene (collectively referred to as BTX), formaldehyde and benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons).

The NEPM adopts a nationally consistent approach to monitoring this initial group of air toxics at sites likely to experience elevated levels (such as near major roads and industrial areas) and establishes a series of benchmarks ('monitoring investigation levels' [MILs]) that, if exceeded, require further investigation and evaluation (see Table 3.8.) A key aim of the NEPM is to develop a robust set of data on ambient levels of these priority air toxics to enable future ministerial councils to set national air quality standards that will protect human health.[148]

A mid-term review of the air toxics NEPM summarised the results of five years' monitoring. Benzene levels at nearly all sites were at or below the MIL. However, some sites near heavily trafficked roads and one in a mixed industrial area (where non-NEPM monitoring methods were used) recorded levels close to or above the MIL. A clear time trend could not be discerned. Toluene and xylene levels were (with a small number of exceptions) well below the MILs, with some signs of a reducing trend for toluene. Most formaldehyde measurements were significantly below the MIL, although the review notes that the dataset is much more limited than for BTX. Due to the limited amount of monitoring, results for benzo(a)pyrene were inconclusive. Overall, the review noted the limited extent of data collection at most sites, expressed caution in relation to interpreting the limited results, and argued for additional monitoring.[149]

Table 3.8 Monitoring investigation levels for air toxics

Pollutant	Averaging period	Monitoring investigation level	Goal
Benzene	Annual average[a]	0.003 ppm	8-year goal is to gather sufficient national data to facilitate development of a standard
Benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons)	Annual average[a]	0.3 ng/m^3	
Formaldehyde	24 hours[b]	0.04 ppm	
Toluene	24 hours[b]	1 ppm	
	Annual average[a]	0.1 ppm	
Xylenes (as total of ortho-, meta- and para-isomers)	24 hours[b]	0.25 ppm	
	Annual average[a]	0.2 ppm	

ng/m^3 = nanograms per cubic metre; ppm = parts per million

a For the purposes of this measure, the annual average concentrations in column 3 are the arithmetic mean concentrations of 24-hour monitoring results.

b For the purposes of this measure, monitoring over a 24-hour period is to be conducted from midnight to midnight.

Source: Adapated from Office of Legislative Drafting[148]

Assessing the condition of ambient air

The qualitative assessment summaries 3.4–3.7 (below), based on the method outlined in Box 3.9, are generalised across periods of up to 11 years. The fact that these assessments indicate that overall air quality is good or very good should not be allowed to obscure the fact that, on a number of days each year, all of these cities experience air quality that does not meet the national health-based standards (i.e. air quality is in the poor or very poor categories). As a result, air pollution in our capitals and major regional centres remains a significant cause of death and illness in the community, particularly affecting the health of sensitive individuals and groups.

Box 3.9 Applying a graded report-card approach to Australia's urban air quality

As part of the State of the Environment reporting process, a qualitative assessment was made of ambient air quality in the eight state and territory capitals and a small number of major regional or industrial centres. Of the seven pollutants for which national health-based standards have been set, photochemical oxidants (as ozone) and particulate matter smaller than 10 micrometres (as PM_{10}) were chosen as key pollutants potentially impacting on human health, reflecting the weight of scientific evidence.

The approach based the characterisation of an airshed from 1999 to 2009 on its worst performing monitoring station, rather than on the total number of exceedences across the airshed, since this is strongly influenced by the number of monitoring stations. Only data from monitoring stations established in accordance with an approved National Environment Protection Measure (NEPM) monitoring plan were considered. (In some cases, less than 10 years of NEPM monitoring data were available, and in one case—Perth—11 years of data were available.) Most large regional cities have only one NEPM monitoring station, and most monitor particles, but not ozone, since they lack the scale of industry and traffic likely to give rise to ozone as a secondary pollutant. In each state, the regional cities selected for analysis of PM_{10} and ozone (where this was monitored) were the worst performing in the state.

It is recognised that the 10-year goals set in the Ambient Air Quality NEPM for ozone and particles allow for one exceedence per year for ozone and five exceedences per year for particles. Nevertheless, given the nature of the health-based standards, any exceedence may have a potentially adverse impact and should therefore be taken into consideration, even if the goal is met.

Ozone levels were evaluated against the four-hour exposure standard rather than the one-hour, as the four-hour standard is more likely to give a better indication of the impact on the general population, rather than on sensitive individuals who are likely to be affected by acute (i.e. shorter term) events.

Procedure

For each year, monitoring data for ozone and PM_{10} from each of the selected stations were converted into air quality index (AQI) values. These were used as the basis for calculating the percentage of observations that fell in each of the five AQI-based qualitative categories (very good, good, fair, poor and very poor) commonly used by Australian environment protection agencies to report air quality.

Each of these yearly percentage distributions for each pollutant at each station was then assessed against the criteria set out in Table A, to assign a general AQI score to each pollutant. The results across the period were represented graphically to assist in identifying any trends. It must be emphasised that the criteria set out in Table A are essentially subjective in nature. In almost all cases, their application resulted in the most frequently occurring AQI category being selected to generalise the year as a whole. In a small number of years, the AQI distribution was bimodal, with the result being borderline between the very good and good categories.

Overall qualitative AQI scores for ozone and PM_{10} were then assigned to each city, based on the most frequently occurring scores during the decade. A summary of the results is presented in assessment summaries 3.4 to 3.7, and the complete set of graphs is available on the State of the Environment website.[a]

Box 3.9 *continued*

Table A Criteria for assigning annual AQI-based qualitative scores

Overall category	Very good (%)	Good (%)	Fair (%)	Poor (%)	Very poor (%)
Very good	>50	>20	<10	<10	<5
Good	>20	>30	<20	<20	<10
Fair	<10	<20	>30	>20	<10
Poor	<10	<20	<20	>30	>20
Very poor	<5	<10	<10	>20	>50

Supplementary rules

If the percentage very good is greater than 45 and is also greater than the percentage good, the assessment grade is very good.

If the percentage good is greater than 75, then the percentage very good can be as low as zero and assessment grade is good.

a www.environment.gov.au/soe

3.4 Assessment summary

Metropolitan cities' score card for ozone (four-hour) NEPM standard, based on analysis of air quality index values, 1999–2008

Component	Summary	Assessment grade: Very poor	Poor	Fair	Good	Very good	Confidence: In grade	In trend
Adelaide	Average percentage frequency distribution: very good 46; good 53; fair 1; poor 0; very poor 0				—		●	●
Brisbane	Average percentage frequency distribution: very good 31; good 64; fair 55; poor 0; very poor 0				—		●	●
Canberra	Average percentage frequency distribution: very good 43; good 55; fair 2; poor 0; very poor 0				↙		●	◒
Melbourne	Average percentage frequency distribution: very good 34; good 63; fair 3; poor 0; very poor 0				—		●	●
Perth	Average percentage frequency distribution: very good 16; good 79; fair 4; poor 0; very poor 0				—		●	●
Sydney	Average percentage frequency distribution: very good 17; good 72; fair 9; poor 2; very poor 0				—		●	●

Recent trends

- ↗ Improving
- ↙ Deteriorating
- — Stable
- ? Unclear

Confidence

- ● Adequate high-quality evidence and high level of consensus
- ◒ Limited evidence or limited consensus
- ○ Evidence and consensus too low to make an assessment

Grades

🟦	Very good	Air quality is considered very good, and air pollution poses little or no risk
🟩	Good	Air quality is considered good, and air pollution poses little or no risk
🟨	Fair	Air quality is acceptable. However, there may be a health concerns for very sensitive people
🟧	Poor	Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range
🟪	Very poor	Air quality is unhealthy, and everyone may begin to experience health effects. People from sensitive groups may experience more serious health effects

NEPM = National Environment Protection Measure

Note: Melbourne assessment based on 2002–08; ozone is not regularly monitored in Darwin or Hobart.

3.5 Assessment summary

Metropolitan cities' score card for particles (PM_{10}) NEPM 24-hour standard, based on analysis of air quality index values, 1999–2008

Component	Summary	Assessment grade Very poor	Poor	Fair	Good	Very good	Confidence In grade	In trend
Adelaide	Average percentage frequency distribution: very good 42; good 51; fair 5; poor 1; very poor 1				—		●	●
Brisbane	Average percentage frequency distribution: very good 63; good 34; fair 3; poor 0; very poor 0					—	●	●
Canberra	Average percentage frequency distribution: very good 55; good 26; fair 11; poor 6; very poor 2 (Note: borderline very good – good)					↗	●	●
Darwin	Average percentage frequency distribution: very good 56; good 42; fair 2; poor 0; very poor 0					—	●	◒
Hobart	Average percentage frequency distribution: very good 73; good 26; fair 1; poor 0; very poor 0					?	●	◒
Melbourne	Average percentage frequency distribution: very good 36; good 50; fair 11; poor 2; very poor 1				—		●	●
Perth	Average percentage frequency distribution: very good 49; good 47; fair 3; poor 0; very poor 0 (Note: borderline very good – good)					—	●	●

Continued next page

Metropolitan cities' score card for particles (PM_{10}) NEPM 24-hour standard, based on analysis of air quality index values, 1999–2008 *continued*

Component	Summary	Assessment grade Very poor Poor Fair Good Very good	Confidence In grade	Confidence In trend
Sydney	Average percentage frequency distribution: very good 50; good 45; fair 4; poor 1; very poor 0 (Note: borderline very good – good)		●	●

Recent trends	↗ Improving	— Stable	
	↙ Deteriorating	? Unclear	
Confidence	●	Adequate high-quality evidence and high level of consensus	
	◐	Limited evidence or limited consensus	
	○	Evidence and consensus too low to make an assessment	
Grades	🟦	Very good	Air quality is considered very good, and air pollution poses little or no risk
	🟩	Good	Air quality is considered good, and air pollution poses little or no risk
	🟨	Fair	Air quality is acceptable. However, there may be a health concerns for very sensitive people
	🟧	Poor	Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range
	🟥	Very poor	Air quality is unhealthy, and everyone may begin to experience health effects. People from sensitive groups may experience more serious health effects

NEPM = National Environment Protection Measure; PM_{10} = particulate matter smaller than 10 micrometres

Note: Hobart assessment based on 2006–08; Melbourne assessment based on 2002–08; Perth assessment based on 2000–08

3.6 Assessment summary

Regional cities' score card for ozone (four-hour) NEPM standard, based on analysis of air quality index values, 1999–2008

Component	Summary	Assessment grade: Very poor	Poor	Fair	Good	Very good	Confidence: In grade	In trend
New South Wales—Kembla Grange	Average percentage frequency distribution: very good 35; good 62; fair 2; poor 1; very poor 0				—		●	●
Victoria—Moe	Average percentage frequency distribution: very good 68; good 31; fair 1; poor 0; very poor 0					?	●	◒

Recent trends

↗	Improving	—	Stable
↙	Deteriorating	?	Unclear

Confidence

●	Adequate high-quality evidence and high level of consensus
◒	Limited evidence or limited consensus
○	Evidence and consensus too low to make an assessment

Grades

🟦	Very good	Air quality is considered very good, and air pollution poses little or no risk
🟩	Good	Air quality is considered good, and air pollution poses little or no risk
🟨	Fair	Air quality is acceptable. However, there may be a health concerns for very sensitive people
🟧	Poor	Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range
🟪	Very poor	Air quality is unhealthy, and everyone may begin to experience health effects. People from sensitive groups may experience more serious health effects

NEPM = National Environment Protection Measure

Note: Ozone is regularly monitored in regional cities only in New South Wales, Queensland and Victoria. Of these states, only New South Wales and Victoria monitor ozone using both the NEPM one-hour and four-hour averaging periods. In Queensland, ozone is monitored at sites in Toowoomba and Townsville, but only using the one-hour averaging period. For this reason, only regional cities in New South Wales and Victoria were included in this assessment summary.

3.7 Assessment summary

Regional cities’ score card for particles (PM_{10}) NEPM 24-hour standard, based on analysis of air quality index values, 1999–2008

Component	Summary	Assessment grade					Confidence	
		Very poor	Poor	Fair	Good	Very good	In grade	In trend
New South Wales—Wagga Wagga	Average percentage frequency distribution: very good 34; good 45; fair 13; poor 6; very poor 2 (Note: Although the overall assessment is good, the distribution has a significant ‘tail’ of 29 days on which the national standard was exceeded)				—		●	●
Queensland—West Mackay	Average percentage frequency distribution: very good 30; good 61; fair 1; poor 0; very poor 2				—		●	●
South Australia—Port Pirie	Average percentage frequency distribution: very good 55; good 34; fair 8; poor 2; very poor 1					↗	●	◒
Tasmania—Launceston Ti Tree Bend	Average percentage frequency distribution: very good 65; good 30; fair 3; poor 2; very poor 1					?	◒	◒
Victoria—Geelong South	Average percentage frequency distribution: very good 39; good 49; fair 9; poor 2; very poor 1				—		●	●

Component	Summary	Assessment grade: Very poor	Poor	Fair	Good	Very good	Confidence: In grade	In trend
Western Australia—Bunbury	Average percentage frequency distribution: very good 46; good 52; fair 2; poor 0; very poor 0				—		●	●

Recent trends

↗	Improving	—	Stable
↙	Deteriorating	?	Unclear

Confidence

- ● Adequate high-quality evidence and high level of consensus
- ◒ Limited evidence or limited consensus
- ○ Evidence and consensus too low to make an assessment

Grades

🟦	Very good	Air quality is considered very good, and air pollution poses little or no risk
🟩	Good	Air quality is considered good, and air pollution poses little or no risk
🟨	Fair	Air quality is acceptable. However, there may be a health concerns for very sensitive people
🟧	Poor	Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range
🟥	Very poor	Air quality is unhealthy, and everyone may begin to experience health effects. People from sensitive groups may experience more serious health effects

NEPM = National Environment Protection Measure; PM_{10} = particulate matter smaller than 10 micrometres

Note: Wagga Wagga assessment based on 2001–08; West Mackay based on 2000–08; Port Pirie based on 2003–10; Geelong South and Bunbury based on 1999–2008; Launceston based on 2006–08

3.1.3 Indoor air quality

Like citizens of other highly urbanised societies, most Australians spend more than 90% of their time indoors, leading to concern about the possible impacts of indoor air quality on our health. Such concern is heightened in situations where indoor pollutant concentrations equal or exceed outdoor levels and indoor exposure becomes the dominant form of exposure.[150]

Symptoms associated with poor indoor air quality can range from acute to chronic, and from mild and generally nonspecific (eye, nose and throat irritation, and headaches and dizziness) to severe (asthma, allergic responses and cancer risk).[95,151-152] Despite the potentially significant health effects of indoor air, data on indoor air quality in Australia are limited, providing no firm basis upon which to form assessments of overall status and trend.

Until recently, there has been no comprehensive study of indoor air quality in typical Australian dwellings; previous studies tended to focus on situations with particular air quality issues, such as emissions from unflued gas heaters and gas cooking appliances. The release in 2010 of a two-part report by CSIRO and the Bureau of Meteorology of 40 typical homes in Melbourne has filled that gap, at least for temperate urban areas.[153] The study found concentrations of indoor air pollutants to be either lower than or comparable with concentrations found in previous Australian studies. The study showed weekly average concentrations of carbon dioxide, carbon monoxide, nitrogen dioxide, formaldehyde, other carbonyls, BTEX (benzene, toluene, ethylbenzene and xylene) and total VOCs to be higher indoors than outdoors, whereas PM_{10}, ozone and fungi concentrations were higher outdoors. Across the 40 dwellings, the ambient 24-hour NEPM advisory reporting standard for $PM_{2.5}$ was equalled or exceeded on 3% of days. In dwellings that relied on gas appliances for cooking, levels of carbon dioxide, carbon monoxide, nitrogen dioxide, $PM_{2.5}$, formaldehyde, benzene and total VOCs were significantly higher than in households that solely used electric cooking appliances. The effect of proximity to major roads on indoor air quality was limited to an increase in nitrogen dioxide levels (accounting for around 20% of indoor nitrogen dioxide in these situations).[153] Unfortunately, although the study has significantly expanded our knowledge of indoor air quality in Australian homes, as the authors note in a separately published overview of the study, ‘the absence of specific guidelines for indoor air quality in Australia prevents an objective assessment of the quality of observed indoor air’.[154]

A typical domestic gas stove
Photo by Daniel Goodings

3.2 Pressures affecting Australia's atmosphere

At a glance

Nitrous oxide, an ozone depleting substance and a greenhouse gas (GHG), is produced by a variety of natural and human-related sources (notably agricultural processes). Although its ozone depleting potential is low relative to chlorofluorocarbon-11 (CFC-11), human emissions are at such a large scale that it is recognised as currently the single most important form of ozone depleting emission, and can be expected to remain so throughout this century. Other GHGs not controlled under the Montreal Protocol, notably carbon dioxide and methane, are expected to significantly affect future stratospheric ozone levels. However, unlike nitrous oxide, the net effect of carbon dioxide and methane is expected to be positive for ozone recovery.

The air quality in Australia's major cities is no longer principally influenced by emissions from industrial point sources. With the exception of a few centres dominated by one or two very large industrial facilities (such as Mount Isa and Port Pirie), widely spread, diffuse emissions now constitute the major source of pollutants in urban areas. Among these, motor vehicles are the single most important source, contributing a range of pollutants: carbon monoxide, particles, various toxic volatile organic compounds (VOCs) and nitrogen oxides (which, together with VOCs, act as precursors to the formation of ozone). In addition, diesel vehicles are an important source of particles. Commercial premises are another important diffuse source of pollutants (notably VOCs and particles) that affect air quality at an airshed scale as well as impacting on amenity at a neighbourhood level, generating complaints about odour, noise and smoke. Similarly, in many urban centres where wood heaters are widely used for home heating, domestic premises are an important diffuse source of particulate pollution during the colder months. A final broad source of diffuse pollution (with origins outside urban areas) is planned burning for purposes such as agriculture, forestry operations and land management. If not well planned, timed and executed, such burns can trigger health problems and loss of amenity in surrounding rural areas and urban centres.

Climate change is likely to also affect air quality. Rising temperature, which is expected to be a main feature of climate change in Australia, is likely to lead to the formation of more ozone by increasing the generation of both natural and human-generated VOCs. Hotter, drier conditions in many parts of the country, together with more extreme weather events (another likely result of climate change) can be expected to increase bushfires and dust storms, leading to short-lived, very high levels of particulate pollution, which, depending on location, may affect large urban populations.

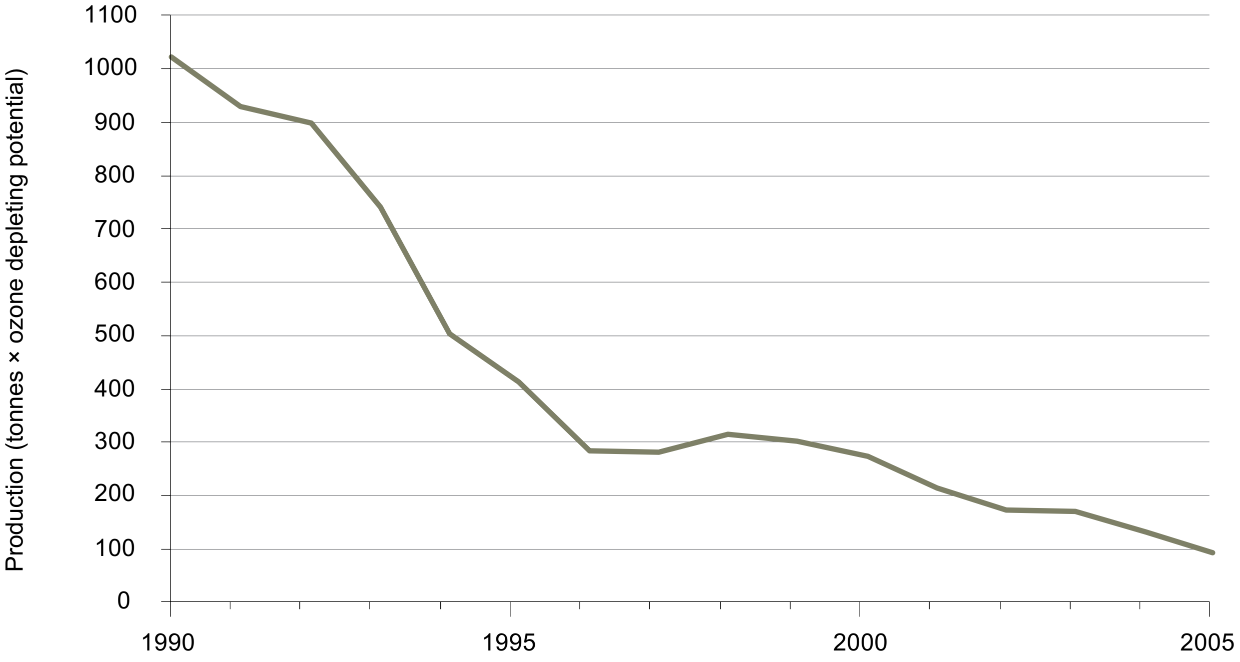
The quality of indoor air is affected by many factors. The more important include building materials (particularly volatile materials like glues and paints), ventilation, furnishings, use of appliances (particularly cooktops, ovens and unflued gas appliances), environmental tobacco smoke and cleaning agents.

3.2.1 Stratospheric ozone

Global production of ODSs continues to decline (Figure 3.30). However, due to the long atmospheric lifetimes of a number of important ODSs, they will continue to impact levels of stratospheric ozone for many decades. In addition, future recovery of the ozone layer will be influenced by emissions of GHGs that are not controlled under the Montreal Protocol—notably carbon dioxide, methane and nitrous oxide—through their effects on temperature, wind and chemistry.[104]

Carbon dioxide has an indirect influence on stratospheric ozone through its effect on temperature, which affects the rates of chemical reactions that control the abundance of ozone. Increasing levels of carbon dioxide have been observed to cause cooling of the mid-to-upper levels of the stratosphere (via radiation to space), leading to a decrease in the rate of ozone loss in these parts of the atmosphere and an increase in the rate in the lower stratosphere. Increases in methane's abundance in the troposphere will lead to more methane reaching the stratosphere. There, it interacts with compounds that contain active chlorine (which is able to destroy ozone) to produce inactive hydrogen chloride, which does not destroy ozone. Methane levels also influence stratospheric water vapour, which affects both ozone and climate. The net effects of carbon dioxide and methane are expected to be positive for the recovery of stratospheric ozone levels.[104] However, this is not the case with nitrous oxide, which is produced by a variety of natural and human-related sources (notably agricultural processes).

As well as being a potent GHG, nitrous oxide from human sources is currently the single most important ODS and can be expected to remain so throughout this century.[156] This reflects the fact that, although the ozone depleting potential of nitrous oxide is only about one-sixtieth that of CFC-11, human emissions are large and increasing. Even in 1987, when CFC emissions were at or near their peak, annual ozone depletion potential–weighted emissions of nitrous oxide were some 17% of the combined emissions of CFC-11, CFC-12 and CFC-112.[156] In 2009, Australia's emissions of nitrous oxide were 26.7 $MtCO_2$-e, which is approximately 0.7% of the world's human-sourced emissions.[38-39]



Source: United Nations Environment Programme Ozone Secretariat[155]

Figure 3.30 Total reported global production of ozone depleting substances

As new countries ratify the Montreal Protocol, the number of countries reporting national production increases. Therefore, the number of countries is different in 1990 and 2009.

3.2.2 Ambient air quality

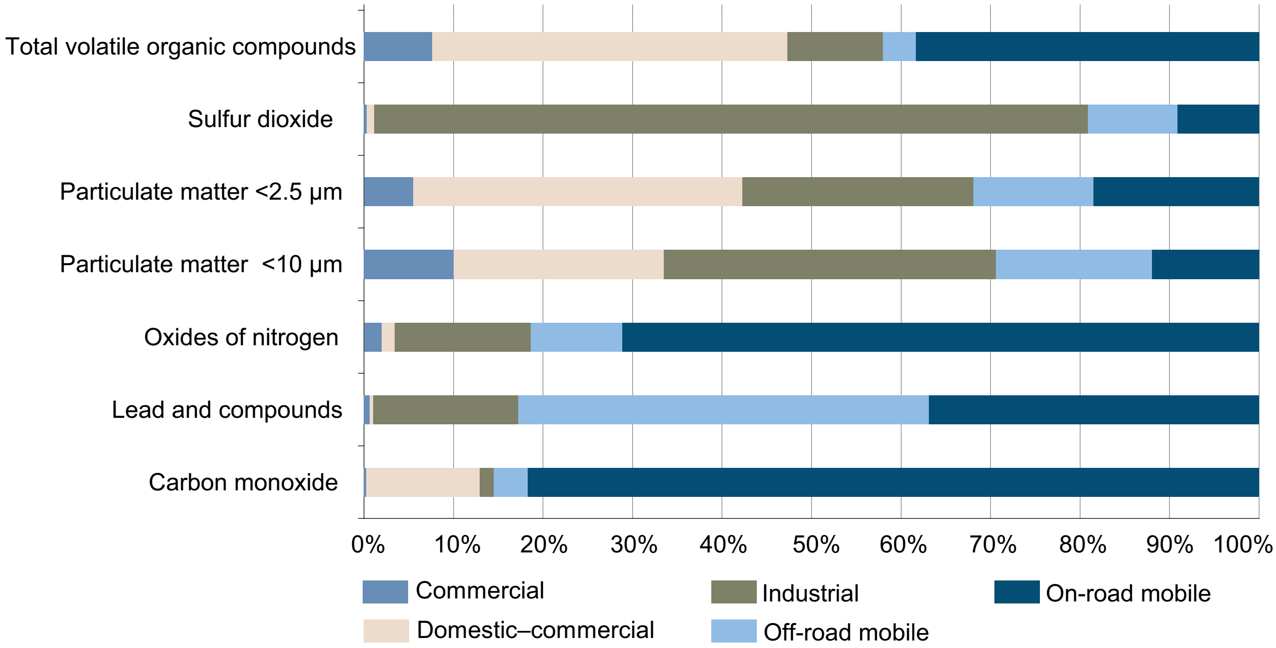
Point-source and diffuse-source pollution

As previously noted, air quality in Australia's urban areas is strongly influenced by short-term meteorology (including extreme events), seasonal conditions, local topography and distance from the sea. The size of the urban centre and the presence of major industrial facilities also play a role in shaping the varying levels of air quality experienced in an urban airshed.

Historically, the most common image of air pollution has been a highly visible plume of unknown content being emitted from a power station or industrial plant. However, both state and national pollutant inventories show that, although industrial point sources still dominate some emission types (notably sulfur dioxide), with the exception of major industrial centres (such as Mount Isa and Port Pirie), diffuse or area sources tend to be the main factors affecting air quality at an airshed scale. These sources include motor vehicles, domestic and commercial solvents, service stations and domestic lawn mowers. The generalisation remains true whether the focus is on the key criteria pollutants (ozone and its precursors and particles) or on the main hazardous air pollutants (air toxics such as benzene, toluene and xylene) (Figure 3.31).[139,157]

It is the diffuse sources (motor vehicles, domestic solid fuel heating, bushfires and various types of planned burning, and dust from roads and agricultural activities) that are the most challenging for government policy makers, regulators and program managers working to improve air quality.

Among diffuse sources of air pollution, motor vehicles are the most pervasive and have the largest impact on urban air quality and human health. In our capital cities, they are the dominant source of NO_x (a generic term for nitric oxide and nitrogen dioxide) and VOCs—the precursors of photochemical smog. Although the combined emissions from industry, electricity generation and wood heating are a larger source of PM_{10} than motor vehicles, because of their ubiquitous presence in our cities, motor vehicles tend to be a more important source of human exposure. Furthermore, discharges from major industrial and power-generation facilities are elevated and thus have less influence at ground level than corresponding ground-level emissions.



Source: New South Wales Department of Environment, Climate Change and Water[157]

Figure 3.31 Proportion of total estimated annual anthropogenic emissions from each anthropogenic source type in the Sydney region

In addition, very fine particles (<1 micrometre) form a major part of vehicle particulate emissions. It is these, together with particles in the range 1 micrometre to less than 2.5 micrometres, that are the focus of increasing concern in relation to cardiovascular and respiratory disease, with which they are strongly correlated.[158] The Australian Bureau of Transport and Regional Economics estimates that, in 2000, motor vehicle pollution was responsible for 900–4500 cases of respiratory and cardiovascular disease and bronchitis, and as many as 2000 premature deaths.

Within an airshed at a neighbourhood level, as state regulators and local government officials know only too well, a broad range of small-scale industrial and commercial activities have the potential to impact on local amenity and health, most often through emissions of odour, dust and noise. Such widespread diffuse-source problems are often historical in nature (the result of residential areas having developed in close proximity to incompatible land uses) and are particularly difficult to resolve.

An important diffuse source of particulate pollution in cool–temperate parts of Australia is domestic wood heaters and open fires. In autumn and winter, in cities such as Melbourne, Hobart, Canberra and Launceston, and in many smaller centres in Tasmania, Victoria and inland New South Wales, smoke from domestic wood heaters is the major source of particulate pollution. In inland centres such as Canberra, cold nights and clear skies frequently occur in autumn and winter, creating temperature inversions. These trap wood smoke near ground level, leading to particle levels above both the NEPM 24-hour PM_{10} standard and the $PM_{2.5}$ advisory level.[6] In centres such as Launceston, local valley topography can increase the frequency and strength of such inversions, leading to incidents of significant particulate pollution.

The term ‘planned burning’ encompasses a broad range of activities associated with forestry, public land management and agriculture. Depending on their location and scale, the smoke generated by such activities has the potential to impact on health and amenity, affecting areas such as tourism, viticulture and outdoor events if the burns are not well planned and executed. Recent work by the Environment Protection Division of the Tasmanian Department of Primary Industries, Parks, Water and Environment indicates that planned burns are a significantly more important diffuse source of particulate pollution than estimated by the National Pollutant Inventory.[159] However, although the potentially adverse impacts of planned burns need to be recognised and managed, they should be considered in the context of potential benefits, such as a reduction in the risk of wildfires.

The term ‘planned burning’ could also be applied to burning carried out as a traditional management practice by Indigenous land custodians in tropical savanna grasslands in northern Australia. These low-impact burns have been employed by Aboriginal people for many thousands of years.[160] Because they take place in remote areas away from population centres, these traditional practices do not raise concerns over impacts on health or amenity, such as are often associated with planned burning in the southern parts of the country.

Climate change and urban air quality

The combination of higher temperatures, more frequent bushfires and more raised dust associated with climate change can be expected to impact adversely on ambient air quality at an airshed scale. CSIRO modelling of the Sydney airshed has shown that higher temperatures, especially higher summer temperatures, can be expected to increase the formation of ozone by increasing the production of VOCs (including from leaves and other biogenic sources), thus impacting respiratory and cardiovascular health. Specifically, under a scenario of high carbon dioxide emissions growth, with air pollution emissions fixed at current-decade levels, Cope et al.[161] found that projected numbers of ozone pollution–related hospital admissions would be 40% (2020–30) and 200% (2050–60) higher relative to 1996–2005. Tang et al.[162] noted the potential for a similar temperature-related increase in emissions of NO_x from some types of soil, which could lead to an increase in ozone formation.

In addition, climate change–driven shifts in atmospheric circulation, such as a change in the exchange between the stratosphere and the troposphere, could lead to relatively small but significant increases in background ozone levels in the troposphere. Such increases in background concentrations could be expected to add to existing ozone pollution levels in urban areas, increasing the length of periods during which regulatory air quality standards are exceeded, with consequent effects on health.[163]

Analysis by Duc and Azzi[164] indicates an increasing trend in background ozone levels in Sydney since the early 1990s. The authors note that this is similar to increasing trends reported from the United States and Europe. While they comment that the reason for the increasing trend in Sydney is 'not entirely clear', they note the possible influence of transfer from the stratosphere, along with increasing global emissions, particularly in north Asia.[164]

Existing monitoring data show strong links between extreme events such as bushfires and dust storms and very high levels of particulate pollution in metropolitan and regional centres. The expected climate change–driven increase in these events will therefore exacerbate episodes of severe particulate pollution. As in the case of ozone, this can be expected to lead to an increase in adverse respiratory and cardiovascular health outcomes, both acute and chronic.[135]

3.2.3 Indoor air quality

The quality of the air inside our homes, offices, public buildings, schools and so on is affected by many factors, including the quality of the outside air, building materials (particularly volatile materials like glues and paints), ventilation, furnishings, appliances (particularly unflued gas appliances), environmental tobacco smoke and cleaning agents.[165-166]

Of the factors impacting on indoor air quality, environmental tobacco smoke is of particular concern because it increases the risk of asthma in children and can worsen the symptoms. Environmental tobacco smoke is also known to trigger asthma symptoms in adults. Another focus of concern is nitrogen dioxide, the major sources of which are unflued gas heating and cooking appliances, and wood stoves and fireplaces. In winter, when homes are likely to be well sealed, even flued heaters and fireplaces can lead to high indoor levels of nitrogen dioxide due to leaks and poor chimney design.[167-168] High nitrogen dioxide levels are associated with coughing, wheezing and asthma attacks. Prolonged exposure to such levels can contribute to the development of acute or chronic bronchitis.[151]

3.8 Assessment summary

Pressures affecting stratospheric ozone, ambient air quality and indoor air quality

Component	Summary	Assessment grade Very high impact	High impact	Low impact	Very low impact	Confidence In grade	In trend
Greenhouse gases	Emissions of nitrous oxide (N_2O), an ozone depleting substance and a greenhouse gas, together with other greenhouse gases (carbon dioxide [CO_2] and methane), are expected to have a significant effect on stratospheric ozone levels. CO_2 and methane are expected to have a positive net effect on ozone recovery. That is not the case for N_2O	Insufficient information to assess likely extent of future impact of N_2O				○	○
Industrial point sources (metropolitan and regional cities)	Local and airshed-wide impacts on health and aesthetics; localised effects on amenity and health near some major point sources			—		●	●
Motor vehicles (metropolitan centres)	Metro-wide direct and indirect impacts of volatile organic compounds, NO_x, ozone and particulates; localised impacts near 'hot spots' such as heavily trafficked roads in residential areas		—			●	●
Domestic and commercial (urban)	Local and airshed-wide impacts on health and aesthetics			—		●	●
Planned burning	Widespread evidence of generally localised effects on amenity and health			?		◒	◒

Component	Summary	Assessment grade				Confidence	
		Very high impact	High impact	Low impact	Very low impact	In grade	In trend
Climate change (airshed scale)	Higher temperatures will be associated with increased photochemical smog (ozone pollution events), and with an increase in serious particulate pollution events due to more frequent bushfires and dust storms. Both outcomes can be expected to adversely affect health			↙		◒	◒
Indoor air pollutants	A broad range of indoor pollutants is known to impact health			?		◒	◒

Recent trends

↗	Improving
↙	Deteriorating
—	Stable
?	Unclear

Confidence

●	Adequate high-quality evidence and high level of consensus
◒	Limited evidence or limited consensus
○	Evidence and consensus too low to make an assessment

Grades

🟩	Very low impact	Few or no impacts have been observed, and accepted predictions indicate that future impacts on values such as health and aesthetics are likely to be minor
🟫	Low impact	Impacts on values such as health and aesthetics have already been observed, most often localised
🟧	High impact	Significant impacts on values such as health and aesthetics have already been observed, mainly affecting more sensitive members of the community
🟥	Very high impact	Currently, a very serious impact on health and aesthetics for the broader population

3.3 Effectiveness of management

3.3.1 Stratospheric ozone

On the basis of the extent of international sign-on and results achieved, the Montreal Protocol is one of the world's most effective international environment protection agreements. Various 'world-avoided' studies have demonstrated the importance of measures implemented under the protocol, not only in avoiding further damage to the ozone layer and allowing its gradual recovery, but also in significantly reducing the extent of climate change in coming decades. This is particularly important at high latitudes, where the avoided ozone depletion would have had a large effect on surface climate.[104,169]

Based on analysis of historical ODS emissions and potential emission scenarios, Velders et al.[170] reach a similar conclusion, noting that 'the climate protection already achieved by the Montreal Protocol alone is far larger than the reduction target of the first

At a glance

The Montreal Protocol on Substances that Deplete the Ozone Layer is one of the world's most effective international environment protection agreements, orchestrating the phase-out of a broad range of ozone depleting substances (including some of the first generation of chlorofluorocarbon substitutes). Australia has ratified the protocol and, as a signatory, all subsequent amendments, and has reduced its use of controlled substances well ahead of its international obligations.

For more than a decade, Australia has had national standards and goals for ambient air quality—the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM)—based on strong empirical evidence about the health impacts of major pollutants. The measure mandates a consistent approach to air quality monitoring, which has been applied by all states and territories, but—recognising the different legislative arrangements in each jurisdiction—does not dictate the means to be applied to achieve the goals. The AAQ NEPM is supported by national emission standards for new vehicles, set in the Australian Design Rules, and by fuel quality standards, both of which are established through Australian Government legislation (the *Motor Vehicle Standards Act 1989* and the *Fuel Quality Standards Act 2000*, respectively).

During the past 30–40 years, state and territory environment protection agencies have employed a variety of regulatory measures (including works approval, licensing and notices) to control and greatly restrict emissions of air pollutants from industrial and commercial sources. More recently, nonregulatory measures (such as codes of practice, market-based mechanisms and cleaner production incentive schemes) have been increasingly used to complement regulatory controls. In some jurisdictions, local government has a role in controlling emissions (mainly of particles and odour) from commercial sources. Local government tends to be the main tier of government responding to complaints at the neighbourhood level about smoke from domestic wood heaters.

Although the size of the Australian vehicle fleet is continuing to grow (as are the distances travelled), emissions are expected to continue to decline over the next decade as a result of tighter national fuel standards and the mandating of improved emission-control technologies under the *Motor Vehicle Standards Act 1989*. State and territory authorities are responsible for enforcing compliance with emission standards on in-service vehicles, and Australian Government officials monitor and enforce compliance with fuel standards.

Australian governments have actively sought to improve indoor air quality through a range of interventions (both regulatory and nonregulatory) targeting environmental tobacco smoke and unflued gas heaters. All states and territories prohibit smoking in cinemas and theatres (originally motivated by concern over risk of fire), in most types of public transport and in areas where food is prepared and consumed. Increasingly, similar bans are being applied to various outdoor public spaces. Unflued gas heaters are regulated in all states and territories; although the regulations vary between jurisdictions, they all require compliance with Australian standards. However, as various studies have shown, conformity with the Australian standards does not guarantee that emissions will not adversely affect health.

commitment period of the Kyoto Protocol'. Additional climate change mitigation could be achieved under the Montreal Protocol through management of substitute fluorocarbon gas emissions and by mandating gases with low global warming potentials as alternatives.

Other world-avoided studies have modelled decreases in ozone levels and resulting increases in ground surface solar UV radiation levels. The excess radiation would have had major adverse effects on terrestrial and aquatic ecosystems and on human health. For example, mid-latitude ozone losses in the Northern Hemisphere would have reduced the time taken to sunburn (under a clear sky at noon) from 15 to 5 minutes. The amount of DNA-damaging UV reaching Earth would have increased between 1980 and 2065 by 550%.[171]

Since its establishment in 1987, controls under the protocol have been progressively expanded to cover a broad range of ODSs (including some of the first generation of CFC substitutes) and to accelerate initial phase-out timetables. Table 3.9 summarises the present control measures.

Table 3.9 Summary of Montreal Protocol measures

Ozone depleting substance	Developed countries	Developing countries
Chlorofluorocarbons	Phased out end of 1995[a]	Total phase-out by 2010
Halons	Phased out end of 1993	Total phase-out by 2010
Carbon tetrachloride	Phased out end of 1995[a]	Total phase-out by 2010
Methyl chloroform	Phased out end of 1995[a]	Total phase-out by 2015
Hydrochlorofluorocarbons	Freeze from beginning of 1996[b] 35% reduction by 2004 75% reduction by 2010 90% reduction by 2015 Total phase-out by 2020[c]	Freeze in 2013 at a base level calculated as the average of 2009 and 2010 consumption levels 10% reduction by 2015 35% reduction by 2020 67.5% reduction by 2025 Total phase-out by 2030[d]
Hydrobromofluorocarbons	Phased out end of 1995	Phased out end of 1995
Methyl bromide (horticultural uses)	Freeze in 1995 at 1991 base level[e] 25% reduction by 1999 50% reduction by 2001 70% reduction by 2003 Total phase-out by 2005	Freeze in 2002 at average 1995–98 base level[e] 20% reduction by 2005 Total phase-out by 2015
Bromochloromethane	Phase-out by 2002	Phase-out by 2002

a With the exception of a very small number of internationally agreed essential uses that are considered critical to human health and/or laboratory and analytical procedures

b Based on 1989 hydrochlorofluorocarbon (HCFC) consumption with an extra allowance (ozone depletion potential weighted) equal to 2.8% of 1989 chlorofluorocarbon consumption

c Up to 0.5% of base-level consumption can be used until 2030 for servicing existing equipment, subject to review in 2015.

d Up to 2.5% of base-level consumption can be used until 2040 for servicing existing equipment, subject to review in 2025.

e All reductions include an exemption for preshipment and quarantine uses.

Notes: The timetable set by the Montreal Protocol applies to bulk consumption of ozone depleting substances (ODSs). Consumption is defined as the quantities manufactured plus imported, less those quantities exported in any given year. Percentage reductions relate to the designated 'base year' for the substance. The protocol does not forbid use of existing or recycled controlled substances beyond the phase-out dates. Further information on these ODSs can be seen in the United Nations Environment Programme Ozone Secretariat's *Handbook for the international treaties for the protection of the ozone layer* (see Section 1.2 of the handbook for links to graphs displaying ODS phase-out timetables). For Australia's accelerated HCFC phase-out timetable, see Part IV of the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*.

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities[172]

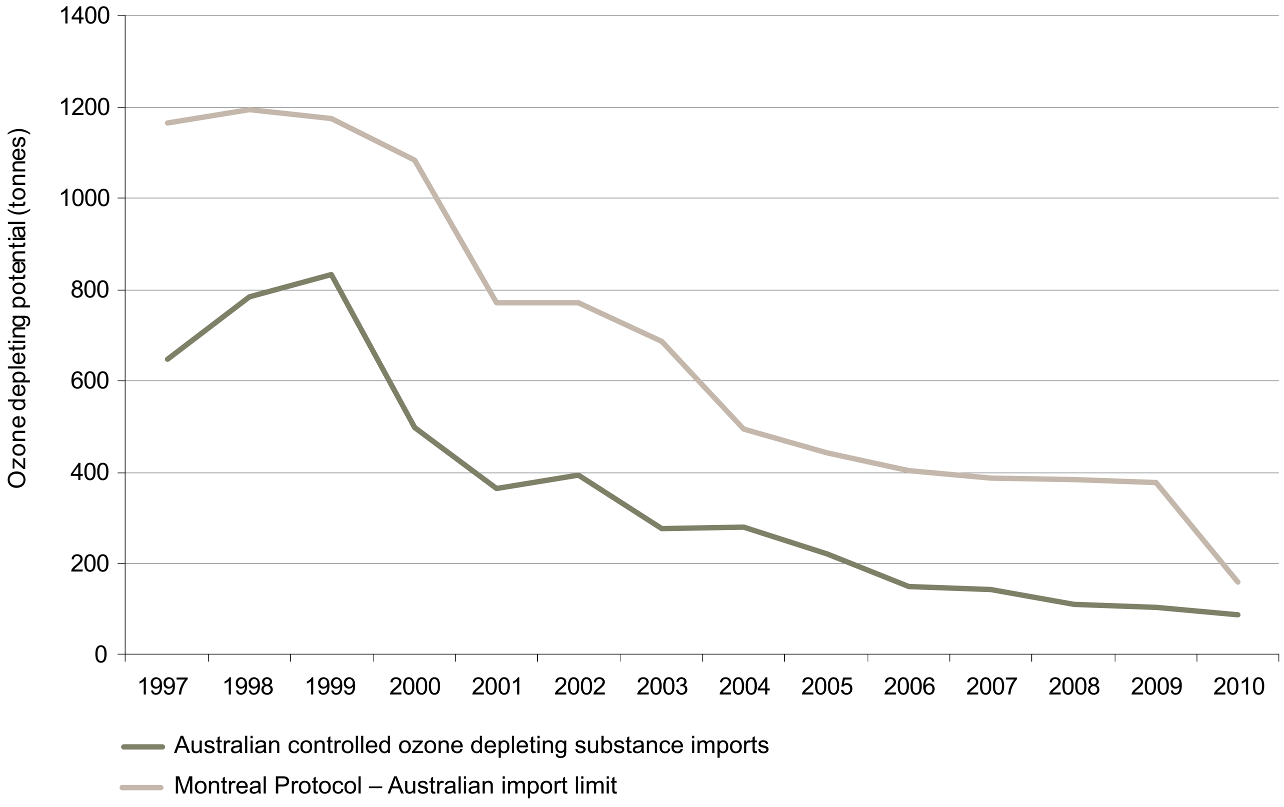
Australia was an early supporter of international efforts to protect the ozone layer and has ratified the Montreal Protocol and all subsequent amendments. It moved quickly to give legislative effect to its obligations under the protocol, establishing the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*. Australia's reduction in the use of substances controlled under the protocol (all of which are imported) has been well ahead of its international obligations (Figure 3.32). For example, Australia will essentially phase-out use of hydrochlorofluorocarbons four years ahead of 2020, the date scheduled under the protocol.[107]

3.3.2 Ambient air quality

National standards

At the national level, the Council of Australian Governments' Standing Council on Environment and Water (previously the Environment Protection and Heritage Council) meets regularly to deal with issues of common concern, including ambient air quality. These ministerial meetings provide a forum for agreement on priorities and resourcing for the development of NEPM standards, policies and programs, and for related studies and other activities.

For more than a decade, Australia has had national standards and goals for ambient air quality (AAQ NEPM), which are based on strong empirical evidence about the health impacts of major pollutants. The standards are enshrined in law, and performance against them is regularly monitored in all our major cities and publicly reported. Achievement of the 10-year air quality goals established in the NEPM depends to a great extent on the effectiveness of actions (both regulatory and nonregulatory) taken by the states and territories to control point and nonpoint pollution sources. Although it is up to the individual state and territory governments how they go about achieving the NEPM



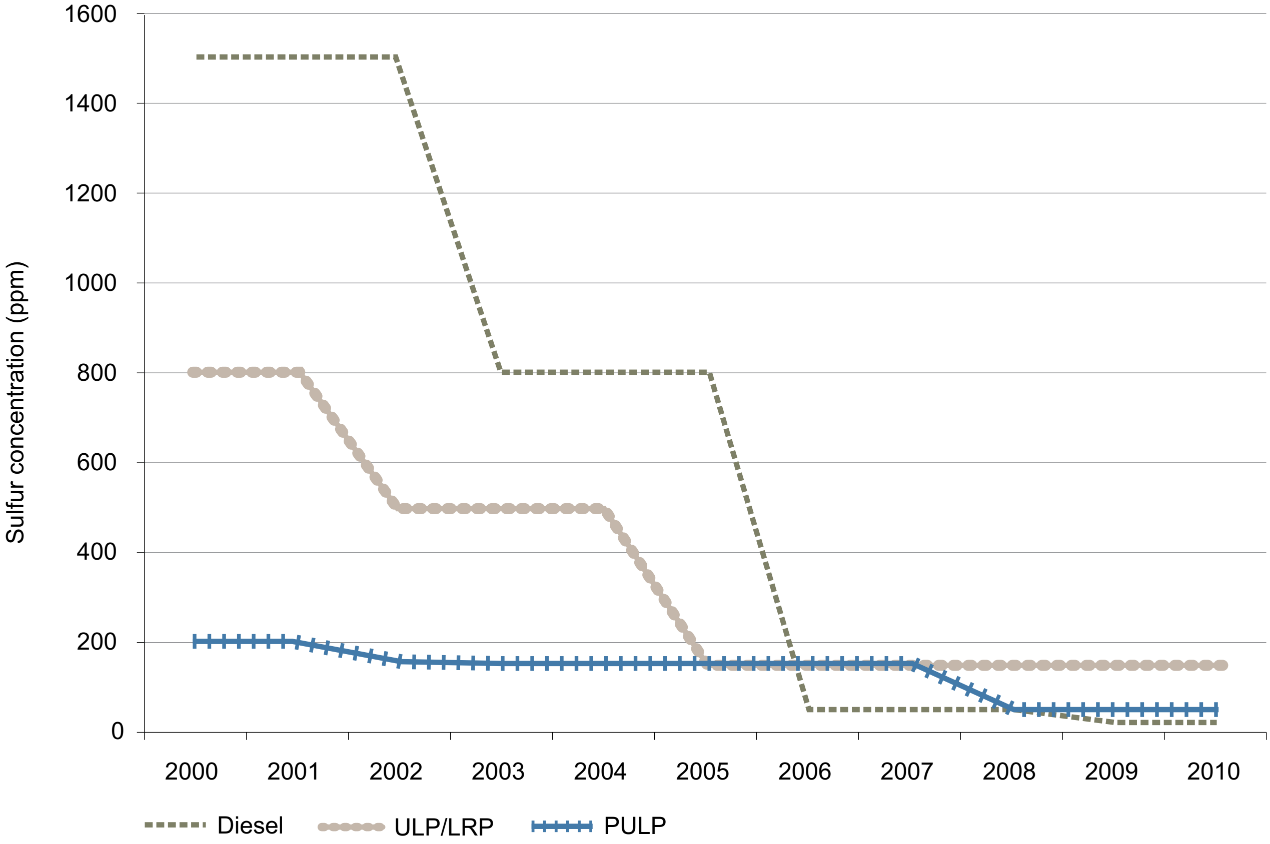
Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities[172]

Figure 3.32 Australia's performance against Montreal Protocol obligations for controlled ozone depleting substance imports goals, the system of public reporting allows interest groups and members of the public to pressure governments and regulators if progress to improve air quality is judged to be lacking or too slow.

The Australian Government also plays an important role in achieving air quality goals, chiefly through its powers to set emission standards for new vehicles (through the Australian Design Rules—ADRs) and fuel quality standards. ADRs are established under the *Motor Vehicle Standards Act 1989*, while vehicle fuel quality standards are set through the *Fuel Quality Standards Act 2000*.

Responding to growing concern over particle and NO_x pollution from diesel vehicles, the National Environment Protection (Diesel Vehicle Emissions) Measure was established in 2001. Unlike the ADRs that set standards for new petrol and diesel vehicles, the diesel emissions NEPM targets in-service vehicles (which are a state responsibility), establishing a range of strategies for governments to employ to reduce emissions.[173-174]

Although, in the past, Australian emission and fuel quality standards have lagged behind equivalent overseas standards, they have been progressively tightened to require more sophisticated vehicle engine and emission-control systems and improved fuel quality. Recent improvements in fuel quality have focused on greatly reducing sulfur content (particularly important in diesel engines, where high sulfur levels prevent the use of catalytic particle filters and NO_x adsorbers) and lowering the volatility of fuels to reduce evaporative losses (a major source of VOCs) (Figure 3.33).



ppm = parts per million

Source: Australian Government Department of the Environment, Water, Heritage and the Arts[175]

Figure 3.33 Sulfur levels in premium unleaded petrol (PULP), unleaded or lead replacement petrol (ULP/LRP) and diesel, 2000–10

Point sources of pollution—industry

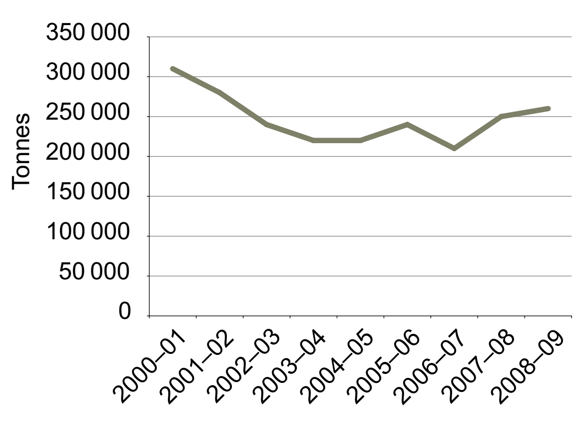
Environment agencies in the states and territories are responsible for controlling emission of pollutants from large industrial point sources, such as power stations, refineries, smelters, manufacturing plants, cement works and abattoirs. Various regulatory measures (including works approvals, licences and notices), together with emissions monitoring and modelling, and enforcement programs, are used to prevent emissions from individual point sources affecting health or amenity at the local level and to prevent such sources collectively leading to exceedence of national ambient standards at a larger scale. These tools are often supplemented by nonregulatory approaches, such as industry codes of best practice and programs to assist firms to identify and implement cleaner production approaches that provide both environmental and financial benefits.

Although discharges from industrial facilities are no longer the dominant source of most air pollutants in our metropolitan centres, a number of important regional centres host large-scale industrial facilities, such as metal smelters and petroleum refineries. Despite major gains in air quality achieved through improved pollution controls and cleaner forms of production, large industrial point sources still significantly affect air quality in some centres (e.g. Mount Isa and Port Pirie) and are therefore a focus for attention by environmental regulators.

Box 3.10 Major industrial point sources, Mount Isa

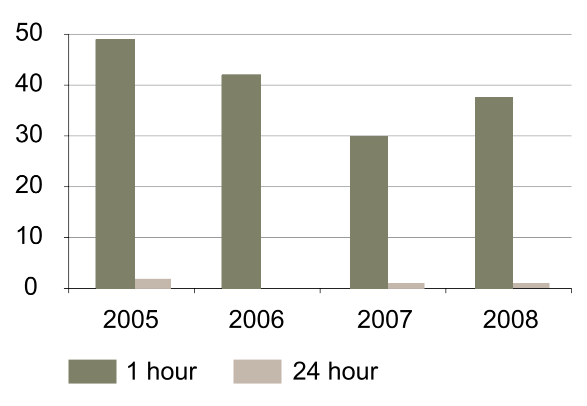
Mount Isa is home to one of Australia's largest lead and zinc smelters. The lead–zinc and copper smelters, operated by the global mining company Xstrata plc since its 2003 takeover of MIM Holdings, have been a source of concern to the local community for decades, chiefly due to their emissions of sulfur dioxide and lead. In May 2011, the company announced that it would phase out copper smelting at Mount Isa by the end of 2016. Until 2008, the smelters operated under the *Mount Isa Mines Limited Agreement Act 1985*. This was one of a number of special agreement Acts applied to specific major industrial facilities that overrode stricter controls under the *Environmental Protection Act 1994* and allowed much higher emission limits than elsewhere in Queensland.[176]

The MIM/Xstrata facilities met the relaxed requirements of the 1985 Act, including standards for sulfur dioxide and lead (as PM_{10}—particulate matter smaller than 10 micrometres) in ambient air, as measured at monitoring stations around Mount Isa. However, despite a general downward trend in total sulfur dioxide air emissions from 2000–01 to 2006–07 (linked to improved pollution controls and cleaner production measures), the one-hour NEPM sulfur dioxide standard continues to be exceeded on a number of occasions each year at Mount Isa's single NEPM monitoring station (Figures A and B).



Source: National Pollutant Inventory[177]

Figure A Total sulfur dioxide emissions to air, Mount Isa



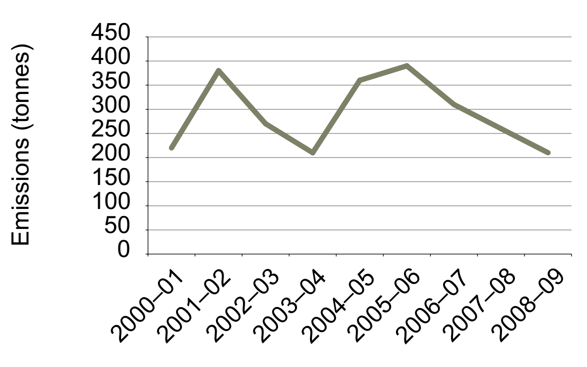
NEPM = National Environment Protection Measure

Source: Queensland Department of Environment and Resource Management (Queensland air monitoring reports)[178]

Figure B NEPM exceedences of sulfur dioxide, Mount Isa

Box 3.10 *continued*

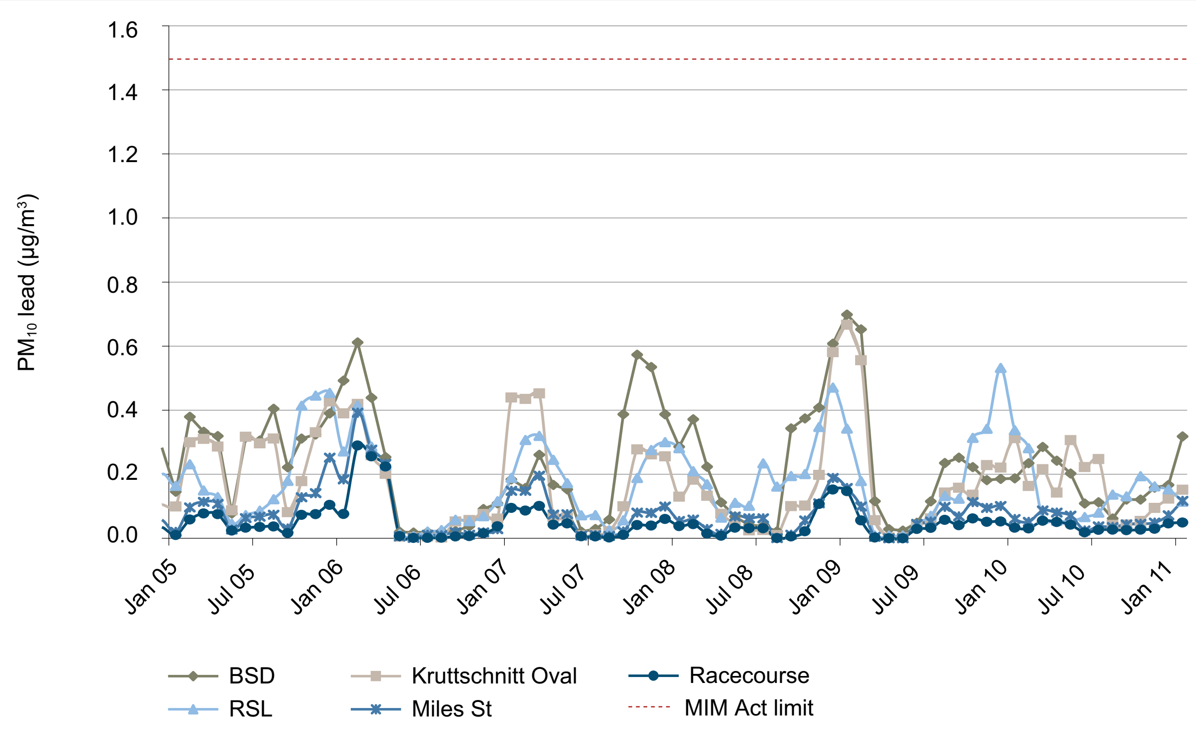
Figure C shows that Xstrata's total lead emissions have fluctuated over the past decade. Available data show a downward trend since 2005–06, which may reflect improvement in pollution controls. Ambient lead monitoring results from five stations around Mount Isa (which record lead as PM_{10}) show no clear reducing trend over the past five years. During that period, the NEPM annual average standard for lead of 0.50 micrograms per cubic metre was exceeded at three stations in 2008 and at one in 2009 (Figures D and E).



Source: National Pollutant Inventory[177]

Figure C Xstrata's total lead emissions to air, Mount Isa

The 2008 amendments to the environmental protection and related Acts established a three-year transitional period, during which the Mount Isa facilities (and other facilities covered by special agreement Acts) have to come in line with national ambient air quality standards. During this period, the Department of Environment and Resource Management has worked with Xstrata and the local community through the Living with Lead Alliance to define best-practice standards that the company will have to meet. These will include tighter emissions standards aimed at ensuring that Mount Isa's ambient air quality meets the national standards for sulfur dioxide, lead and other pollutants, as required under Queensland's Environmental Protection (Air) Policy.



BSD = Base Supply Depot; µg/m³ = microgram per cubic metre; RSL = Returned and Services League

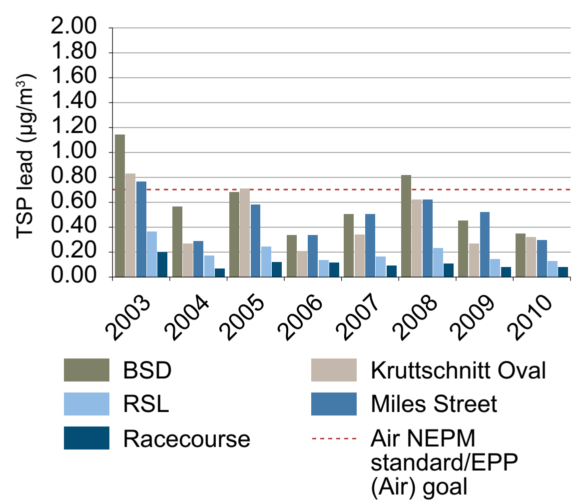
Source: Queensland Department of Environment and Resource Management[179]

Figure D PM_{10} lead concentration

A running quarterly concentration is calculated monthly.

Continued next page

Box 3.10 *continued*



BSD = Base Supply Depot; EPP = Environment Protection Policy; NEPM = National Environment Protection Measure; RSL = Returned and Services League

Source: Queensland Department of Environment and Resource Management[179]

Figure E Total suspended particulate (TSP) lead concentration

Data are to January 2011. Annual average concentration is based on a calendar year.

Diffuse sources of pollution—motor vehicles

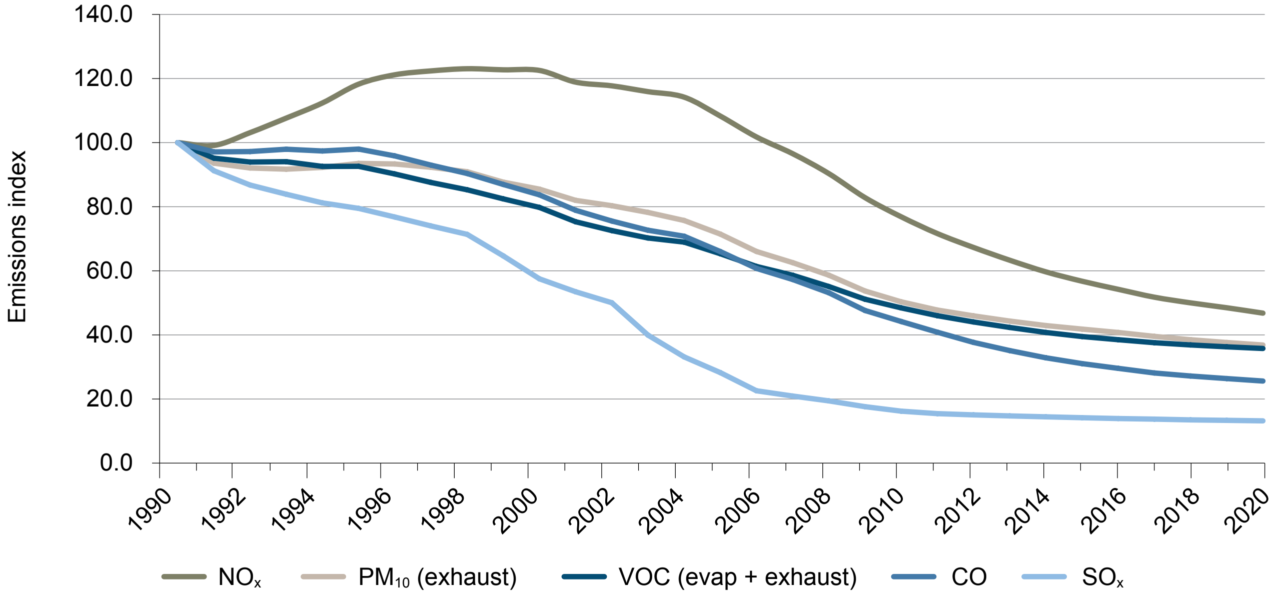
The nature and scale of the impact of motor vehicles on air quality in our major cities is generally well understood (e.g. Bureau of Infrastructure, Transport and Regional Economics;[180] Bureau of Transport and Regional Economics;[158] Environment Protection Authority Victoria[141,181]). Significant reductions in vehicular emissions followed the tightening of ADR emission limits for carbon monoxide and hydrocarbons in 1986, and the national introduction of three-way catalytic converters and unleaded fuel in the 1990s. These reductions have been maintained, despite increasing numbers of vehicles and distances travelled. By contrast, NO_x levels continued to rise through the 1990s, because ADR NO_x limits were not tightened until 1997–99, when ADR 37-01 was introduced. This, combined with continued growth in numbers of vehicles and distances travelled, resulted in a lag of several years before improved emission controls led to a plateauing of NO_x levels.

The Bureau of Infrastructure, Transport and Regional Economics has developed projections for metropolitan cities (Figure 3.34). These indicate continuing reductions in carbon monoxide, VOCs (evaporative and exhaust emissions), PM_{10} (exhaust emissions) and NO_x through to 2020, due to the increasing proportion of newer vehicles that meet the latest ADR requirements for engine and emission controls, and to improved fuel standards. However, the projections are based on a 'business as usual' case—that is, continued economic and population growth, no domestic carbon price in place, no further emission standards (after 2007–08 for diesel vehicles and 2008–10 for light-duty petrol vehicles), and only mid-range increases in future petrol prices (based on International Energy Agency reference case projections). As a result, they do not factor in further reductions in emissions that should follow the progressive introduction of tighter standards announced by the Australian Government in June 2011.[182]

From 1 November 2013, Euro 5 emission standards for light vehicles will apply to all new-model vehicles, with existing models to comply from 1 November 2016. All new-model vehicles must comply with Euro 6 standards from 1 July 2017. Existing model vehicles must meet Euro 6 standards from 1 July 2018.[183] As the regulation impact statement for the review of the Euro 5/6 light vehicle standards noted: '[adoption of the standards] would lead to significant reductions in NO_x emissions from petrol vehicles, and HC and NO_x emissions from diesel vehicles, and dramatic reductions in PM emissions from diesel vehicles'.[183] Table 3.10 summarises the expected improvement in emissions.

These improvements, together with those associated with the earlier introduction of Euro 3 and Euro 4 standards, should continue to counter the effect of further growth in vehicle numbers and distances travelled.[184-186] However, although the general outlook is therefore encouraging, it needs to be acknowledged that local vehicle pollution 'hot spots' continue to exist in our major cities. These are usually associated with very heavily trafficked roads, often carrying a significant proportion of heavy commercial vehicles through residential areas.[181] There is a growing body of evidence that residents living on or near such roads not only experience loss of amenity, but also suffer a range of adverse health effects.[187-188]

Although diesel-fuelled registered vehicles still constitute only a relatively small fraction of all registered vehicles (2.2 million, or 13.8%, at 31 March 2010), these figures represent an increase of 57.4% over the previous five years.[186] The progressive tightening of diesel fuel standards is expected to contribute to a reduction in particle and NO_x levels over time (Figure 3.34) by enabling the use of catalytic particle filters and NO_x adsorbers. The case study in



CO = carbon monoxide; NO_x = nitrogen oxides; PM_{10} = particulate matter smaller than 10 micrometres; SO_x = sulfur oxides; VOC (evap + exhaust) = volatile organic compounds from evaporative and exhaust emissions

Source: Bureau of Infrastructure, Transport and Regional Economics;[180] D Cosgrove, Principal Research Scientist, Bureau of Infrastructure, Transport and Regional Economics, pers. comm., May 2011

Figure 3.34 Base-case projected growth in major pollutant emissions from motor vehicles for Australian metropolitan areas, 1990–2020 (index with 1990 = 100)

'Metropolitan' refers to all travel undertaken within the eight state and territory capital cities.

Box 3.12 describes how agencies in New South Wales are working to build on the gains flowing from improved diesel fuel standards by supporting the retrofitting of exhaust emission-control devices to diesel engines in both on-road and off-road situations.

Diffuse sources of pollution—commercial and domestic

In major urban centres, air quality is also affected by many small commercial sources whose size and large numbers generally make a licence-based approach to control inefficient and impracticable. Similarly, numerous small domestic sources, such as lawn mowers and solid-fuel heaters, add to the overall burden of urban air pollutants and are difficult to regulate.

When problems do arise with small commercial sources, they often take the form of a loss of local amenity due to emissions of odour, dust or noise. Environment protection regulators most often come in contact with these local problems as a result of complaints from neighbours. Responses can include regulatory tools, such as abatement notices and compulsory works orders, or requirements to carry out an environmental audit to clarify the source of the problem and identify the most effective solution.

Table 3.10 Emissions reduction from adoption of Euro 5 and Euro 6 light vehicle standards

	Emission reduction (%)[a]					
	Euro 4 → Euro 5			Euro 5 → Euro 6		
Vehicle fuel type	HCs	NO_x	PM	HCs	NO_x	PM
Petrol/LPG	–	25	na	–	–	–
Diesel (and direct injection petrol)	25	30	80–90	26–40	55	–

– = no change; HCs = hydrocarbons; LPG = liquefied petroleum gas; na = not applicable; NO_x = nitrogen oxides; PM = particulate matter

a To nearest 5%; a range indicates that the percentage reduction varies with vehicle category.

Source: Australian Government Department of Infrastructure and Transport[183]

Box 3.11 Nitrogen dioxide—a future concern?

Although the outlook for the immediate future is for further reductions in motor vehicle emissions (primarily nitrogen oxides [NO_x] and carbon monoxide), this is no basis for complacency, as the number of vehicles and total distance travelled continue to increase, potentially eroding past gains achieved through tighter standards and improved technology. In this context, it is worth noting increased concern in Europe over rising levels of nitrogen dioxide in urban air, attributable to vehicle emissions.[189]

This increase is associated with an increase in the nitrogen dioxide:NO_x emissions ratio from road traffic. A study of roadside nitrogen dioxide and NO_x levels in London from 1997 to 2003 showed a statistically significant fall in NO_x averaged across 36 sites, but no significant trend in nitrogen dioxide. The study concluded that the increasing use of certain types of diesel particle filters on buses contributed significantly to the observed change, along with the growth in numbers of diesel passenger cars, and new technologies and management approaches being applied to light and heavy engines. Although peak nitrogen dioxide levels in Australia's cities are only half to one-third the NEPM standard, the importance of diesel vehicles in the Australian fleet is continuing to increase, so the possibility of unintended consequences flowing from some types of improved diesel engine controls will need to be considered.[6,190]

Often, however, such problems are best addressed proactively and at a larger scale, working with industry associations to inform small to medium-sized firms of cost-effective ways of improving environmental performance. In Victoria, the Environment Protection Authority has combined with the Victorian Employers' Chamber of Commerce and Industry to run Grow Me the Money®.[b,192] This program assists firms to carry out audits and develop and implement action plans that will improve environmental outcomes (and often their relations with the neighbours), while improving their 'bottom line'. A number of states operate similar cooperative schemes—for example, the CleanBiz program in Tasmania.[c]

Well-framed state land-use planning policies, together with local planning schemes and permits, also play an important part in preventing loss of local amenity due to emissions of odour, dust and noise from industrial and commercial premises. Use of planning controls to isolate offensive industrial and commercial operations from residential and other sensitive land uses is not an alternative to requiring such operations to comply with relevant environmental laws. However, planning controls have an important role to play by:

- preventing sensitive uses from 'coming to the menace' (i.e. locating near incompatible noxious or dangerous facilities)
- setting planning permit conditions that complement the requirements of environment protection regulators.[193]

Since the banning of incinerators from suburban backyards during the 1980s and 1990s, smoke from solid-fuel home heating has been the focus of concern about particulate pollution from domestic premises. Open fires and heaters that do not meet the relevant Australian standards (notably AS/NZS 2918 relating to installation, AS/NZS 4012 relating to power and efficiency, and AS/NZS 4013 relating to the rate of particle emission) are the major source of the problem. When compared with noncompliant appliances, modern compliant wood heaters should generate less than half the particulate pollution per kilogram of wood burned and one-third the pollution of open fires.

Box 3.12 Diesel vehicles pollution reduction programs

New South Wales (NSW) has been running two separate programs focusing on reducing exhaust emissions from diesel vehicles.

Diesel vehicle retrofit program

The NSW Office of Environment and Heritage, in conjunction with the NSW Roads and Transport Authority, has established a diesel vehicle retrofit program,[191] which involves retrofitting engine exhausts with pollution reduction devices, primarily to reduce particulate pollution. Some devices can also reduce carbon monoxide and volatile organic compounds via a catalyst.

The program, which commenced in 2005, has had more than 70 vehicle fleets participate and has retrofitted 520 vehicles. As at April 2011, it is estimated that completed retrofits will result in 4.7 tonnes less particulate pollution per year.

Clean Machine Program

The NSW Clean Machine Program began in 2010. It aims to reduce diesel exhaust emissions from diesel plant and equipment used mainly in construction and industrial activities, such as cranes, dozers, loaders, graders, tractors and pumps.

The Office of Environment and Heritage partners with public sector and private sector organisations to implement the program through improved procurement practices, worksite guidelines and the subsidised retrofit of older engines with pollution reduction devices. As at April 2011, five organisations had formally joined the pilot program and committed to retrofit up to 35 machines.

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[b] www.growmethemoney.com.au
[c] www.environment.tas.gov.au/index.aspx?base=3119

However, as Meyer et al.[194] noted, measurement of in situ emission rates from some 20 households in Launceston showed that, when operated in homes, even compliant heaters do not meet the AS/NZS 4013 particle emission rate of four grams per kilogram of wood burned. The authors concluded that the main factor determining the rate of particle emissions is combustion efficiency, which depends on the rate of air flow. In most cases, they found that heaters were operated with dampers set to significantly reduce the air flow, thus generating higher PM$_{10}$ emissions. They further concluded that the test protocol specified in AS/NZS 4013 failed to accurately represent emissions performance in domestic usage and that it should be replaced by a test cycle that properly reflects actual domestic operational practices.

During the past decade, the Australian Government Department of Sustainability, Environment, Water, Population and Communities (and its predecessors) and environment agencies in affected states and the Australian Capital Territory have worked on a number of fronts to reduce domestic wood smoke in urban areas. In Launceston, which faced a chronic wood smoke problem, the Australian Government (working with the state government and the City of Launceston) made available $2.05 million in rebates to assist residents to replace open fires and older wood heaters with modern, less polluting heaters, including natural gas heaters. By its end in 2004, the program had achieved a reduction in wood heater use in households from 45% to 30%.[195]

Federal, state and territory attention has also focused on:

- supporting research into factors affecting emissions
- further improving installation and emission standards
- ensuring that new wood heaters meet the Australian standards (e.g. Victoria has required this via a statutory policy)
- informing potential purchasers of the importance of buying a compliant heater and having it properly installed
- running public education programs providing advice on best operating practices.

Planned burning

As noted in Section 3.2.2, recent work by the Environment Protection Division in Tasmania indicates that smoke from planned burns is a more significant source of diffuse particulate pollution than previously thought. The case study in Box 3.13 describes work being done in that state to monitor the effects of planned burning on air quality and to use real-time monitoring data to inform decision-making and management of burns.

3.3.3 Indoor air quality

Whereas Australia has had national standards and goals set for key pollutants in outdoor (i.e. ambient) air, there are no standards or guidelines for pollutant levels in indoor air. There are regulations and codes that address indoor air quality, but (with the exception of regulations dealing with gas heating appliances) these apply to workplaces and to commercial premises and public buildings, rather than to residential dwellings.[152] Despite these limitations, Australian governments have actively sought to improve indoor air quality through a range of interventions (both regulatory and nonregulatory) targeting environmental tobacco smoke and unflued gas heaters.

In the case of environmental tobacco smoke (also known as passive smoking), powers to control smoking in public places lie mostly with state and territory governments. All states and territories prohibit smoking in cinemas and theatres (originally motivated by concern over risk of fire), in most types of public transport and in areas where food is prepared. Over the past decade or so, most jurisdictions have extended such prohibitions to cover cars carrying children and a wide variety of public places, including government buildings, airports, premises where food is consumed, pubs and nightclubs, and shopping centres. Increasingly, similar bans are being applied to various outdoor public spaces. States and territories have also used occupational health and safety legislation to require smoke-free work environments.[198]

■ The Milky Way seen from Parkes, New South Wales
Photo by Phil Hart

Box 3.13 Tasmania’s planned burning issue

A key pressure on air quality in Tasmania is smoke emissions from planned (prescribed) burning that can impact on human health, amenity, tourism and viticulture. Most of the concern surrounds burning by the forestry industry in autumn, although other sectors contribute both in autumn and at other times of the year.

According to National Pollutant Inventory (NPI) data, smoke from planned burning contributes only 3% of total particle emissions in Tasmania.[a] However, a recent review indicates that the NPI methodology for estimating planned burn emissions is seriously deficient.[159] It is now estimated that smoke from planned burning is responsible for approximately 50–80% of total particle emissions in Tasmania (the proportion varies from year to year, depending on the level of burning undertaken).[196]

Tasmania’s Forest Practices Authority, in consultation with the Environment Protection Authority (EPA), has established the Coordinated Smoke Management System (CSMS).[b] The CSMS provides for the coordination of planned burns to minimise the risk of high smoke levels in individual airsheds. It restricts the number of burns on days when weather forecasts and modelling predict poor smoke dispersal. Participation is voluntary and is currently limited to major forestry operators and the Tasmanian Parks and Wildlife Service.

To facilitate the assessment of the effectiveness of the CSMS and to provide real-time air quality data that can be fed into the CSMS decision-making process, the BLANkET (Base-Line Air Network of EPA Tasmania) smoke-monitoring network has been established by the EPA. BLANkET consists of a network of 17 indicative air quality monitoring stations (Figure A). Stations are located in regions away from the major centres of Launceston and Hobart, but in areas near where the forest industry and other sectors conduct planned burns.

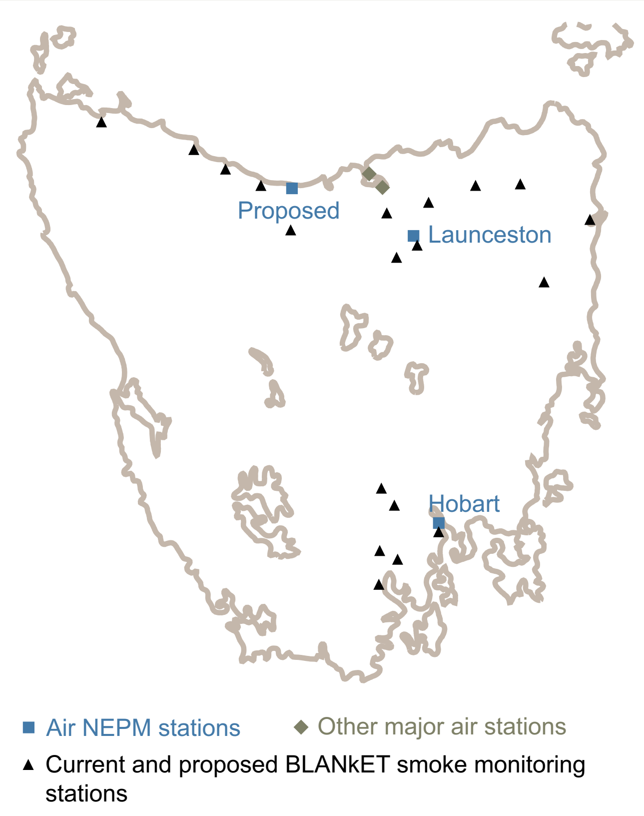

Figure A Air monitoring stations in Tasmania

Each BLANkET station consists of a low-cost optical particle counter that measures particulate matter smaller than 2.5 and 10 micrometres ($PM_{2.5}$ and PM_{10}), a meteorological station and a communications link. Real-time data are displayed on the EPA’s website.[c] Performance of the stations has been very good, and there is high correlation between data from BLANkET and from reference low-volume air samplers at National Environment Protection Measure (NEPM) monitoring stations. The indicative data collected from the BLANkET network show that daily average particle levels above the NEPM PM_{10} standard and the NEPM $PM_{2.5}$ reporting standard are sometimes measured in communities close to planned burn events.

The technology developed for the BLANkET network could also be used to facilitate the determination of population exposure to $PM_{2.5}$ and PM_{10}. For Tasmania, this approach is likely to provide a more realistic estimate of population exposure than inventory development and modelling, and at a lower cost.

Source: Tasmania Department of Primary Industries, Parks, Water and Environment (EPA Division)[197]

a www.npi.gov.au
b www.environment.tas.gov.au/file.aspx?id=7583
c www.environment.tas.gov.au

As noted in Section 3.2.3, there is concern about the impact of unflued gas heaters on indoor air quality and therefore health. Although these heaters are primarily known as a source of nitrogen dioxide, they also produce carbon monoxide and formaldehyde. Unflued gas heaters are regulated in all states and territories. Although the regulations vary between jurisdictions, they all require compliance with Australian standards AS 4553-2000 (AG 103-2000): Gas space heating appliances, and AS 5601-2002 (AG 601-2002): Gas installations.[199] However, as various studies have shown, conformity with the Australian standards does not guarantee that levels of nitrogen dioxide will not adversely affect health.[167-168]

In New South Wales, longstanding public concern over the use of unflued low-NO_x gas heaters in schools led the government to commission a major independent review of respiratory health effects on children exposed to such heaters. The review, by the Woolcock Institute of Medical Research, found that, although exposure to these heaters was not linked to significant reductions in lung function, it did cause an increase in respiratory symptoms, especially in children with a predisposition towards developing allergic reactions. The review concluded that 'it is important to seek alternative sources of heating that do not have adverse effects on health'.[200] In response, the New South Wales Minister for Education and Training announced in July 2010 that the use of unflued heaters would be phased out in all New South Wales public schools.[201]

Cosy living room with a modern gas fireplace
Photo by Werner Stoffberg

3.9 Assessment summary

Effectiveness of atmospheric management

Summary	Assessment grade				Confidence	
	Ineffective	Partially effective	Effective	Very effective	In grade	In trend
Stratospheric ozone						
Understanding: High level of understanding of nature and sources of ozone depleting substances (ODSs) and of the chemical processes through which they impact on stratospheric ozone. Likely future effect of greenhouse gases on recovery of stratospheric ozone is not as well understood. Links between reductions in ozone in the stratosphere, increased exposure to ultraviolet (UV) radiation and health effects (notably increased risk of skin cancer) are well understood				↗	●	●
Planning: Signatories to the Montreal Protocol have well-established planning, policy-setting and regulatory mechanisms to give effect to their obligations to phase out ODSs				—	●	●
Inputs: The necessary public and private sector resources are being applied to achieve phase-out schedules agreed under the Montreal Protocol. Assistance is available to developing nations to implement agreed phase-outs				—	●	●
Processes: A range of processes have been established under the Montreal Protocol to facilitate and monitor action by signatories to implement agreed phase-outs				—	●	●
Outputs and outcomes: World production of ODSs continues to decline, and monitoring shows that atmospheric levels of ODSs peaked in the mid-1990s				↗	●	●
Pollution (industrial point sources)						
Understanding: Very good understanding of air pollutants (types, sources and processes), of relevant industries and industrial processes, and of technologies and practices to prevent or control pollution				—	●	●
Planning: States and territories have well-established plans, policies and regulatory systems to monitor and control these sources				—	●	●
Inputs: Levels of resourcing to support regulatory and nonregulatory programs vary from jurisdiction to jurisdiction, generally reflecting the nature and extent of industrial sources in the state or territory				—	●	●
Processes: All jurisdictions have well-established process to monitor and control these sources, including inspection and enforcement processes				—	●	●
Outputs and outcomes: Jurisdictions apply works approvals, licensing and related regulatory mechanisms to limit types and quantities of pollutant emissions. Although performance levels vary, inspection and enforcement by environmental regulators, together with emissions monitoring and reporting, provide a sound basis for ensuring effective control of these sources				↗	●	●

Summary	Assessment grade				Confidence	
	Ineffective	Partially effective	Effective	Very effective	In grade	In trend
Pollution—diffuse sources (motor vehicles)						
Understanding: Very good understanding of pollution types, sources and processes, and of interaction of fuels and control technologies				—	●	●
Planning: Australian Government and state governments cooperate in relation to planning introduction of improved fuel and technology standards. Appropriate policy and legislative standards in place at national and state and territory levels				—	●	●
Inputs: Adequate resourcing at national level for development and enforcement of standards for fuels and new-vehicle technology. Resourcing for in-service vehicle testing and enforcement at state and territory level is variable			—		●	●
Processes: Respective roles of Australian Government and state and territory governments are clear. Well-established national processes for promulgating and enforcing fuel and new-vehicle emission-control standards, and good coordination between Australian Government and state and territory governments via ministerial councils and officials' working groups				—	●	●
Outputs and outcomes: National fuel and new-vehicle emission technology standards continue to be tightened. Bureau of Infrastructure, Transport and Regional Economics projections show continuing improvements in vehicle pollutant emissions until 2020			↗		●	●
Pollution—diffuse sources (commercial and domestic)						
Understanding: Generally sound understanding of pollution types, sources and processes (chiefly via the National Pollutant Inventory [NPI] and state agency emissions inventories), although the reliance on United States data for some NPI emission factors (in the absence of verification) raises concerns about the accuracy of some NPI data			—		●	●
Planning: States and territories and (in some jurisdictions) municipalities have established plans, policies and regulatory systems to monitor and control these sources			—		●	●
Inputs: Resourcing levels to support regulatory and nonregulatory programs vary from jurisdiction to jurisdiction and among municipalities			—		●	●
Processes: All states and territories (and many municipalities) have well-established processes to monitor and control these sources, including inspection and enforcement processes			—		●	●
Outputs and outcomes: Generally effective control of diffuse emissions such as volatile organic compounds from commercial premises and particles (wood smoke) from homes benefits air quality at both the airshed and local level. Ambient monitoring against the National Environment Protection (Ambient Air Quality) Measure standards shows that the standards are met on the great majority of days in all major cities. However, complaints about smoke and odour at the local level continue to be a major focus for investigation and enforcement action by state and municipal officials			—		●	●

Continued next page

Effectiveness of atmospheric management *continued*

Summary	Assessment grade				Confidence	
	Ineffective	Partially effective	Effective	Very effective	In grade	In trend
Pollution—diffuse sources (planned burning)						
Understanding: Recent work in Tasmania indicates that smoke from planned burns is a more significant source of diffuse particulate pollution than previously believed		↗			◒	◒
Planning: Burning for forestry regeneration and related operations and for fuel reduction and habitat management purposes on public land is subject to various guidelines or codes of practice and is usually well planned and executed. Individual property managers make decisions on timing for planned agricultural burning, but must observe any local, regional and statewide restrictions			—		◒	◒
Inputs: Highly variable; unable to assess					○	○
Processes: In most, if not all, states and territories, authorities responsible for planned burns associated with forest operations and management burns on public land have formal arrangements with environment protection agencies, health agencies and local municipalities, which cover prior notification, suitability of local meteorological conditions, monitoring and public health warnings			—		◒	◒
Outputs and outcomes: Although the position is variable among jurisdictions, there is anecdotal evidence indicating improved cooperation between agencies responsible for planned burning and environment and health authorities. There is also improved notification and greater recognition of the significance of local impacts on health, amenity, tourism and so on		↗			◒	◒

Summary	Assessment grade				Confidence	
	Ineffective	Partially effective	Effective	Very effective	In grade	In trend
Indoor air quality						
Understanding: Although understanding is improving as a result of recent studies, most have focused on particular problems, such as unflued gas heaters or environmental tobacco smoke		↗			◒	◒
Planning: Although there are Australian standards for building materials and home heating devices, there is no national standard for indoor air quality	—				◒	◒
Inputs: Variable across jurisdictions. Attention is largely restricted to unflued gas heaters and environmental tobacco smoke		—			◒	◒
Processes: Unflued gas heaters are regulated in all jurisdictions. There has been significant growth in restrictions on smoking indoors		↗			◒	◒
Outputs and outcomes: Some areas of significant improvement (e.g. restrictions on indoor smoking in public venues and workplaces; New South Wales phase-out of unflued gas heaters in public schools), but overall highly variable		↗			◒	◒

Recent trends
↗ Improving
— Stable
↙ Deteriorating
? Unclear

Confidence
● Adequate high-quality evidence and high level of consensus
◒ Limited evidence or limited consensus
○ Evidence and consensus too low to make an assessment

Grades
🟩 Very effective
🟫 Effective
🟧 Partially effective
🟥 Ineffective

3.4 Resilience of Australia's atmosphere

3.4.1 Stratospheric ozone

A number of the key ODSs persist in the atmosphere for long periods. Therefore, despite the success of the Montreal Protocol in phasing out CFCs and other major ODSs (apart from nitrous oxide), depletion of stratospheric ozone will continue for many decades.[104] The World Meteorological Organization's 2006 *Scientific assessment of ozone depletion* concluded that, averaged across the whole of the global atmosphere, the decline in ozone stopped around 1996.[202] The 2010 scientific assessment repeated this conclusion, noting that 'average total [column] ozone values in 2006–09 have remained at the same level for the past decade, about 3.5% and 2.5% below the 1964–1980 averages, respectively, for 90°S–90°N and 60°S–60°N'.[104] Similarly, monitoring of the maximum area of the Antarctic ozone hole (Figure 3.21) shows it to have been relatively stable since the mid-1990s. Recent simulations of the continuing effects of controls under the Montreal Protocol indicate that the time for total column ozone to recover to 1980 benchmark levels will vary with latitude and will occur last over Antarctica around 2045 to 2060. This recovery will occur well before stratospheric levels of ODS-derived chlorine and bromine decline to 1980 levels.[104]

At a glance

Recent simulations of the continuing effects of controls under the Montreal Protocol indicate that the time for total column ozone (i.e. the ozone in a column of air between the ground and outer space) to recover to 1980 benchmark levels will vary with latitude and will occur last over Antarctica around 2045 to 2060.

The frequency, duration and severity of episodes of poor air quality in urban centres are strongly influenced by short-term meteorological conditions (principally temperature and wind conditions), in combination with local topography. Air quality is usually restored to acceptable levels once the immediate conditions change. Therefore, our urban airsheds may be considered highly 'resilient', in terms of the common dictionary definition of the word, but human resilience to the effects of prolonged or recurring exposure to air pollutants is limited.

3.4.2 Ambient air quality

Australia's metropolitan cities all experience episodes of poor air quality (measured in terms of particulate pollution, or pollution by ozone and its precursors NO_x and VOCs). The frequency, duration and severity of these episodes are strongly influenced by short-term meteorological conditions (principally temperature and wind conditions), in combination with local topography. Air quality is usually restored to acceptable levels once the immediate conditions change. In this context, our major urban airsheds are highly 'resilient', in terms of the common dictionary definition of the word. In contrast, application of the ecologically meaningful terms 'resilience', 'sensitivity' and 'adaptability' to the atmospheres of urban places is not particularly helpful in understanding either their dynamics or the effects of localised or widespread inputs of pollutants. However, if urban air pollution is considered from the perspective of the humans who cause most of it and are impacted by it, then resilience is a more useful concept.

Human resilience in the face of prolonged or recurring exposure to air pollutants is limited. Individuals vary in their sensitivity to exposure to particular air pollutants, with those most sensitive accounting for the great majority of the observed deaths and illness attributed to poor air quality. Unfortunately, our capacity to adapt to unacceptably high levels of air pollution is inherently limited. We can leave the affected area, shelter indoors (of limited value without effective air filtering), avoid strenuous exercise, wear face masks and, in the case of asthmatics and others with respiratory ailments, take prescribed medicines. Although necessary during periods of very poor air quality, these short-term adaptive strategies are not substitutes for action to mitigate the pollution at source through a range of regulatory and nonregulatory measures.

3.5 Risks to Australia's atmosphere

3.5.1 Stratospheric ozone

As discussed in Sections 3.3.1 and 3.4.1, the prognosis for the future of the stratospheric ozone layer over the next half-century is one of continuing recovery. Over that period, GHGs (notably carbon dioxide, methane and nitrous oxide) that are not controlled under the Montreal Protocol are expected to significantly affect future stratospheric ozone levels.[104,156]

Unlike carbon dioxide and methane—whose net effects are likely to be positive for the eventual recovery of the ozone layer—human-sourced emissions of nitrous oxide will have a negative impact. (In terms of their weighted ozone depleting potential, nitrous oxide emissions are larger than any of the ODSs controlled under the Montreal Protocol and are growing.) Consequently, as Ravishankara et al.[156] noted, 'increases in anthropogenic N_2O [nitrous oxide] emissions or decreases due to abatement strategies would … affect the date for the recovery of the ozone layer'. A delay in the recovery date could delay realisation of certain health benefits (principally avoided cases of skin cancer) that are expected to accompany recovery. On the other hand, there is also the potential for reducing the recovery period through effective action to reduce nitrous oxide emissions.

At a glance

Greenhouse gases (notably carbon dioxide, methane and nitrous oxide) that are not controlled under the Montreal Protocol are expected to significantly affect future stratospheric ozone levels. In the case of carbon dioxide and methane, the effect is expected to be positive, but human-sourced emissions of nitrous oxide could (in the absence of effective abatement strategies) slow the rate of recovery of stratospheric ozone levels. Should that occur, it could delay the full realisation of health benefits expected to accompany the recovery.

During the past 30 or so years, state and territory environment protection agencies (often working together with local government) have successfully employed regulatory and nonregulatory measures to greatly reduce threats to urban air quality from industrial and commercial activities. The risk of this situation changing markedly during the next decade is assessed as low, despite continuing growth of the economy. Similarly, the risk of a significant decline in local air quality due to increase in particle (wood smoke) pollution from domestic sources is assessed as low.

Motor vehicles are the main diffuse source of air pollution in urban areas, and the size of the Australian fleet is continuing to grow, as are the distances travelled. Despite this, projections to 2020 indicate a continued decline in vehicle emissions of the main air pollutants (carbon monoxide, nitrogen oxides [NO_x], particles and volatile organic compounds [VOCs]). This positive outlook is strengthened by the Australian Government's recent (June 2011) announcement of the progressive introduction of tighter emission-control standards, starting in 2013. Taking into account these competing factors, the risk of a marked deterioration in urban air quality over the next decade is conservatively assessed as medium.

The higher temperatures associated with climate change are expected to elevate ambient levels of VOCs, increasing the potential for ozone pollution in Australia's larger metropolitan centres, where peak ozone levels already at times exceed national air quality standards. Climate change is also expected to affect the likelihood of bushfires, which, depending on location, can cause very serious particulate pollution in population centres. The level of risk associated with these outcomes is assessed as medium.

Rising domestic heating and cooling costs can be expected to promote better sealing of dwellings to reduce loss of heated and cooled air. This will lead to reduced air exchange rates and a deterioration in indoor air quality.

3.5.2 Ambient air quality

Industrial point sources

If not effectively controlled, emissions from industry can place health and amenity at risk, not only at the neighbourhood level, but more generally at the airshed level. During the past 30 or so years, state and territory environment protection agencies (working together with local government) have successfully employed a range of measures (both regulatory and nonregulatory) to greatly reduce the threat from industrial sources. As a result, apart from in major industrial centres or smaller centres with one or two significant industrial sources, diffuse sources (motor vehicles and commercial and domestic sources) tend to be the more important threats to urban air quality at an airshed scale.

A possible exception to this generalisation is the potential impact on urban air quality that could accompany any significant increase in local generation of electricity using cogeneration (i.e. combined heat and power) facilities. As noted by the Victorian Environment Protection Authority:

> … cogeneration facilities can yield significant greenhouse emissions reduction benefits, but may pose a potential threat to air quality, as the burning of natural gas releases significant amounts of NO_x. Air quality considerations will therefore be taken into account where cogeneration facilities are proposed in urban areas.[203]

Diffuse sources—motor vehicles

Motor vehicles are a significant source of anthropogenic carbon dioxide emissions in Australia, comprising some 90% of transport emissions, which in turn made up 15% of Australia's net carbon dioxide equivalent emissions in 2009.[13,43] However, despite their contribution to climate change, the most immediate threat posed by motor vehicles is to air quality at the urban airshed scale, where vehicles typically account for around 80% of carbon monoxide emissions, two-thirds of NO_x, 40% of VOCs and 30% of particles (as PM_{10}).[157]

From 2005 to 2010, motor vehicle registrations increased by 15.4% (averaging 2.9% annually); the bulk of this growth was in passenger vehicles, which make up 76% of the total Australian fleet.[186] If growth were to be maintained at this rate, the number of vehicles would double in 24 years.
As noted earlier in this chapter, despite significant growth in vehicle numbers and distances travelled (which increased by 6.8% between 2003 and 2007), advances in motor vehicle engine and emission-control technology (together with improved fuel standards) have driven down emissions of carbon monoxide and VOCs.[180,185] Projections to 2020 show these gains being maintained and levels of NO_x declining. (These projections are based on a 'business as usual' scenario that does not factor in the progressive application of tighter emission-control standards starting in 2013, which should reinforce the projected gains.)

The threat, however, is that the combination of increasing vehicle numbers, distance travelled and congestion (which leads to more exhaust and evaporative emissions) may in future cancel out gains in technology, resulting in increased impacts on health and reduced amenity. For example, emerging concerns in Europe over increases in vehicle emissions of nitrogen dioxide accompanying technology-driven reductions in NO_x could foreshadow similar concerns in Australia, if the proportion of diesel vehicles in the fleet continues to grow. (Data show diesel registered vehicles increasing from 10.1% of the fleet to 13.8% between 2005 and 2010.[186])

Diffuse sources—commercial and domestic

Commercial premises can pose a threat to health and amenity at the local level, mainly through emissions of particles and VOCs. VOC sources include aerosols, surface-coating operations and solvents (the latter being a particular cause of odour complaints). Commercial food-processing operations can also place local amenity at risk due to odour emissions. As previously discussed, smoke from poorly designed and operated domestic wood heaters can pose a significant seasonal risk to amenity and health at both neighbourhood and airshed scales. Collectively, domestic and commercial sources annually contribute around one-third of VOCs to the Sydney and Melbourne airsheds, and approximately one-quarter to one-third to particulate pollution in Sydney and one-half in Melbourne. In the case of Melbourne, the contribution of both VOCs and particles is concentrated in winter, as it is strongly associated with domestic heating.[157,204]

Climate change

Climate change poses a threat to urban air quality and health through increases in particulate pollution (associated with more frequent bushfires and dust storms) and increases in the formation of ozone and other components of photochemical smog. The latter phenomenon is driven by increasing temperatures, and long-range transport of pollutants associated with large-scale changes in atmospheric circulation.[205]

3.5.3 Indoor air quality

Despite significant reductions in the percentage of Australian homes using wood as a source of home heating,[206] the cost of the main alternatives to wood (i.e. electricity and gas) have risen steeply in recent years and can be expected to continue to rise.[207] Such rises may create pressure on households to return to open fires or wood heaters for domestic heating. Should that occur, the quality of indoor air in those homes can be expected to be adversely affected, since any form of fuel burning in a dwelling has been shown to be positively correlated with carbon dioxide, carbon monoxide, nitrogen dioxide and $PM_{2.5}$.[154]

Similarly, increasing concern over heating efficiency and loss of heat through poorly fitting fixtures, such as doors and windows, is likely to lead to better home sealing to prevent loss of heat during winter and cool air in summer. If ventilation is reduced in this way, levels of indoor pollutants can be expected to rise.

3.10 Assessment summary

Current and emerging risks to Australia’s atmosphere

	Catastrophic	Major	Moderate	Minor	Insignificant
Almost certain					
Likely					
Possible			🟧 Increased deaths and illness associated with air pollution from growing motor vehicle fleet 🟧 Adverse health impacts due to increased ground-level ozone linked to rising temperatures 🟧 Deterioration of indoor air quality due to better sealing of buildings		

	Catastrophic	Major	Moderate	Minor	Insignificant
Unlikely			🟧 Localised impacts on health and amenity due to increased air pollution from commercial and domestic sources 🟧 Localised impacts on health and amenity due to increased air pollution from industry 🟧 Delayed recovery of stratospheric ozone layer, leading to a slowdown in expected reduction in skin cancer rates		
Rare					

⬜ Not considered

Note: Timeframes are within the next 50 years (stratospheric ozone) and within the next 20 years (urban air quality).
Explanation of terms:

Almost certain: >90% probability of occurring during the specified timeframe

Likely: >66% – ≤90% probability of occurring during the specified timeframe

Possible: >33% – ≤66% probability of occurring during the specified timeframe

Unlikely: >10% – ≤33% probability of occurring during the specified timeframe

3.6 Outlook for Australia's atmosphere

Global observations of atmospheric levels of the major ODSs show that they peaked in the mid-1990s and have declined since then. This has led to a parallel decline in the stratospheric levels of the breakdown products of ODSs responsible for destroying ozone. The decline is expected to continue with the ongoing phase-out of these ODSs under the Montreal Protocol. As a result, the prospects for recovery of the stratospheric ozone layer to 1980 benchmark levels by around mid-century continue to be good.

Air quality in Australia's major urban centres is generally good. Levels of carbon monoxide, lead, nitrogen dioxide and sulfur dioxide have decreased over the past two decades; however, ozone and particle levels have not declined. National health-based standards are rarely exceeded for prolonged periods, and very high levels of pollution are usually associated with short-lived extreme events such as bushfires and dust storms, which generate very high levels of particulate pollution.

Despite this broadly favourable situation, there is clear evidence that such periods of poor urban air quality have serious adverse impact on human health (particularly on the health of susceptible individuals). Research into the health effects of particles and ozone, along with pollutants such as sulfur dioxide, indicates that there is no threshold level below which they have no health effect. This means that sensitive individuals, such as asthmatics and people with respiratory or cardiovascular disease, may be affected even when air quality standards are met.[6]

Emissions of air pollutants from major industrial point sources are generally well controlled in all Australian jurisdictions. Their effect on urban air quality is unlikely to increase, and may well diminish with the continued uptake of cleaner technologies. Similarly, there is no evidence to suggest that urban air quality will decline due to an increase in emissions from diffuse commercial sources. As is the case with industrial sources, continuing uptake of improved practices and technologies (driven by a desire for improved efficiency, as well as by the prompting of regulators) may see a reduction in emissions of some pollutants such as VOCs.

At a glance

As a result of the success of the Montreal Protocol in controlling ozone depleting substances, the stratospheric ozone layer is expected to recover to 1980 benchmark levels by around mid-century.

The outlook for Australia's urban air quality is generally good. However, there is clear evidence that periods of poor urban air quality (usually associated with short-lived extreme events) have serious adverse impact on human health (particularly on the health of susceptible individuals). Although levels of carbon monoxide, lead, nitrogen dioxide and sulfur dioxide have decreased over the past 10 years, ozone and particle levels have not declined, and ongoing effort will be required to secure past gains and achieve further improvements. Prospects for achieving reductions in levels of ozone and particles will be influenced by a number of factors, most notably vehicle technology, the extent of ongoing urban sprawl, the availability of reliable public transport, and the impact of climate change on urban airsheds.

There are limited Australian data on which to assess the outlook for indoor air quality. Despite this, the marked increase in government intervention to restrict areas in which smoking is permitted indoors provides grounds for suggesting an improving trend in indoor air quality, at least in commercial premises where food is prepared or consumed, in shopping malls and in public buildings.

Air pollution from domestic sources (largely particulate pollution from wood smoke) can be expected to continue to reduce air quality at the neighbourhood level in areas where wood heaters are still widely used. However, unless rising costs of domestic heating prompt a marked increase in the use of wood as a fuel, domestic premises are unlikely to be a source of significant deterioration in urban air quality.

Motor vehicles are the main diffuse source of air pollution in urban areas, and the size of the Australian fleet is continuing to grow, as are the distances travelled. Despite this, and despite concerns about the effects of growing traffic congestion and continuing urban sprawl on air quality, projections to 2020 (based on a 'business as usual' scenario, which does not include further tightening of emission standards) indicate a continued decline in vehicle emissions of the main air pollutants (carbon monoxide, NO_x, particles and VOCs).[184] The recently announced progressive introduction of tighter emission controls (Euro 5 starts in 2013 and Euro 6 in 2017) should reinforce these projected gains.[182]

There are reasonable grounds for optimism that reductions achieved in some urban air pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, lead) during the past decade can be maintained or even extended. However, this is not the case with particles or the secondary pollutant, ozone. Monitoring results for these pollutants continue to show that peak ozone levels occasionally exceed the standard in some centres and that standards for particulate pollution are often exceeded for short periods in most metropolitan cities.[6] Prospects of achieving significant reductions in peak levels of particles and ozone will be influenced by:

- the rate at which vehicles (particularly passenger vehicles) shift to hybrid, electric, or other forms of low-emission or no-emission propulsion
- improvements in public transport
- increased take-up of cleaner forms of production
- continuing reductions in the use of wood as a fuel for domestic heating
- urban sprawl.

Perhaps the largest influence will be the rising temperatures and more frequent extreme events associated with climate change.

The outlook for indoor air quality is difficult to assess because of the limited availability of Australian data upon which to form assessments of overall status and trend. Nevertheless, it is likely that increasing levels of restriction on smoking indoors will produce improvements in the quality of indoor air, at least in public venues and workplaces.

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■ Thunderstorm over Darwin, Northern Territory
Photo by Jacci Ingham

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