Atmosphere

A0 Introduction

Key Findings

- Victoria has warmed by 0.6°C since the 1950s; a faster rate of warming than the Australian average and the last ten years have been hotter than average in Victoria, with 2007 being the hottest year on record.
- Since 1990, changes to both global temperature and sea level have tracked at the upper limit of projections, indicating that projections may be underestimates of likely climate change scenarios.
- Victoria's greenhouse emissions have increased by approximately 12% since 1990.
- Full recovery of stratospheric ozone is possible but is highly dependent upon adherence of both developed and developing countries to international agreements. In addition, an enhanced greenhouse effect and future atmospheric concentration of nitrous oxide and methane may reverse anticipated ozone recovery.
- By international standards, Victoria has good air quality. Increased frequency and severity of bushfires, and low rainfall attributed to climate change, will produce added pressures on air quality. The higher temperatures may also lead to a greater potential for ozone formation leading to increased incidence of smog.
- Australia has particular vulnerabilities to climate change and environmental degradation, but these should not act as a constraint on its environmental policy responses, rather they increase the risk of not acting strongly and urgently to climate change risks.
- The window of opportunity to stabilise levels of greenhouse gas emissions is rapidly diminishing.

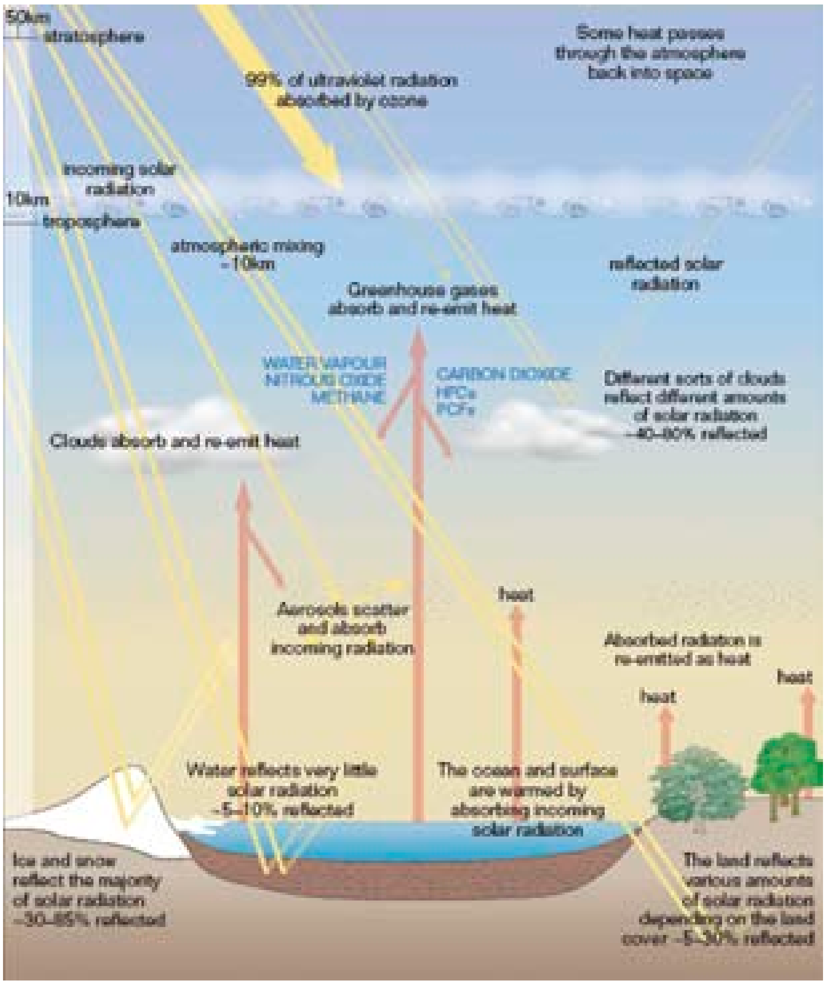
Victorian atmosphere assets

The Earth's atmosphere is about 800 kilometres thick. It protects living things from harmful solar radiation and ensures a suitable temperature range for life as well as providing the air that we breathe and providing the transport mechanism for water molecules that fall as rain. Air is a mixture of oxygen, nitrogen, carbon dioxide and other gases such as hydrogen and ozone. These gases are densest in the boundary layer at the Earth's surface where a very thin skin of air supports life (see Figure A 0.1). The atmosphere provides essential ecosystem services, but continued provision of those services is threatened by human activities.

A key service provided by the atmosphere is moderation of the climate. Victoria's climate is naturally highly variable. El Niño, La Niña and the Southern Oscillation create variable weather patterns, with the effect being more marked in the north of the State[1]. Traditionally reports on the state of the environment have considered the state of the climate. However, without excluding natural variability, given the broad scientific acceptance that climate change is unequivocal this report will focus on indicators of climate change. The other issues reported are stratospheric ozone and air quality, both themselves subject to the effects of climate change.

Climate change is viewed as the most critical of all environmental issues as it has the potential to drive radical systemic change, create consequential economic turbulence, and affect people both here and globally. Victoria has been a leader in taking action on climate change. By 2010 Australia's Carbon Pollution Reduction Scheme will be introduced. Australia and Victoria are now participating in international movements to gain a global agreement on reducing greenhouse gas emissions and adapting to an inevitably changed climate. This is a fast-moving area of policy, and the evolution of measures will continue well beyond the release of this report. The commentary in this report should be viewed, therefore, as part of a dynamic pattern of governmental, industry amd community effort which has a long way to go.

Figure A0.1 Chemical and transport processes in the atmosphere
Source: Garnaut 2008



Adaptation to climate change as a policy is necessary to cope with the change locked into the system by the level of greenhouse gases already emitted. This situation has come about as a result of a failure by the global community to agree on how to adequately mitigate against climate change. However, if global greenhouse gas emissions are not brought under control and subsequently reduced, it will condemn Victorians to dangerous climate change, including further reductions in water availability, sea level rise, migration of farming, and also to wider global risks to trade and the forced migration of peoples from severely affected regions of the world.

A problem recognised in the 1980s was that certain chemicals had the capacity to damage the ozone layer, the layer in the atmosphere that protects the planet from harmful solar radiation. This was the first global atmosphere problem. The breakdown of the ozone layer as a result of aerosols such as chlorofluorocarbons lead to an international collaboration in order to reduce and reverse the damage. The Montréal Protocol on Substances that Deplete the Ozone Layer came into force in 1989. This brought in the first effective global ban on discharge of certain atmospheric substances.

In addition to a global depletion, in the 1980s a hole in the ozone layer (a pronounced thinning, predominantly in the lower portion of the ozone layer), was discovered over Antarctica. At its maximum, about the year 2000, the hole was approximately 30 million km^2, almost four times the size of Australia, and its depth was down to 60% of 1970s ozone thickness. It has since stabilised at this size, with significant year-to-year variations largely driven by stratospheric temperature fluctuations.

In policy terms air quality, the relative state of a local or regional airshed, was the first obvious issue related to the atmosphere to prompt community reaction and policy action. It was a switch to fossil fuels, coal and oil, that underwrote the industrial revolution. Unknown then, this range of gases, particularly those involving carbon, provided the seeds of today's greenhouse problem.

This was also the period when urbanisation accelerated, as industrial employment released individuals from a direct relationship with and dependence on the land. The first laissez-faire industrial cities were the locus of the new poor air quality, compounded after the Second World War by the increasingly universal adoption of the internal combustion engine as the source of individual mobility.

Not surprisingly a reduction in air pollution and its direct health consequences was the first and most significant subject of modern environmental objectives. With this came the argument that most of these discharges were an unpriced externalisation of wastes to the environment and that the costs were borne in degraded and unhealthy air.

This section shows that motor vehicles and fires are significant sources of pollutants that lead to formation of smog. The Victorian EPA has led the State to an air quality standard that by international standards is very good.

Overall Condition

Condition of the climate

It can be argued that the single greatest environmental, social and economic challenge facing Australia and Victoria is climate change. Climate Change is seen as a driving force for environmental change, and the topic is widely covered in this Report.

Victoria has warmed by 0.6°C since the 1950s; a faster rate of warming than the Australian average. The last ten years have been hotter than average in Victoria, with 2007 being the hottest year on record. Victoria experienced a hot and dry period between 1997 and 2007. In parts of northern Victoria this decade is the driest since the droughts of 1938-1945 and 1895-1902. Since 1961 global average sea level has risen by approximately 10 cm. Williamstown has registered a sea level rise of 18 cm over the last hundred years.

Since 1990 carbon dioxide emissions, mean global temperature and sea level rise have tracked at the upper limit of projections, indicating that projections may be underestimates of likely climate change scenarios.

Victoria's greenhouse emissions have increased by approximately 12% since 1990. In 2006, the stationary and transport energy sectors accounted for 85% of total greenhouse gas emissions in Victoria.

Condition of stratospheric ozone

Emission of certain chemicals such as chlorofluorocarbons (CFCs) leads to the depletion of stratospheric ozone, exposing both marine and terrestrial life to additional harmful amounts of ultraviolet radiation. Global emission of those substances peaked in the late 1980s to early 1990s at 2.1 million tonnes per year, and by 2005 had declined by 70% to 0.5 million tonnes. Worldwide ozone losses of 4% per decade occurred from the late 1970s until the late 1990s.

The Antarctic ozone hole reached a maximum area (approximately 30 million km^2) and depth (60% ozone losses since the late 1970s) about the year 2000, resulting in 50% to 130% more ultraviolet-B radiation reaching the Earth's surface. It has since stabilised. Major ozone losses over Melbourne from the late 1970s until the early 1990s have been 7% - 8% per decade. Ultraviolet levels under clear-sky conditions increased by 10% per decade over southern Australia from the late 1970s to the late 1990s. Since the late 1990s ultraviolet levels have declined by 5%.

Ozone depletion halted in the late 1990s leaving ozone levels over Melbourne relatively stable, but at a level at least 10% lower than they were in the late 1950s. Despite longer term stabilisation, the lowest ozone level recorded over Melbourne since 1956 was seen in the summer of 2006/2007.

Stratospheric ozone recovery may have commenced in 2000, but is currently masked by solar cycle effects. Significant ozone recovery is expected over the next 5 years. Full recovery of stratospheric ozone is possible but highly dependent upon adherence of both developed and developing countries to international agreements. In addition, an enhanced greenhouse effect and future atmospheric concentration of nitrous oxide and methane may reverse anticipated ozone recovery.

Condition of air

The condition of Victoria's air can be considered good. However the State Environmental Protection Policies (SEPPs) made by the Victorian EPA to regulate these matters show a need for a continued high level of investment and effort in compliance and monitoring. Levels of fine particles and ozone do not always meet the objectives in Victoria's ambient air quality policy and in those instances people are exposed to adverse health impacts. Ozone in air is distinguished from ozone in the stratosphere (commonly known as the ozone layer) which has the beneficial effect of absorbing harmful radiation.

By international standards, Victoria has good air quality which has been relatively stable over the last decade despite increased pressures from a growing population and economy. Bushfires and dust storms resulting from a prolonged below-average rainfall have recently affected air quality across Victoria with air quality being poor in 2003 and 2006 due to the impact of severe bushfires.

Increased frequency and severity of bushfires, and drought attributed to climate change, will produce added pressures on air quality. The higher temperatures predicted may also lead to a greater potential for ozone formation.

Pressures on Victoria's atmosphere

There is now overwhelming evidence that recent rapid climate change is linked to elevated concentrations of greenhouse gases in the atmosphere. Human activities are the main contributor to increased greenhouse-gas concentrations, largely through the combustion of fossil fuels, which releases carbon dioxide and other greenhouse gases.

Observations and modelling of the climate system lead to the conclusion that enhanced concentrations of greenhouse gases are the dominant cause of warming during the past several decades[2]. The IPCC states that *"no known mode of internal variability leads to such widespread, near universal warming as has been observed in the past few decades"*[3], which leaves external factors, such as human activities, as the most likely causes of the warming. The IPCC[4] in its Fourth Assessment Report in 2007 concluded that anthropogenic greenhouse gas emissions are very likely (greater than 90% probability) to have c aused most of the observed increases in global average temperature since the mid-20th century.

Whilst use of ozone depleting substances has been phased out reducing the pressure on the ozone layer, additional factors may mean that ozone recovery may not occur by 2040 as previously predicted. One of the consequences of climate change is that as the lower atmosphere warms, the upper atmosphere cools. A cooler stratosphere means more polar stratospheric clouds and more ozone depletion. Climate change may delay full ozone recovery by as much as 50 years[5]. In addition, the long-term growth of nitrous oxide in the atmosphere may cause significant ozone depletion after about 2060.

The pressures on Victoria's air quality are increasing with its growing population and economy. The most significant sources of fine particle emissions in Victoria are from dust storms, bushfires, industry and motor vehicles. Wood heaters and planned burning can also be a significant source of particles. Motor vehicles are a major source of the pollutants that lead to formation of smog, which can also form downwind of bushfires. As the climate changes, average temperatures are predicted to increase leading to an increase in dust storms and fire. Higher temperatures will also cause greater emissions of pollutants and an increase in the speed of the chemical reactions that lead to formation of smog.

Management Responses

Responses to the challenge of climate change – by governments, business and industry and by the wider community – are currently dominating international, national and local policy debates around environmental sustainability. Those responses are important not only to address the problem of climate change but they are also relevant for adressing the associated atmospheric issues of stratospheric ozone depletion and air quality. The responses presented here are the overarching tools used to address these issues. They are considered in further detail in subsequent sections of this part of the report.

Reducing Greenhouse Emissions

Response Name
United Nations Framework Convention on Climate Change (UNFCCC)

Responsible Authority
Commonwealth Government

Response Type
International Agreement

The UNFCCC was one of three conventions adopted at the 1992 Rio Earth Summit. The central objective of the UNFCCC is to stabilise greenhouse gas concentrations at a level where dangerous human interference with the climate system is prevented.

Upon ratification, signatory governments are committed to a voluntary non-binding aim to reduce greenhouse gases. The main outcome of the UNFCCC to date has been the Kyoto Protocol, negotiated and signed in 1997. Under the Protocol, developed countries have been given the initial responsibility in tackling climate change as they are the source of most greenhouse gas emissions to date. Developing countries have no immediate restrictions under the Convention.

Reducing Emissions of Ozone Depleting Substances

Response Name
Montréal Protocol on Substances That Deplete the Ozone Layer

Responsible Authority
Department of the Environment, Water, Heritage and the Arts

Response type
International Treaty

The Montréal Protocol is the principle mechanism responsible for the decrease in global atmospheric concentrations of ozone depleting substances (ODS) since 1998. The Protocol came into force in 1989 and its main purpose is to protect the ozone layer by phasing out the use and production of ODSs in a limited period. Due to its results it is considered very successful. The Multilateral Fund for the Implementation of the Montréal Protocol has been established to help developing countries in their efforts to phase out ODSs.

Improving air quality

Response Name
State Environment Protection Policy (Ambient Air Quality)

Responsible Authority
Victorian Environment Protection Authority

Response Type
Policy

The Ambient Air Quality SEPP contains the national indicators, standards, goals and monitoring and reporting protocol of the National Environment Protection Measure for Ambient Air Quality (AAQ NEPM). Currently there are 16 EPA operated air quality stations (12 in Melbourne, 2 in Geelong and 2 in the Latrobe Valley) that monitor the common air pollutants and some air toxics. Site-specific monitoring is also undertaken to better understand local or sub-regional air pollution. The data provides important information on whether air quality objectives are being met, and allows trends in air quality to be tracked. This information is used to guide the development of Government policies and strategies to improve Victoria's air quality.

Evaluation of atmosphere responses

Climate change is already unavoidable due to existing levels of greenhouse gases in the atmosphere. While climate change action has traditionally focused on mitigation, governments are becoming increasingly attentive to adaptation as the reality of unavoidable climate change becomes clear. Whilst Victoria's own emissions on a global scale are small, per capita they are amongst the worst in the world. This shows a real opportunity for change and provides the means by which Victoria could become a leader in emissions reduction. Such skills would be transferable to other nations that might be struggling with ways to reduce emissions and importantly, provide an opportunity to demonstrate a pathway to a low carbon economy whilst maintaining economic growth.

The Montréal Protocol on substances that deplete the atmosphere, the principal global mechanism responsible for the decrease in global atmospheric concentrations ODSs has been highly successful in phasing out the use and production of ODSs in a limited period. The Multilateral Fund for the Implementation of the Montréal Protocol should be useful in assisting developing countries in their efforts to phase out ODSs. Despite the success of these responses there are still some ozone depleting substances in use in Victoria. These are used for fumigation of shipping containers and in the grain and strawberry runner industries.

The Victorian EPA, the second such organisation to be established in the world, has been working to improve Victoria's air quality for over 35 years. Victoria established its first statewide policy framework for the management of air quality in 1981, with the development of the State Environment Protection Policy (SEPP) (The Air Environment). The current regulatory framework for protecting Victoria's air environment is provided by the Ambient Air Quality and Air Quality Management SEPPs. These tools have been highly successful in guiding EPA's monitoring and reporting on air quality. That knowledge enables EPA to work with the community, industry and government to tackle sources of pollution. However, there are some areas where improvements could potentially be made. This is likely to require action from a range of agencies across Government.

Recommendations

A0.1 Encourage an Australian program of action on climate change which sees effective multilateral and bilateral action and develop a strong program of state-based mitigation policy measures including building a climate change "test" into all major policy, infrastructure and expenditure decisions.

A0.2 Continue to support CSIRO monitoring and reporting of atmospheric ozone concentrations and review developments that may lead to suitable greenhouse neutral replacements for ozone depleting substances that are still in use.

A0.3 Continue to support the EPA in monitoring and reporting air quality and actively seek solutions to managing air quality in light of the increased pressures predicted from a growing population and climate change.

A1 Climate change

Key findings

- Global atmospheric concentrations of greenhouse gases have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values. Impacts of climate change on stratospheric ozone; air quality; land and biodiversity; inland waters; and coasts, estuaries and the sea are addressed throughout this report.
- There are large natural year to year variations in climate. Natural climate variability will influence actual warming values in any single year or decade. The global warming influence due to increasing greenhouse gases is at global scales and cumulative over many years. At short time scales, natural variability can offset that warming influence and cause short term cooling. The long-term warming trend is unequivocal.
- Australia naturally has a highly variable climate. Because of its geography, Australia has further vulnerability to damage through variations induced by climate change than most other developed countries.

Observed changes

- Victoria has warmed by 0.6°C since the 1950s - a faster rate of warming than the Australian average. The last ten years have been hotter than average in Victoria, with 2007 being the hottest year on record. Six out of Victoria's ten hottest years on record have occurred since 1990.
- Rainfall during the last ten years has been markedly lower than the long-term average, with 2007 being one of the three driest years since 1900.
- Serious rainfall deficiencies over the past 11 years have reduced inflows to storages 30–60% below long-term averages. Water scarcity has been statewide in extent, exacerbated by high temperatures, and has worsened over time, with flow in the Murray and Melbourne storages reaching record lows in 2006.
- Since 1961 global average sea level rose approximately 10 cm. Williamstown has registered a sea level rise of 18 cm over the last hundred years.
- Victoria's greenhouse gas emissions have increased by approximately 12% since 1990.
- In 2007, the IPCC declared that climate change is 'unequivocal' and, with a probability over 90%, this change is due to post-industrial human activity.
- Since 1990, carbon dioxide emissions, global mean temperatures and sea levels have tracked at the upper limit of projections, indicating that projections may be underestimates of likely climate change scenarios. The greater the warming, the greater the risk of tipping into irreversible climate change. Climate change feedback loops further increase these risks.

Projections

- Projections indicate that by 2030 warming in Victoria is likely to range from 0.6°C to 1.2°C on 1990 temperatures and by 2070 from 0.9°C to 3.8°C. The 2030 rise is largely locked in by the current level of emissions, with the 2070 projections dependent on rates of global growth and measures put in place to reduce greenhouse gas emissions.
- In most Victorian catchments, runoff into waterways is projected to decrease between 5% and 45% by 2030 and between 5% and 50% by 2070.
- Fire risk is forecast to increase substantially in Victoria, with the number of very high or extreme fire danger days across south-eastern Australia expected to increase by up to 25% by 2020 and up to 230% by 2050.
- By 2070 drought frequency is likely to increase by between 10% and 80% in the southern half of the State and by between 10% and 60% in the northern half.
- More frequent extreme weather events are predicted, with increasing damage from flooding, high winds and coastal storm surges and inundation; a current 1 in 100 year extreme storm surge could occur around every 5 years by 2070. Projected sea level rises will further exacerbate these problems.

Context and policy responses

- Globally, between 1970 and 2004, greenhouse gas emissions covered by the Kyoto Protocol have increased by 70% (24% since 1990).
- Without additional policies, global greenhouse gas emissions are projected to increase by 25-90% by 2030, relative to 2000.
- In its 2007 report, the United Nations Intergovernmental Panel on Climate Change (IPCC) found that carbon dioxide emissions need to peak no later than 2015 and be reduced by 50-85% by 2050 (from 2000 levels) to limit global average temperature increases to 2.0 - 2.4° C.
- The 2007 United Nations Framework Convention on Climate Change (UNFCCC) Bali Roadmap and IPCC Working Group Reports indicated potential greenhouse gas emissions reductions by developed countries of 25-40% by 2020 and 80-95% by 2050 (from 1990 levels).
- Australia, and Victoria, have committed to reducing emissions by 60% by 2050 from 2000 levels, with interim targets yet to be announced.
- Early global action to reduce greenhouse gas emissions reduces the risks associated with climate change, reduces long term costs and provides greater flexibility should emerging science cause mitigation responses to be adjusted over time.
- While being responsible for only 1.5% of total global emissions, Australia is the 14th largest emitter of greenhouse gases in the world. On a per capita scale of the top 25 emitting countries, Australia is the second highest.
- In 2006, approximately one fifth of Australia's greenhouse gas emissions came from Victoria. Between 1990 and 2006, Victoria's emissions grew by 12% and could increase 40% above 2000 levels by 2050 in the absence of effective mitigation.
- The Australian Garnaut Climate Change Review has proposed that Australia should offer to play its full, proportionate part in a global agreement designed to achieve a 450 ppm CO_2-e concentration. However, it further proposes not to focus on a single trajectory, but to have a set of options available during the negotiations for the international post Kyoto Protocol arrangements.
- Momentum has built rapidly in terms of public awareness and support for Government action, however, in the context of current global economic instability and ongoing concerns about international economic competitiveness, strong community support will continue to be required.
- Critical decisions on Australia's and the world's commitment to reduce greenhouse gas emissions will be made in 2009.

Description

The climate challenge

Climate change confronts humanity with the possibility of catastrophic change to life on Earth.

Worldwide scientific collaboration is presenting a range of increasingly disturbing scenarios. These stem from a combination of key human activities, namely: the dramatic growth in global greenhouse gas emissions since the industrial revolution, the consumption of fossil fuels and the continued clearing of forests and land for agriculture and settlements. These factors, coupled with a lack of global consensus and progress in reversing these trends, have turned the risk of catastrophic damage to the economy, society and the natural environment from a *possibility* to a *probability* within our lifetimes.

Tackling climate change throws up some very difficult challenges. The first is that people cannot immediately visualise it – it happens slowly, imperceptibly. The impacts have long lead times but strong action has to occur now if risks and their associated costs are to be avoided. Up front costs must be borne now to bring benefits and reduced costs in the future. Climate change requires us to measure how we value the welfare of future generations relative to our own.

Global action is required, based on principles of international and intergenerational equity if all nations are to be engaged. However the world is composed of sovereign nations which historically pursue their own best interests. Achieving international agreement poses a huge challenge for the world community. In conducting his Climate Change Review, Professor Ross Garnaut declared "There is a chance, just a chance that humanity will act in time and in ways that reduce the risk of climate change to acceptable levels".

Historically, attempts at gaining international agreements have often foundered on the so-called 'north-south divide' between developed and developing nations. Over the past 150-200 years, developed nations have been able to lift their societies out of poverty, based on the benefits of industrialisation. A major consequence of this economic growth, however, has been greenhouse gas emissions polluting the Earth's atmosphere.

The top 25 greenhouse gas emitting countries in the world together account for over 87% of global emissions. While being responsible for only 1.5% of total global emissions[6], Australia is the 14th largest emitter of greenhouse gases in the world. On a per capita scale of the top 25 emitting countries, Australia is the second highest[7]. In 2006, approximately one fifth of Australia's emissions came from Victoria[8], which generated over 120 million tonnes of greenhouse gases. Between 1990 (the base year used for greenhouse emissions monitoring under the Kyoto Protocol) and 2006, Victoria's emissions grew by 12%[9].

The developed world is largely responsible for current global levels of greenhouse gas concentrations. Developing countries, in particular the fast growing economies of China, India, Brazil and others are seeking to lift the living standards of their societies and will soon become some of the largest greenhouse gas emitting countries in the world. Without mitigation, developing countries would account for about 90% of the emissions growth over the next decade and beyond[10]. In international negotiations, they attribute the changing climate to 'the West' and look to the developed world to take responsibility for its historical emissions, and to take the lead in global emissions reduction efforts. Developed countries, including Australia, have formally agreed to lead in responding to climate change. In reality, the world needs both developed and developing countries to take urgent action on the level of greenhouse gases.

Nevertheless, the United States of America and until recently, Australia, were amongst the few developed countries not to take climate change seriously. Powerful internal interests argued and continue to argue that the science is wrong and the threat is without foundation. These voices are still influential and they argue strongly for delayed or no action. Certainly they seem to be heavily involved in arguing for an ever slower response.

Scientific evidence

There is now overwhelming evidence that recent rapid climate change is linked to elevated concentrations of greenhouse gases in the atmosphere. Human activities are the main contributor to increased greenhouse gas concentrations, largely through the combustion of fossil fuels and land clearing, which releases carbon dioxide and other greenhouse gases.

Observations and modelling of the climate system lead to the conclusion that enhanced concentrations of greenhouse gases are the dominant cause of warming during the past several decades[11]. The Intergovernmental Panel on Climate Change (IPCC) states that "*no known mode of internal variability leads to such widespread, near universal warming as has been observed in the past few decades*"[12], which leaves external factors, such as human activities, as the most likely causes of the warming. The IPCC[13] in its Fourth Assessment Report, 2007, concluded that anthropogenic (human-induced) greenhouse gas emissions are very likely, with greater than 90% probability, to have caused most of the observed increases in global average temperature since the mid-20th century. It further describes climate change as 'unequivocal'.

The most recent deliberations of the international and Australian scientific communities are discussed in detail in this section. They point to ever stronger conclusions that greenhouse gas emissions are growing at a rate beyond that expected even three years ago, and that impacts are tracking at the upper limits of projections in the IPCC scenarios. Understanding of feedback systems and thresholds in the climate system is still incomplete, raising the possibility of irreversible climate change and climate change happening faster than previously expected.

The Australian Garnaut Climate Change Review Report states "We will delude ourselves if we think that scientific uncertainties are cause for delay. … Delaying now is not postponing a decision. To delay is to deliberately choose to avoid effective steps to reduce the risks of climate change to an acceptable level."

Australia's vulnerability

Australia is particularly vulnerable both to the impacts of climate change itself and to the responses adopted internationally to address its impacts. Key vulnerabilities include:

- the hot, dry and naturally variable climate becoming hotter and drier over much of the agricultural production zones and in the large population centres
- the fragility of Australia's megadiverse ecosystems and unique biota whose evolutionary adaptation capabilities is likely to be exceeded within the short timeframes involved
- high variability of rainfall from year to year, with increasing competitive pressures on available resources due to population growth and increased scarcity
- extreme drought, flooding and weather events and high risk of bushfires, all predicted to increase with climate change
- the particular sensitivity of temperate agriculture to climatic changes
- dependence on emissions-intensive coal for electricity, with many energy intensive manufacturing industries in the economy
- high transport energy requirements due both to Australia's size and the legacy of low density urban design
- high population growth rate and concentration of settlements and infrastructure along coastlines, exposed to projected increase in the frequency and severity of extreme weather events
- significance of fossil fuels in Australia's export trade and predominance of trade links with developing nations, especially in the Asia/Pacific regions
- the vulnerability of many of our nearest neighbours, which are low-lying, island states subject to significant impacts from sea level rise and where adaptive capacity is relatively low. The UN has predicted there could be up 150 million 'climate change refugees' across the world by 2050.

In summary, new ecosystems will replace the existing systems with major risks for productive agriculture and the sustainability of human settlements. Climate change is projected to have broad and significant environmental, economic and social impacts in Australia. Understanding of Australia's particular environmental vulnerability to climate change is developing but in its infancy.

Key issues for Australia

Australia stands to be the developed country most affected by significant climate change because of its hot, dry and highly variable climate. Small variations in climate are more damaging to Australia than to many other developed countries.

On a per capita basis, Australians emit more greenhouse gases to the atmosphere than any other country in the world apart from the United States of America. However its total contribution overall amounts to just 1.5% of global greenhouse gas emissions.

Avoiding dangerous impacts of climate change requires the world's largest emitters (both developed and developing nations) to make deep cuts to their greenhouse gas emissions.

The Garnaut Review Report points to Australia's strong interest in taking mitigating action to lead the engagement of developing nations in an international agreement and decisive action to mitigate climate change. The Report also states that Australia (and the world) has squandered much of the available time over the past 15 years to mitigate emissions and contain climate change impacts.

The UK Government's Stern Report, the Garnaut Climate Change Review and Australian business peak bodies have advised that the sooner action is taken to cut emissions, the less costly mitigation will be to economies around the world.

It is clear the world is now facing risks of catastrophic, irreversible climate change. Failure to act in time to reduce global greenhouse gas emissions will represent an implicit acknowledgement that this generation, particularly in developed countries, cannot afford to wear the costs of mitigation for the welfare of the world, its ecosystems and future generations.

There has been much deliberation. Time is now running out for decisive action.

Objectives

- To reduce Victoria's greenhouse gas emissions towards achieving a stable global climate
- To reduce Victoria's vulnerability through adaptive responses
- To foster further government and community response to address the challenge of climate change in Victoria

Photo: Jane Tovey

A1.1 The natural and enhanced greenhouse effect

The natural greenhouse effect reduces the loss of heat by radiation from the Earth's surface, keeping the surface of the planet warmer than it would otherwise be. This is due to the presence in the atmosphere of greenhouse gases, which absorb a proportion of the heat before it is lost to space, and radiate some back to the surface (see Figure A1.1.).

Naturally occurring greenhouse gases keep the planet warm enough to sustain life. Without these gases, the planet's average temperature would be about 33°C colder - more like the moon.

However, human activities, predominately the burning of fossil fuels, intensive agriculture and land clearing, are causing greenhouse gas concentrations to rise above natural levels, further heating the planet. This is called the enhanced greenhouse effect. As the concentrations of these gases in the lower atmosphere grows, global temperatures rise, causing changes to weather conditions worldwide. The enhanced greenhouse effect is often referred to as global warming or climate change.

There are large natural year to year variations in climate. Natural climate variability will influence actual warming values in any single year or decade. The global warming influence due to increasing greenhouse gases is at global scales and cumulative over many years. At short time scales, natural variability can offset that warming influence and cause short term cooling. The long-term warming trend is unequivocal[14].

The main greenhouse gases are water vapour, carbon dioxide, methane and nitrous oxide. The Earth's climate is also influenced by natural cycles, such as 100,000 year glacial cycles due to wobbles in the Earth's orbit, 11 year sunspot cycles and 2–7 year El Niño cycles due to air-sea interactions.

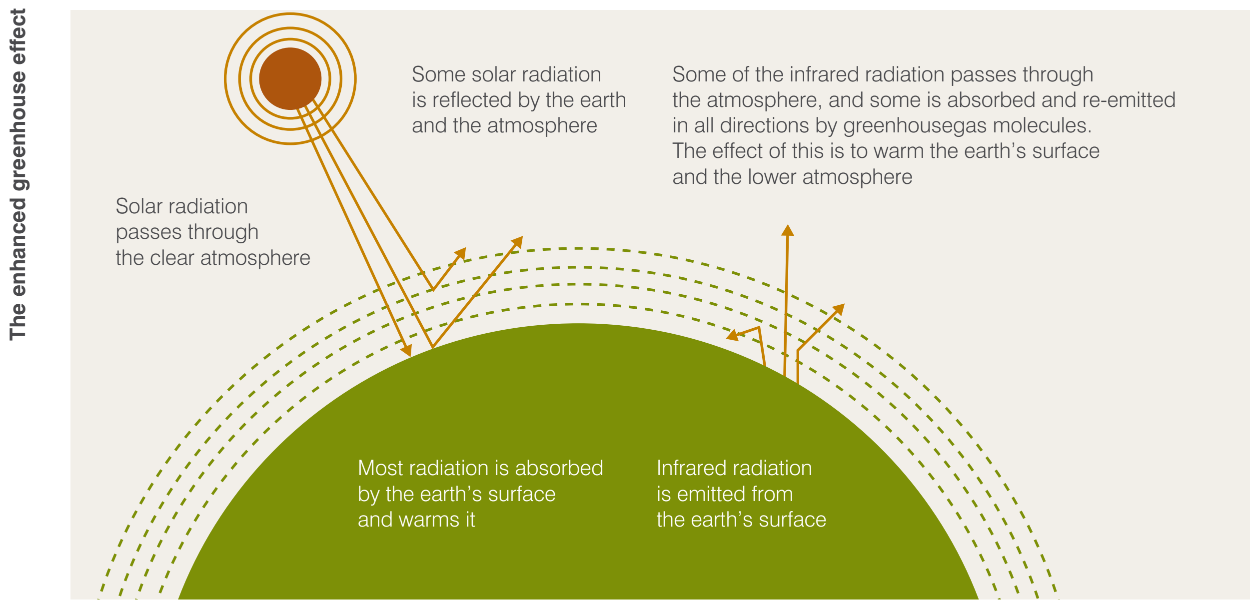
Burning of fossil fuels, some forms of agricultural activities and land clearing have contributed to high concentrations of carbon dioxide, methane and nitrous oxide in the atmosphere. These anthropogenic emissions are considered very likely – greater than 90% probability – to be the cause of most of the observed increase in global average temperatures since the mid-20th century[15].

Since the industrial revolution around 1750, the concentration of carbon dioxide has increased by one-third, methane has risen by 150% and nitrous oxide has grown 18%. The increases in carbon dioxide are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture.

Globally, between 1970 and 2004, greenhouse gas emissions covered by the Kyoto Protocol have increased by 70% (24% since 1990). Without additional policies, global greenhouse gas emissions are projected to increase by 25-90% by 2030, relative to 2000[16].

The global dependence on fossil fuels continues to increase rapidly. The populations and resource intensities of developed nations are growing and developing nations such as China and India also now are emitting significant levels of greenhouse gases as they continue their pathways of economic growth and higher living standards.

Figure A1.1 The Greenhouse Effect
Source: Department of Sustainability and Environment, 2006



Box A1.1 Greenhouse gases

The main greenhouse gases generated by human activity are:

- carbon dioxide (CO_2), which is the most important anthropogenic greenhouse gas and is the main contributor to human-induced climate change. Carbon dioxide accounts for about two thirds of greenhouse gases produced by human activities. The primary source of the increased atmospheric concentration of carbon dioxide since the pre-industrial period results from fossil fuel use, with land-use change providing another significant but smaller contribution. Photosynthesis by plants removes CO_2 from the atmosphere. Before the industrial revolution, CO_2 concentrations were typically around 280 ppm. By 2005, this had risen to almost 379 ppm.
- methane (CH_4), which is not as abundant as CO2, but is 21 times more effective at trapping heat. It is released when vegetation decomposes in oxygen-free environments (such as in a fire or landfill), as well as from animal digestive processes.
- nitrous oxide (N_2O), which occurs naturally in the environment, although human activities increase its atmospheric concentrations. This gas is most often released when chemical fertilisers and manure are used in agriculture.

Other greenhouse gases include some manufactured gases such as sulfur hexafluoride, chlorofluorocarbons (CFCs) and some of their replacements.

Water vapour is another particularly important greenhouse gas. However, direct human emissions of water vapour are negligible. Rather it is the response of water vapour to atmospheric warming which dictates its importance for climate change. A warmer atmosphere holds more water vapour, thereby increasing greenhouse trapping and resulting in further warming. This positive feedback therefore acts to amplify the warming initiated by increases in anthropogenic greenhouse gases such as carbon dioxide and methane

The greenhouse effect of these gases occurs in the troposphere layer of the atmosphere where they are concentrated. The lifetime of carbon dioxide in the atmosphere is difficult to quantify because it is continuously cycled between the atmosphere, ocean and biosphere, which involves a range of processes with different timescales. Around half the CO_2 emitted is removed on a time-scale of 30 years, a further 30% is removed within a few centuries, and the remaining 20% may stay in the atmosphere for thousands of years. Methane's atmospheric lifetime is about 8.4 years and nitrous oxide's is around 114 years[17].

For purposes of measurement, all greenhouse gases are converted to a common unit, called CO_2 equivalent (CO_2-e) and are measured in parts per million (ppm). Parts per million (ppm) is the ratio of the number of greenhouse gas molecules to the total number of molecules of dry air.

The best estimate of total CO_2-e concentration in 2005 for all long-lived greenhouse gases is about 455 ppm CO_2-e. However, the corresponding value after the net effect of all anthropogenic forcing agents (including the effect of cooling aerosols) are taken into account is 375 ppm CO_2-e. It is the combined effect of all the influences on radiative forcing and the consequent net CO_2-e concentration that is most relevant to the consideration of changes to the climate system[18].

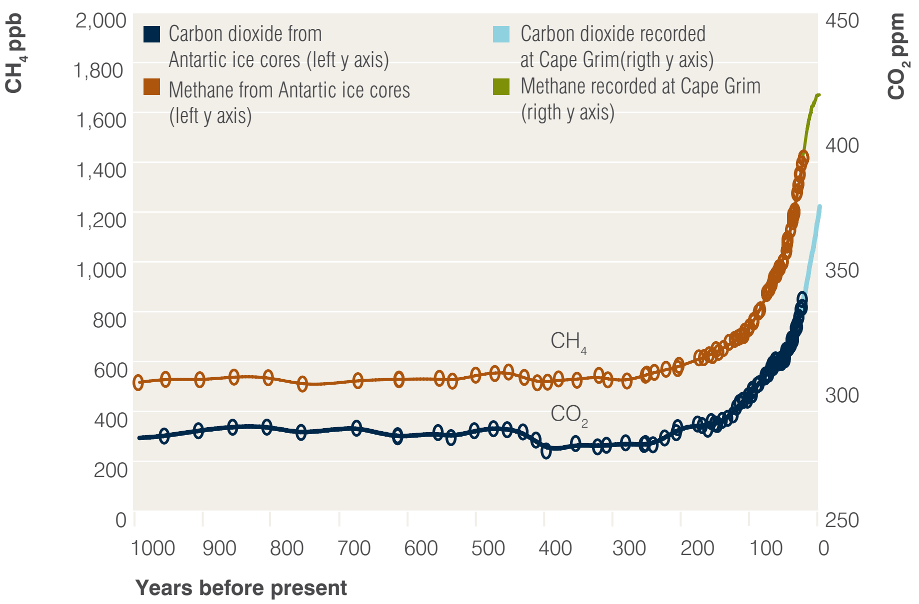
Greenhouse gases are generated through a range of activities including agricultural practices and industrial processes (see Table A1.1).

Figure A1.2 shows the long-term change in the atmospheric concentration of carbon dioxide and methane over the last 1000 years, based on ice core analysis and direct atmospheric measurements, including at Cape Grim in north west Tasmania.

Table A1.1 Examples of economic activities generating greenhouse gases
Source: Energy Information Administration (2005)[19]

Carbon Dioxide	Nitrous Oxide	Methane
Energy generation	Agriculture soil management	Coal mining
Transport	Transport	Landfills
Cement manufacture	Sewage treatment	Waste management
Metal production (e.g. aluminium, steel and iron)	Landfills	Rice cultivation and other agriculture (e.g. cattle)

Figure A1.2 Atmospheric concentrations of carbon dioxide and methane over the last 1000 years (data from ice cores and Cape Grim)
Source: CSIRO 2007



The global growth rate in annual carbon dioxide emissions has increased from 1.1% per year in the 1990s to more than 3% per year between 2000 and 2004[20]. This is primarily due to increased fossil fuel use, but also to land-use change (the main change being land clearing)[21]. Further, agriculture has played a major role in the growth of nitrous oxide.[22]

Unlike other greenhouse gases, methane has stabilised in the last decade. After rapid growth of atmospheric methane concentrations over the past 200 years, the rate of growth has decreased since the early 1990s and the level has remained relatively stable since 1999. The decrease in the growth rate in the 1990s was due to a reduction in anthropogenic emissions[23,i]. Although anthropogenic methane emissions have been rising again since the late 1990s, this increase is being offset by the drying of wetlands, caused by draining and climate change, leading to reductions in natural methane emissions[24]. The overall effect has been a stabilising of methane concentrations since the turn of the century.

Global climate change: A disturbing picture

The most recent scientific publications paint a disturbing picture for the atmosphere and the climate. At the same time it is becoming apparent that CO_2 concentrations, global mean temperature and sea level rise have been growing at a faster rate than the highest of the range of possible emission scenarios considered by the IPCC in 2001[25] (see Figure A1.3). Therefore, it must be borne in mind that the projected upper limits of warming are conservative. There is a significant possibility that warming may occur in excess of these values, particularly later in the century, although the likelihood of this occurrence is impossible to estimate at this stage[26].

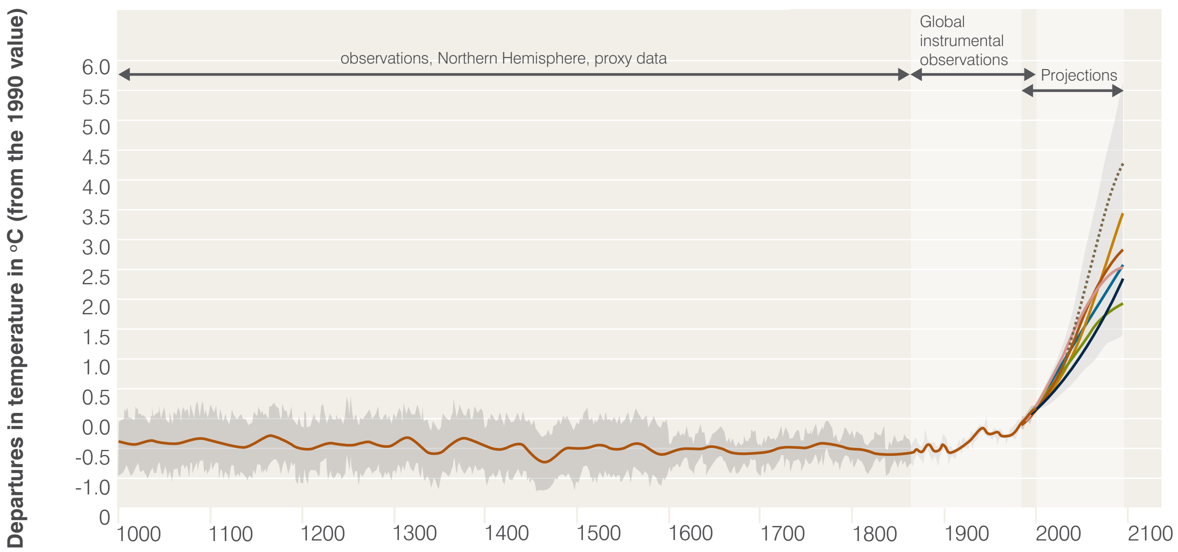
In a paper published in *Nature* in 2008, Rosenzweig *et al* noted that[27] "most of the observed increase in global average temperatures since the mid-twentieth century is very likely to be due to the observed increase in anthropogenic greenhouse gas concentrations, and furthermore that it is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica, we conclude that anthropogenic climate change is having a significant impact on physical and biological systems globally and in some continents". Climate change's effects are not something to be considered only in the future, they are already happening now.

While CO_2 concentrations, global mean temperature and sea level rise have been tracking at the upper end of the range of IPCC predictions, the ability of terrestial and ocean sinks to remove carbon dioxide from the atmosphere is decreasing, altering global carbon budgets[28]. These factors, coupled with an increasing global CO_2-e growth rate[29], are likely to speed up climate change and exacerbate the impacts of climate change in the future. Natural climate variability will influence actual warming values in any single year or decade[30].

Observations of greenhouse gas emissions indicate that current concentrations of carbon dioxide and methane far exceed those at any time in the last 650,000 years[31]. Over the last century global surface temperatures rose by 0.7°C and northern hemisphere summers are, on average, 12.3 days longer than at the beginning of the 20th century. Glaciers have retreated, snow cover has decreased in most regions and Arctic sea-ice has reduced in thickness by almost 50%.

Sea levels have risen by around 20 cm over the last century (see Figure A1.4)and the oceans have become more acidic[32]. More recently, a trend has been observed in relation to an increasing area of low biological productivity in the north and south Pacific and Atlantic oceans which may also indicate that other changes are underway that were not entirely predicted or understood[33].

Figure A1.3 Variations in the Earth's surface temperature Year 1000 to Year 2100
Source: IPCC 2001



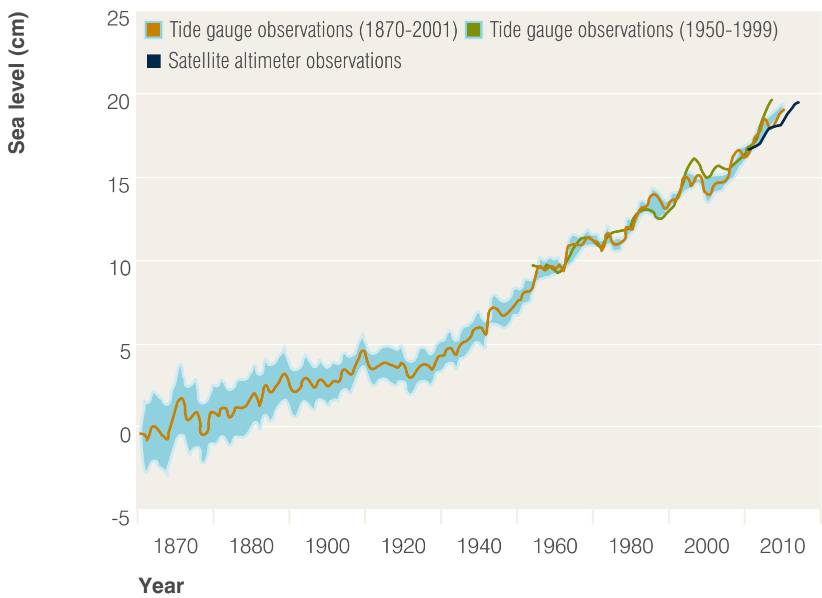
i Possible reasons for reduction in anthropogenic emissions include: the economic crisis in some OECD countries (not USA) between 1990 and 2000; fewer emissions from the oil and gas industry; and capture and better use of methane from landfills.

IPCC projections indicate that global sea level will likely rise by approximately 20 to 60 cm (relative to 1990 levels) by 2100 due to thermal expansion alone. However, in the long term, the IPCC has warned of the potential sea-level rise associated with contraction of the Greenland ice sheet and the partial loss of polar ice sheets. This melting of ice sheets in Antarctica and Greenland may add an extra 10 to 20 cm to this, bringing the total projected sea level to somewhere between 20 cm and 80 cm[34]. Global climate models indicate that mean sea level rise on the east coast of Australia may be greater than the global mean sea level rise.

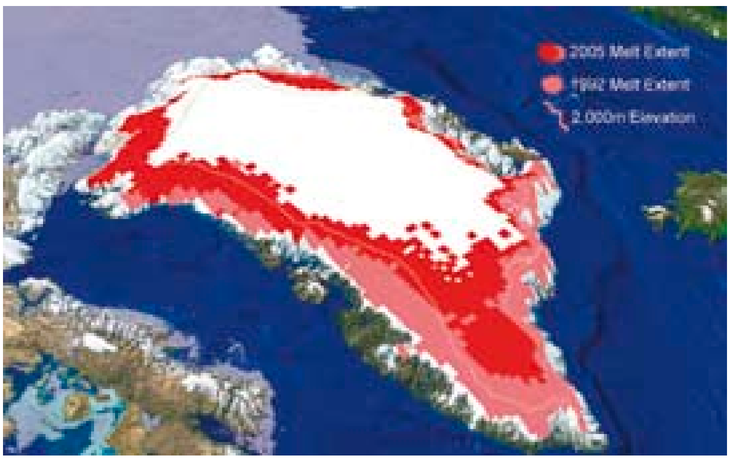
Such loss of polar ice is important as white surfaces reflect more solar radiation than dark surfaces, so as global warming melts ice and snow, it leaves behind dark ocean or land; those surfaces then absorb more solar radiation than before, so adding to warming, which melts more ice and snow, and so on[35]. This is known as the Albedo effect. Indeed, the IPCC's Fourth Assessment Report in 2007 notes that as a result of the uncertainties of such climate-carbon cycle feedbacks, the upper values of sea-level rise projections should not be considered upper bounds for sea-level rise. This contrasts with the IPCC projections for global mean temperature rises which include upper limits.

In addition, the IPCC report notes that current models indicate virtually complete elimination of the Greenland ice sheet and a resulting contribution to sea-level rise of about 7 metres if global average warming were sustained for millennia in excess of 1.9 to 4.6°C. It also notes that more rapid sea-level rise on century time-scales cannot be excluded.

Figure A1.4 Global average sea level rise from 1870 to 2005
Source: Church and White (2006); Holgate and Woodworth (2004); Leuliette et al. (2004)



Trend of melting of the Greenland ice sheet
Source: Cooperative Institute for Research in Environmental Sciences (CIRES),University of Colorado[36]



Just like marine ecosystems, land-based ecosystems normally act as carbon sinks, taking carbon from the atmosphere and using it for growth. However, as these ecosystems heat up, their balance is altered. Plants become less and less effective at taking in carbon dioxide[37], while micro-organisms in the soil become more and more effective at putting it out, causing the ecosystem as a whole to go from being a carbon sink to being a carbon source.

Melting of the Arctic permafrost threatens to release vast quantities of carbon dioxide and methane trapped in frozen vegetation. Recent research estimates that a major melt of large tracts of the permafrost in high latitudes of Russia, Canada, Alaska and Scandanavia could release billions of tonnes of greenhouse gases. Release of even a fraction of the gases currently trapped would dramatically accelerate climate change[38]. The risk is a feedback loop whereby increased greenhouse gases cause temperature rises that further melt the permafrost and release even more gases.

The IPCC has indicated sea level rise may occur far faster than the models have predicted as a result of such feedback loops.

Whilst climate change is unequivocal, major uncertainties in some impacts of climate change remain where climatic feedback loops cannot be predicted accurately with current models. Ever more worrisome evidence, however, is being found that climate feedback loops are more dangerous than previously considered. Long term potential impacts on global thermohaline circulation, melting of the glacial permafrost, terrestrial uptake of carbon, the rate of ocean acidification and the possibility of masking of climate change through anthropogenic emissions of aerosols are all examples of abrupt changes to the climate that may cause severe consequences to ecosystems and human settlements. Further, as noted by the IPCC, CSIRO and Bureau of Meteorology, the upper limits of warming projected to date tend to be conservative, and there is a significant possibility that warming and sea-level rise may occur in excess of projections, particularly later in the century[39].

The complexity of the global climate system, incomplete understanding of the drivers of change to this system and our capacity to project future emissions - plus the dependency of these on the effectiveness of international responses - makes it profoundly difficult to accurately predict the consequences of climate change on natural and human systems. The risk inherent in this uncertainty is that predictions of the extremity and effects of climate change may dramatically underestimate the speed and scale of the changes. In order to counter the risk of extreme consequences, governments must respond quickly and decisively to climate change. Due to the complexity and scale of changes required and the competing interests involved this has not occurred, to date.

The top 25 greenhouse emitting countries in the world together account for over 87% of global emissions. While being responsible for only 1.5% of total global emissions[40], Australia is the 14th largest emitter of greenhouse gases in the world. On the emissions per capita scale of the top 25 emitting countries (see Figure A1.5), Australia is the 2nd highest per capita[41]. In 2006, approximately one fifth of these emissions came from Victoria[42], which generated over 120 million tonnes of greenhouse gases. Between 1990 and 2006, Victoria's emissions grew by 12%[43].

Relative to other OECD countries, Australia's high emissions are mainly the result of the high emissions intensity of energy use, rather than the high energy intensity of the economy or exceptionally high per capita income. Transport emissions are not dissimilar to those of other developed countries. Australia's per capita agricultural emissions are among the highest in the world, especially because of the large numbers of sheep and cattle.

The high emissions intensity of energy use in Australia is mainly the result of our reliance on coal for electricity. The difference between Australia and other countries is a recent phenomenon: the average emissions intensity of primary energy supply for Australia and OECD countrieswas similar in 1971[44].

Box A1.2 Key milestones in the developing international scientific consensus on sustainable development and climate change

1972 - The Limits to Growth: report detailing consequences of world's rapid population growth and use of finite resources

1987 - Our Common Future: the Brundtland Report, alerted the world to the urgency of making progress toward economic development that could be sustained without depleting natural resources or harming the environment.

1988 - The Intergovernmental Panel on Climate Change (IPCC) set up by the United Nations Environment Programme (UNEP) and the World Meteorological Organization to provide periodic assessments of published information on climate change to decision-makers.

1989 - Montreal Protocol on Substances That Deplete the Ozone Layer.

1990 - IPCC First Assessment Report.

1992 - Earth Summit – UN Conference on Environment and Development in Rio de Janeiro.

1994 - The United Nations Framework Convention on Climate Change (UNFCCC) comes into force, with the ultimate aim of stabilising atmospheric greenhouse gas concentrations at levels that would prevent dangerous anthropogenic interference with the climate system.

1995 - IPCC Second Assessment Report "The balance of evidence suggests a discernible human influence on global climate."

1997 - Kyoto Protocol adopted - UN agreement to reduce global greenhouse gas emissions by an average 5% on 1990 levels; Australia a signatory but does not ratify.

2001 - IPCC Third Assessment Report "The Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities."

2005 - Kyoto Protocol comes into force.

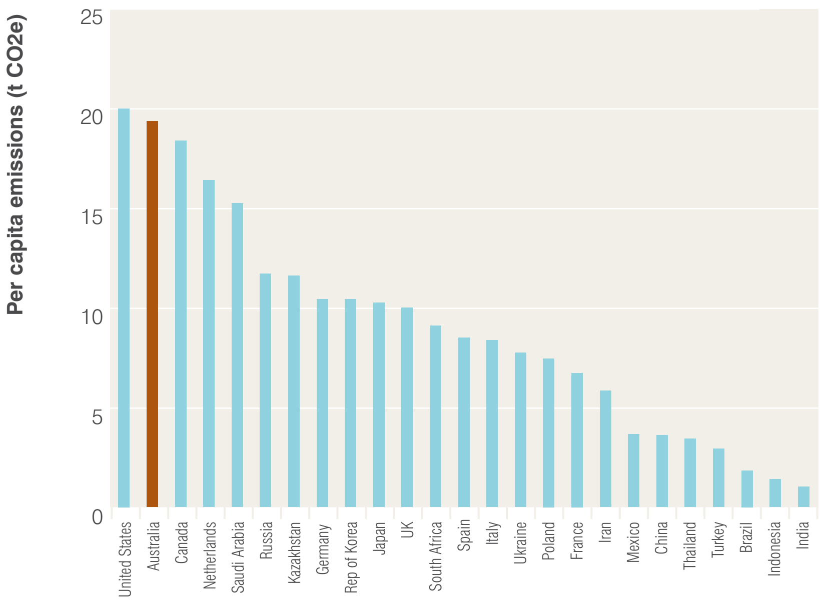
2007 - IPCC Fourth Assessment Report identifies unequivocal climate change; "Most of the observed increase in global average temperature since the mid 20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations"; determined emissions need to peak in 2015.

2007 - The UNFCCC Bali Roadmap establishes a two-year process to develop a binding international agreement for the post-Kyoto period (2013 onwards).

2007 - Australia ratifies the Kyoto Protocol.

2009 - *Copenhagen IPCC/UNFCCC meeting* to finalise the post Kyoto (2013+) agreement on action to reduce greenhouse gas emissions and the single most important stage in determining whether the will to take action is present.

Figure A1.5 Per capita greenhouse gas emissions of world's 25 highest emitting countries
Source: World Bank



Stabilisation of atmospheric CO_2 levels International and national perspectives

The UNFCCC, as the focus and legal framework for international responses to climate change, establishes as its ultimate objective "the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"[45]. The IPCC does not define what constitutes 'dangerous' climate change. In its 2001 Assessment Report it stated "natural, technical, and social sciences can provide essential information and evidence needed for decisions on what constitutes "dangerous anthropogenic interference with the climate system. At the same time, such decisions are value judgments determined through socio-political processes, taking into account considerations such as development, equity, and sustainability, as well as uncertainties and risk"[46].

The IPCC 2007 Report has provided 'best estimates' of the likely global average temperature rise and sea level rise associated with a range of different long term CO_2 and CO_2-e stabilisation levels[47](see Table A1.2).

Box A1.3 The IPCC Special Report on Emission Scenarios (SRES)

In 2000 the IPCC prepared the Special Report on Emission Scenarios (SRES). This report developed different 'storylines' to describe distinctly different directions for future development, and examined the relationship between emissions and possible global economic development and intervention scenarios.

- The B1 scenario is a lower emissions growth scenario and assumes that there is a rapid shift to less fossil-fuel intensive industries.
- The A1B scenario is a medium emissions growth scenario where there is a balanced use of different energy sources – not just fossil fuels.
- The A1FI is a higher emissions growth scenario and assumes a continuation of strong economic growth based on continued dependence on fossil fuels. CO_2-e concentrations more than triple, relative to pre-industrial levels, by 2100. A global temperature increase of 4.0°C (2.4 to 6.4°C) is likely. This scenario represents the highest level of late 21st century emissions that were thought to be plausible back in 2000. However, recent evidence indicates that CO_2-e emissions have been growing at a more rapid rate.

The above three scenarios are used commonly by the CSIRO to model climate change projections for Australia and Victoria and are seen throughout this section of the Report.

- Additional scenarios modelled by the IPCC and shown in IPCC data, for example, in Figure A1.4 are:
- The A1T scenario – future development based on non-fossil fuel and very rapid economic growth
- The A2 scenario - very heterogeneous, self-reliant development; regionally-oriented economic development;

The B2 scenario – emphasis on local solutions to economic, social and environmental sustainability

With the continuing rise in global emissions and its predicted continuance throughout the 21st century, action is required to halt and reverse the growth in emissions.

Table A1.2 IPCC estimates of temperature and sea level rise associated with various CO_2-e stabilisation levels
Data source: IPCC, 2007b

CO_2 concentration at stabilisation (ppm) (2005 = 379 ppm)	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005=375 ppm)	Peaking year for CO_2 emissions	Change in global CO_2 emissions in 2050 (% of 2000 emissions)	Global average temperature increase above pre-industrial level (°C)	Global average sea level rise above pre-industrial, from thermal expansion only (metres)
350-400	445-490	2000-2015	-85 to -50	2.0-2.4	0.4-1.4
400-440	490-535	2000-2020	-60 to -30	2.4-2.8	0.5-1.7
440-485	535-590	2010-2030	-30 to +5	2.8-3.2	0.6-1.9
485-570	590-710	2020-2060	+10 to +60	3.2-4.0	0.6-2.4
570-660	710-855	2050-2080	+25 to +85	4.0-4.9	0.8-2.9
660-790	855-1130	2060-2090	+90 to +140	4.9-6.1	1.0-3.7

Figure A1.6 shows projections of global average warming at 2090-2099 relative to 1980-1999 for a range of IPCC scenarios[48]. Shading denotes a plus/minus one standard deviation range of individual model annual averages. The orange line represents a case where greenhouse gas concentrations were held constant at year 2000 values. The grey bars on the right indicate the multi-model *mean warming* (solid line within each bar) and the likely *range of warming* of the six IPCC scenarios examined in the Special Report on Emissions Scenarios (SRES), together with results from independent models and observational constraints[49].

Discussion around the UNFCCC stabilisation objective has underpinned the ongoing development of elements of the Convention itself (such as the Kyoto Protocol) and subsequent elements of the international response. While a definition of "dangerous interference" is still subject to interpretation, many analysts have adopted the view that anything greater than two degrees warming must be prevented to ensure that impacts on major ecosystems are avoided[51].

The European Union has stated that once the global temperature increase exceeds 2°C, climate impacts on ecosystems, food production and water supply are projected to increase significantly and the unexpected response of the climate becomes more likely and irreversible catastrophic events may occur[52].

The IPCC estimates 2°C aligns with atmospheric CO_2-e concentrations stabilised at 350 ppm.

The definition of dangerous interference can be informed by an understanding of the likely impacts associated with various warming levels. Recent thinking around examples of these specific impacts presented by the IPCC is in Figure A1.7 below.

Figure A1.6 Warming trends associated with various IPCC scenarios
Source: IPCC[50]

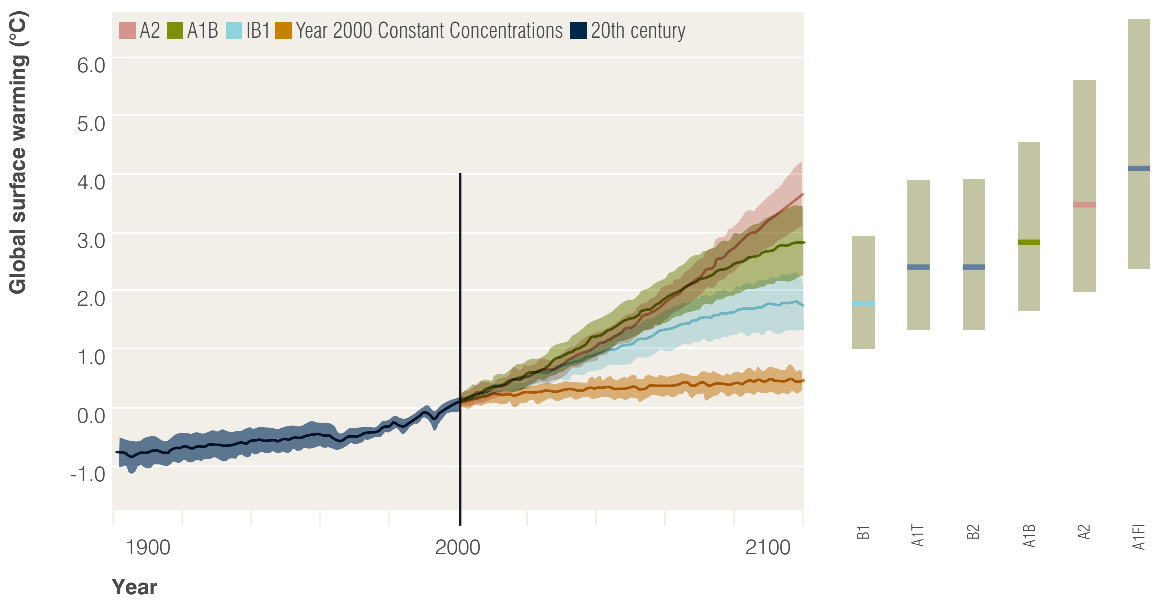
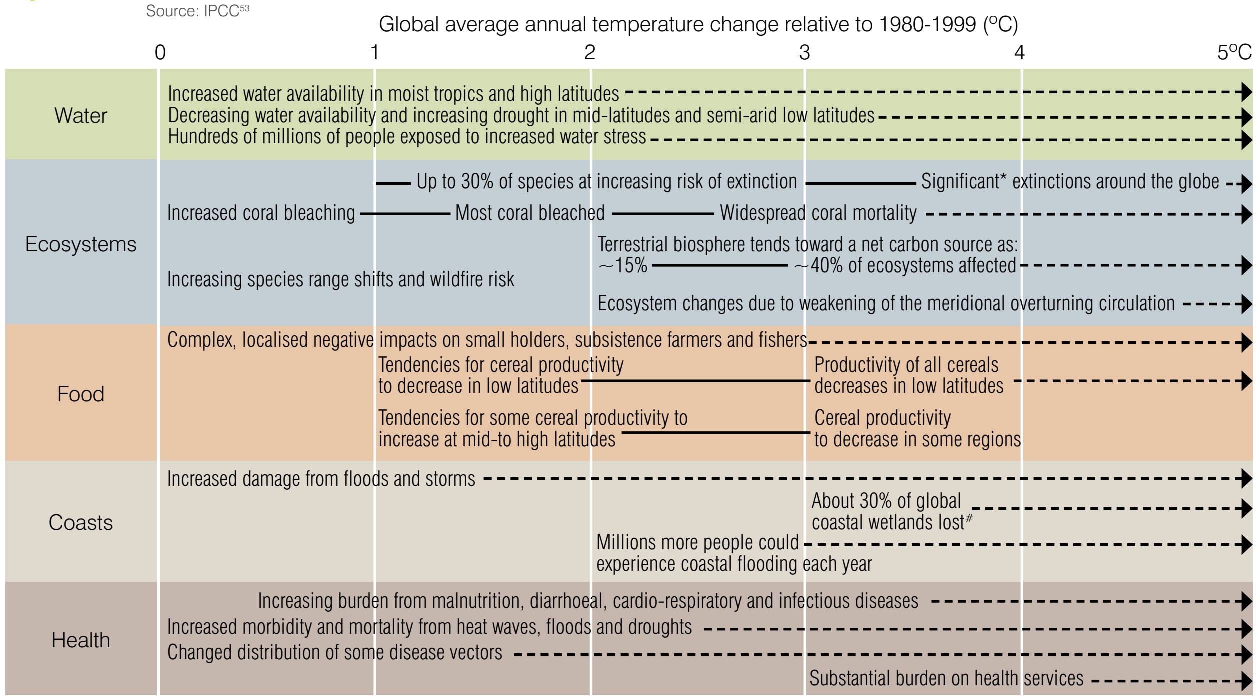


Figure A1.7 Estimates of potential climate impacts associated with different warming levels
Source: IPCC[53]



*Significant is defined here as more than 40% #Based on average rate of sea level rise of 4.2mm/year from

A1.2 State of the climate

The question of the target set for stabilisation of emissions is one the IPCC and policymakers are still grappling with. Importantly, debate is now moving to the nearer term, and the year by which emissions would need to peak. The IPCC's Fourth Assessment Report in 2007 found emissions need to peak no later than 2015 and be reduced by 50-85% by 2050 (from 2000 levels) to avoid temperature increases greater than 2.4°C. Further work noted that this would indicate emission reductions by developed countries of 25-40% by 2020 and by 80-95% by 2050[54] (from 1990 levels).

In his acceptance speech for the 2007 Nobel Peace Prize, the IPCC's Chairman Dr Rajendra K Pachauri said,

> "We, have a short window of time to bring about a reduction in global emissions if we wish to limit temperature increase to around 2°C".

In terms of Australia's response, the Commonwealth Government has now ratified the Kyoto Protocol, and has established a target of 60% reduction in emissions by 2050[55]. This target reflects the global average cut identified by the IPCC. This is a milestone for the management of climate change in Australia, but only the very beginning.

As an important input to Australia's developing response, the Garnaut Review Interim and Draft Reports suggested that Australia should go beyond a 60% cut in emissions by 2050 if global warming is to be managed, and supported the IPCC's view that global emissions needed to peak in the near future to avoid dangerous climate change[56,57].

Indicator A1: Observed surface temperature

Over the last 100 years the global mean temperature has risen by 0.74°C[58]. Average surface temperatures in Australia have risen by as much as 0.9°C since 1910. The warming has not been uniform throughout the country, with some regions (for example, the southern part of Northern Territory) reporting increases of 0.20°C per decade and other regions (for example, central-eastern parts of New South Wales) as little as approximately 0.05°C per decade[59] (see Figure A1.8).

Figure A1.9 shows variations from Victoria's long-term annual mean temperature. The black line shows the 11-year running average. Mean temperatures in Victoria have risen by approximately 0.6oC since 1950[60]. In addition, the last 10 years have been warmer than the mean, with 2007 being the hottest year on record for Victoria.

Figure A1.8 Australian annual mean temperature anomalies 1910-2007
Source: Bureau of Meteorology
Note : The data shows temperature difference from the 1961-90 mean. The black line shows the 11 year running average.

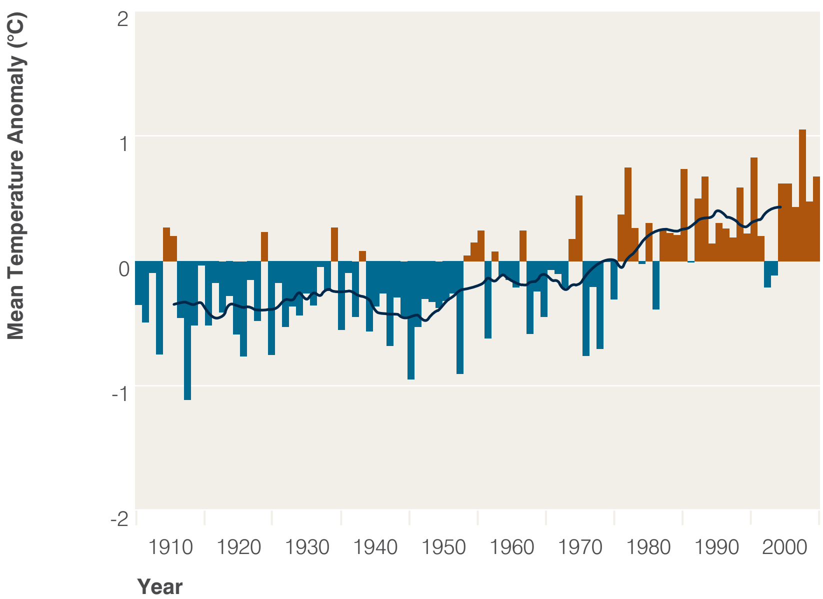
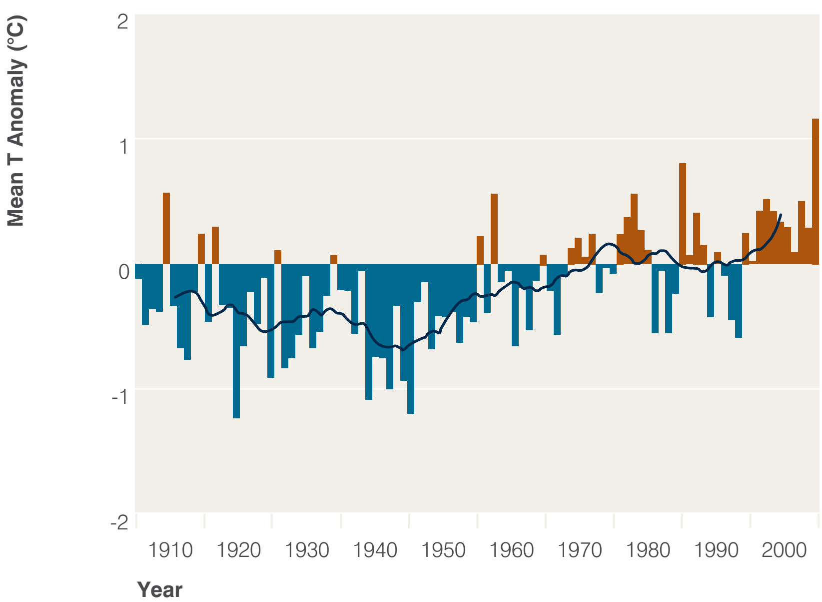


Figure A1.9 Victorian annual mean temperature anomalies 1910 to 2007
Data source: Bureau of Meteorology
Note : The data shows temperature difference from the 1961-90 mean.



In Victoria, the rate of warming has been faster over the last 50 years (Figure A1.10), increasing from a range of 0.05°C to 0.1°C to between 0.10°C and 0.15°C per decade in most of the State[61]. Some zones, including the south-east of metropolitan Melbourne, the far east of Victoria, and small patches in north-western Victoria around Swan Hill and Kerang, have warmed even faster, at 0.15°C and 0.20°C per decade. Other exceptions include zones which have warmed at a lower rate of between 0.05°C and 0.10°C per decade (for example a strip in central-western Victoria and an area in the north-east of the State).

The rate of warming has also varied by season. Mean maximum temperature increases have been greatest in winter and least in summer (see Figure A1.11), whereas mean minimum temperature increases have been greatest in summer and spring. Mean minimum temperatures have showed a slight decrease in some eastern parts of Victoria in autumn and winter (see Figure A1.12).

This increase in mean temperature coincides with increases in both the mean daily maximum and minimum temperatures. Since 1950, daily maximum temperatures have increased by 0.8°C and daily minimum temperatures by 0.4°C[62], indicating a general warming of both days and nights in Victoria.

The number of days on which the temperature exceeds 40°C has increased[63]. The number of cold days (days on which the maximum temperature drops below 15°C) has decreased[64].

Corresponding to the increase in average temperatures, Victoria has experienced a decrease in the average annual number of cold and frost nights (nights on which the temperature dropped below 5°C and 2.2°C, respectively). Further, the annual number of hot nights (nights on which the temperature remains above 20°C) has increased. However, some areas of the State with increased clear skies and reduced soil moisture associated with climate change may experience additional frosts.

Extreme temperatures have important effects on natural systems as well as agriculture and infrastructure. For example very hot days cause peaks in energy demand, which have important ramifications for the security of Victoria's energy supply. As far as agriculture is concerned, there are potentially widespread impacts on productivity, some less obvious. For example, yields of stone fruit such as apricots and nectarines in some locations may be reduced due to inadequate chilling.

Figure A1.10 Mean temperature trends in Victoria, 1910-2006 and 1950-2006
Data source: Bureau of Meteorology, Australia

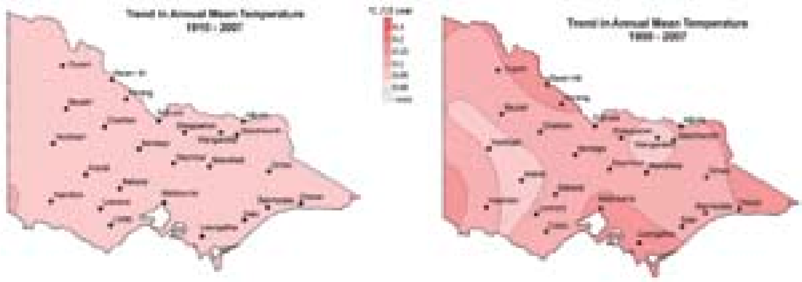


Figure A1.11 Trends in seasonal average daily maximum temperature in Victoria, 1950-2007 (°C/10 yrs)
Data source: Bureau of Meteorology, Australia

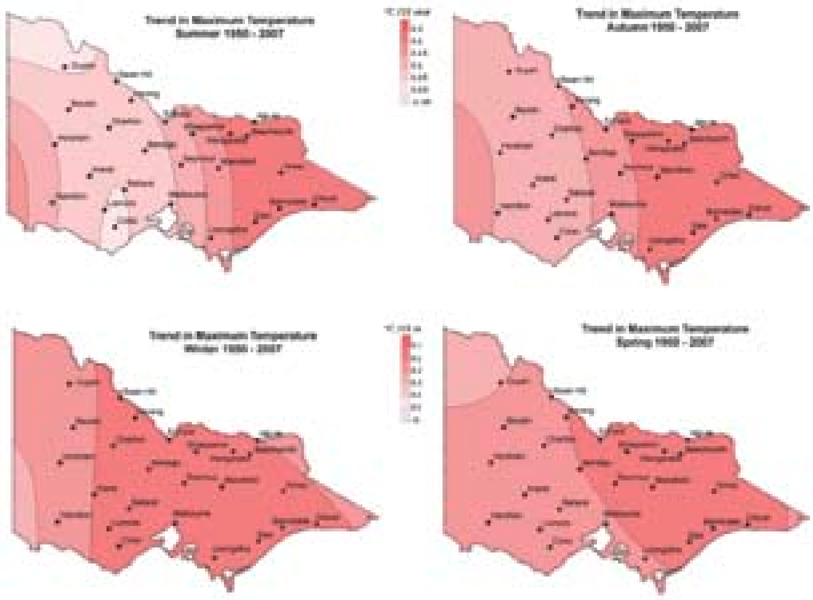
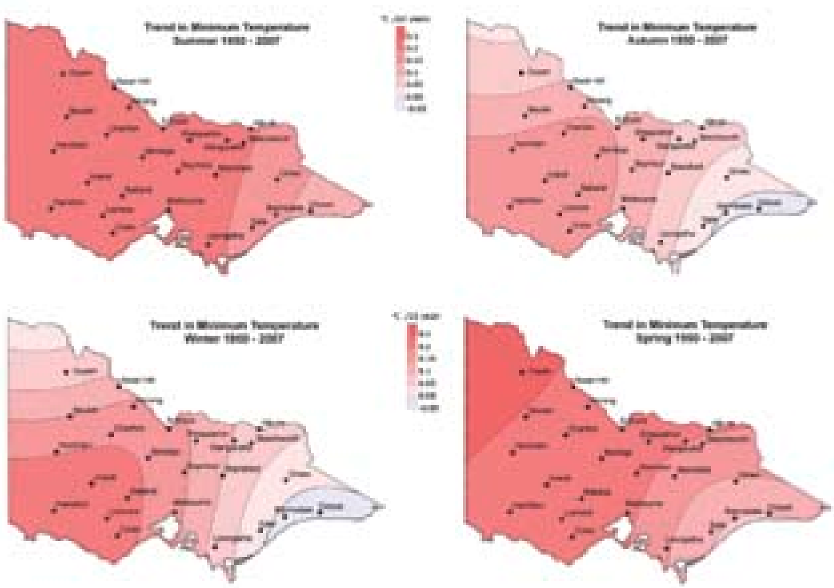


Figure A1.12 Trends in seasonal average daily minimum temperature in Victoria, 1950-2007 (°C/10 yrs)
Data source: Bureau of Meteorology, Australia



Indicator A2 Projected changes in temperature

The latest CSIRO/Bureau of Meteorology (BoM) projections of future average temperatures in Australia are based on 23 different computer models of the climate system developed by leading international research centres[65]. The projections give "best estimate" changes in temperature as well as information on the uncertainties associated with these changes. All 23 computer models show that the climate of Victoria will warm during the 21st century and best estimates show that the State is likely to warm at a slightly faster rate than the global average. The projections indicate that current patterns of temperature change are likely to continue, with rates of change varying according to region and season. The north and east of the State are expected to experience greater temperature increases than the south and west. Seasonal analysis indicates that warming will be greatest in summer and least in winter.

Best estimates of increases in long-term annual average temperature across Victoria by the year 2030 are +0.6°C to +1.2°C relative to the climate of 1990. This average incorporates average summer temperature increases of +0.6°C to +1.4°C and average winter increases of between +0.5°C and +1.0°C. Estimates for 2030 are not dependent on emission scenarios as they are the result of previous emissions and are highly likely to occur regardless of future emissions.

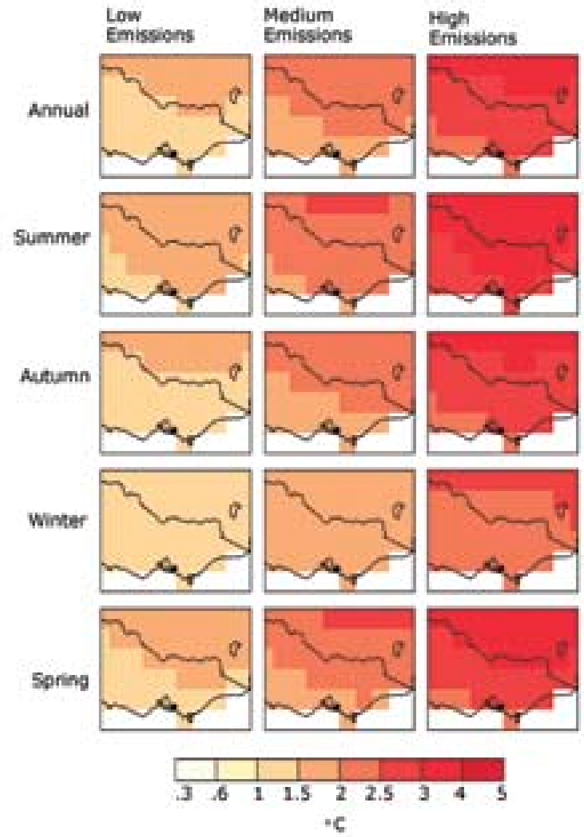
In contrast, the extent of increases in annual average temperature by 2070 is dependent on the rapidity and effectiveness of global responses to climate change. Figure A1.13 illustrates the likely temperature increases according to the rate of global greenhouse emissions between the present and 2070. It is clear that even if the IPCC's low emissions scenario (see Box A1.3) is achieved, an increase of up to 2°C is still possible. In a high emissions scenario, increases are projected to be as high as 3°C, with a range of 1.0°C to 4.0°C[66].

Melbourne currently experiences an average of nine days over 35°C per year. If the best estimates of changes in temperature eventuate, then this number could increase to between 10 and 13 by 2030 and to between 12 to 26 by 2070, depending on future greenhouse gas emissions[67].

Figure A1.13 Best estimates of changes in average temperatures in Victoria by 2070

Source: CSIRO

NOTE: Scenario equivalence with Special Report on Emissions Scenarios68: low emissions=B1 scenario; Medium emissions=A1B scenario; High emissions=A1F1scenario (see Box A1.3).

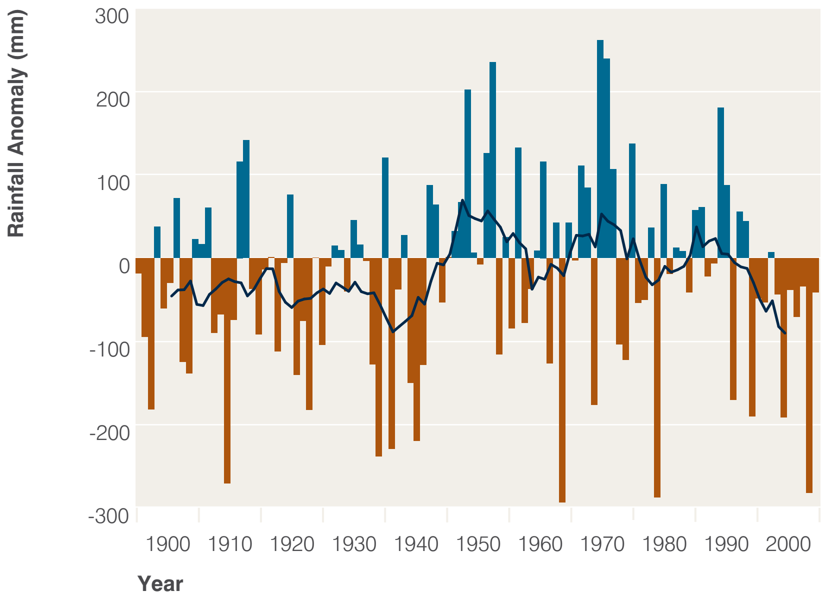


Indicator A3 Observed average rainfall

Observations of annual rainfall in Victoria over the last 100 years show natural high rainfall variability, with a clear descending trend over the last ten years (see Figure A1.14). The gradual increase in annual total rainfall across most of the 20th century reversed abruptly after 1985. Rainfall during the last ten years has been markedly lower than the long-term average, with 2007 one of the three driest years since 1900.

Figure A1.14 Long-term trend in Victoria's annual rainfall, 1900-2007

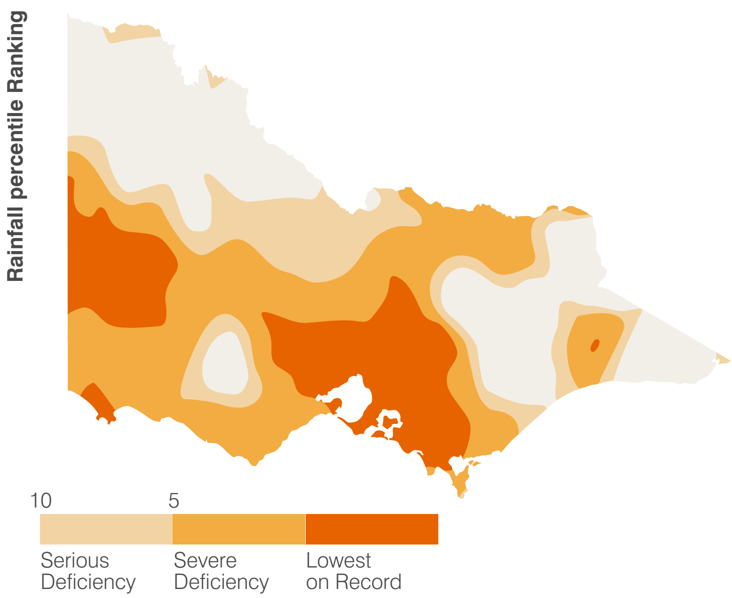
Data source: Bureau of Meteorology, 2007



Reduced rainfall, together with higher maximum and minimum temperatures, resulted in an exceptionally hot and dry decade for Victoria between 1997 and 2006[69]. 2007 was the warmest year on record. The exceptionally dry years in 1997, 2002 and 2006 were associated with El Niño events.

Figure A1.15 shows the distribution of rainfall deficiencies for the last ten years in Victoria. The majority of the State is suffering serious deficiencies, and large areas (including the Port Phillip, Westernport, and Wimmera catchments) are experiencing the lowest rainfall levels on record. The majority of this rainfall decline is due to much drier autumns[70]. Since the 1950s, Victoria has experienced a 40% reduction in autumn rainfall[71]. This is partly due to increasing sea surface temperatures in the Indian Ocean and partly due to climate change[72]. "This is important because autumn rainfall "wets up" the soil in catchments, allowing winter rain and snow to flow into rivers. Decent autumn rain also gives crops and pastures a start after the heat and dry of summer. Victoria has now experienced eight dry autumns in a row, and indeed 16 of the past 19 autumns have received below-average rainfall"[73].

Figure A1.15 Rainfall deficiencies in Victoria: 1997-2007
Source: Bureau of Meteorology, 2008



Indicator A4 Projected changes to average rainfall

Unlike changes in radiation and temperature, precipitation changes are not directly influenced by increased concentration of greenhouse gases. However, a warmer atmosphere can hold more water vapour, and hence produce heavier precipitation. Also, changing the temperature patterns across the planet means that the wind patterns (the circulation) will change the rain patterns. A key change to the atmospheric circulation is poleward expansion of the Hadley circulation, the exchange of air from the tropics to mid-latitudes. This, together with an intensification of the hydrological cycle, tends to produce lower relative humidity and precipitation in the subtropics (the desert regions), extending to the mid-latitudes in some seasons[74].

The "best estimate" projections for Victoria indicate decreases in average annual rainfall across the State, although some computer models show increases in the north and east of the State. Seasonal analysis indicates greater rainfall decreases in winter and spring than in summer and autumn.

The best estimate of change in annual average rainfall in Victoria by the year 2030 is around -4.0% relative to the climate of 1990. Best estimates of changes in seasonal average rainfall are -3.0% to -5.0% for winter and 0% to -3.0% for summer.

As with projected temperature estimates, the extent to which annual average rainfall is affected by climate change depends on the scenario considered. (see Figure A1.16). Under a low emissions scenario best estimate of annual rainfall reduction is 6%. A high emissions scenario could see annual rainfall decrease by 11% across a major part of the State.

Projections indicate that there will be seasonal differences in rainfall reductions, with winter and spring rainfall decreasing most drastically. Under a low emissions scenario, estimates of winter and spring rainfall decreases are up to 10%, and under a high emissions scenario reductions in winter and spring rainfall are between 10% and 40% on (current rainfall levels) (see Figure A1.16).

Despite the projected changes to average conditions, rainfall totals in individual years will continue to be strongly affected by the high level of natural climatic variability in Victoria.

In interpreting these projections, it should be noted that in the future evaporation is also very likely to increase due to higher air temperatures, and therefore increases in rainfall do not automatically translate to greater water supply or availability[76,77]. CSIRO has estimated that in most Victorian catchments, runoff will decrease between 2% and 30% by 2030 and between 5% to up to 50% by 2070.

The best estimate changes in climate suggest that under a high emissions scenario, the climate of Melbourne could come to resemble the current climate of Adelaide by 2070 in terms of seasonal average temperatures and annual rainfall total, although Melbourne is very unlikely to have the marked winter rainfall maximum of Adelaide. Similarly, under a high emissions scenario the climate of Mildura could come to resemble the current climate of the northwest corner of New South Wales by 2070.

Projections of extreme heavy rainfall events for Australia indicate these will be more common than increases in mean precipitation (which is mostly decreasing), and that dry spells in the future will be longer and interrupted by high density rainfall events[78].

Figure A1.16 Best estimates of changes in average rainfall totals in Victoria by 2070
Source: CSIRO and BOM, 2007
NOTE: Scenario equivalence with Special Report on Emissions Scenarios[75]: Low emissions=B1 scenario; Medium emissions=A1B scenario; High emissions=A1F1 scenario (see Box A1.3).

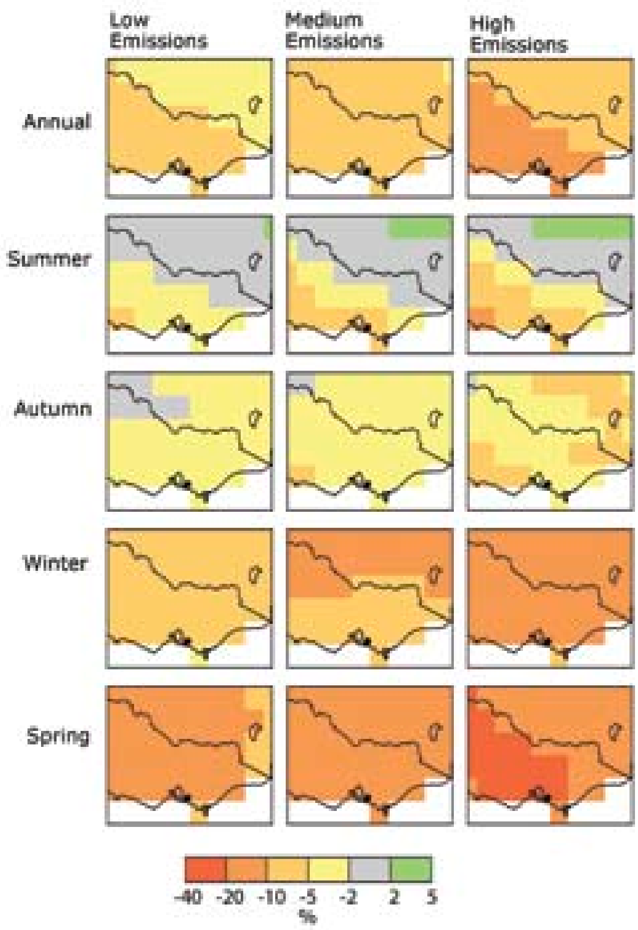
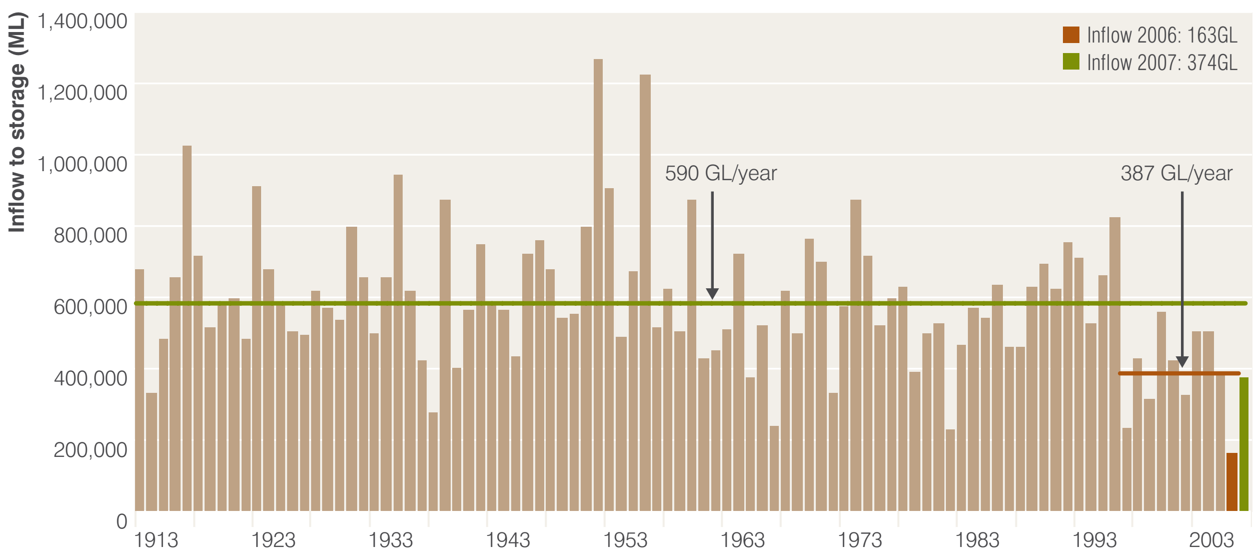


Figure A1.17 Annual inflows to Melbourne's water storages
Source: Melbourne Water



Indicator A5 Observed inflows to storages

In addition to very low rainfall levels in 2006, Victoria registered unusually high temperatures, contributing to high evaporation and low run-off and inflows to storages[79] (see Figure A1.17).

Serious rainfall deficiencies over the past 11 years have reduced inflows to storages of 30-60% below long-term averages. Water scarcity has been statewide in extent and has deepened over time, with flow in the Murray and the Melbourne storages reaching record lows in 2006. For parts of northern Victoria, the last decade ranks as one the three driest decades on record[80].

Indicator A6 Projected runoff to dams and catchments

Projected changes in rainfall and higher rates of evaporation will result in less runoff to dams and catchments. CSIRO has estimated future changes in runoff to Victoria's 29 catchments. Indications are that by 2030, catchments located in the north east and south east may experience up to 30% reductions in runoff; those in the north west can expect reductions ranging from 5% to 45%, while the southwest can expect reductions ranging from 5% to 40%. By 2070 (see Figure A1.18), runoff into catchments in East Gippsland may increase by 20% or decrease by 50% depending on changes in rainfall. The rest of the State can expect declines of 5% to 50%.

Indicator A7 Snow cover

The snow season over south-east Australia has shortened in recent decades, most likely due to higher temperatures in early spring, causing faster melting of snow on the ground and possibly less snowfall[81]. Snow observations show that in south-east Australia snow depths have declined by approximately 40% in the past 40 years[82]. Snow projections for Australia, including Victorian alpine systems, based on temperature and precipitation changes indicate that snow area, depth and duration are likely to decline[83].

Indicator A8 Incidence of drought

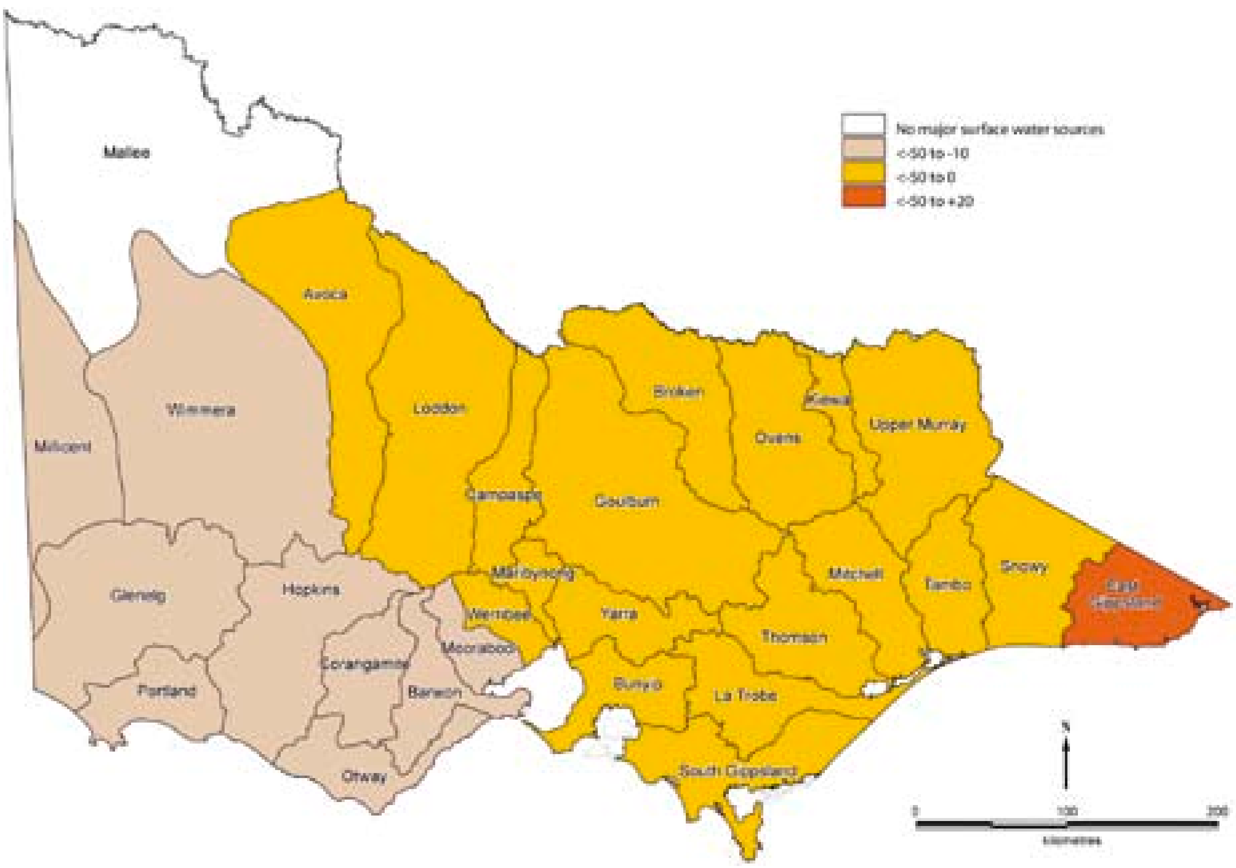
Droughts will continue to impact on Victoria with latest estimates indicating frequency likely to increase by between 10% and 80% in the southern half of the State and by between 10% and 60% in the northern half by 2070.

Drought has a range of definitions, including meteorological, agricultural and hydrological. Meteorological drought incorporates aspects such as low rainfall, high temperatures, high winds, low relative humidity, greater sunshine and less cloud cover. Agricultural drought relates to changes in soil conditions and water deficiency, and hydrological drought refers more to reduced stream flow and impacts on agriculture[84].

Basing assessments purely on rainfall, recent meteorological droughts in Australia have been no more severe than droughts in the early 20th century. However, according to agricultural and hydrological conceptions, incidence of drought in south-eastern Australia is increased beyond the typical variability experienced during the last century[85]. This is because hydrological and agricultural droughts are influenced by the effect of high temperatures on evaporation[86]. Hydrological and agricultural droughts are typically accompanied by higher than average daytime temperatures and lower then average night-time temperatures, due to reduced cloud cover.

While drought and floods are common in Victoria, the past decade of dry years has not been followed by years of above average rainfall, as has been the pattern in the past (see Figure A1.14). Soil moisture has not recovered, exacerbating reduced inflows to storages and prolonging the impacts on agricultural and hydrological systems. See Part 4.2 Land and Biodiversity and Part 4.3 Inland Waters.

Figure A1.18 Projected changes in annual average runoff by 2070
Source: DSE 2008



Indicator A9 Observed Sea level

Sea-level rise is the result of thermal expansion of ocean water in response to global warming and increases in ocean mass from the melting of glaciers, with smaller contributions from the polar ice sheets. Global sea levels have risen by about 17 cm during the 20th century[87], with a rise of approximately 10 cm since 1961.

The average rate almost doubled from 1.8 mm/yr between 1961 and 1992 to an average rate of 3.1 mm/yr since 1993[88].

Two major climate variations influence the oceans around Australia: El Niño Southern Oscillation (ENSO) and the Southern Annular Mode (SAM). While ENSO plays a major role in sea-level variability in the western Indian Ocean and eastern tropical Pacific, SAM is a major driver of sea-level variability in the southern and mid-latitude Indian and Pacific Oceans[89].

In Australia, average sea-level rise has been 1.2 mm per year during the 20th century[90]. Sea level rose 1.8 mm per year or 18 cm over the last hundred years in Williamstown (see Figure A1.19).

As noted earlier, since 1990 both global temperature and global sea level have been tracking at the upper limit of IPCC projections, indicating that projections are likely to underestimate the true rate of change to the climate[91].

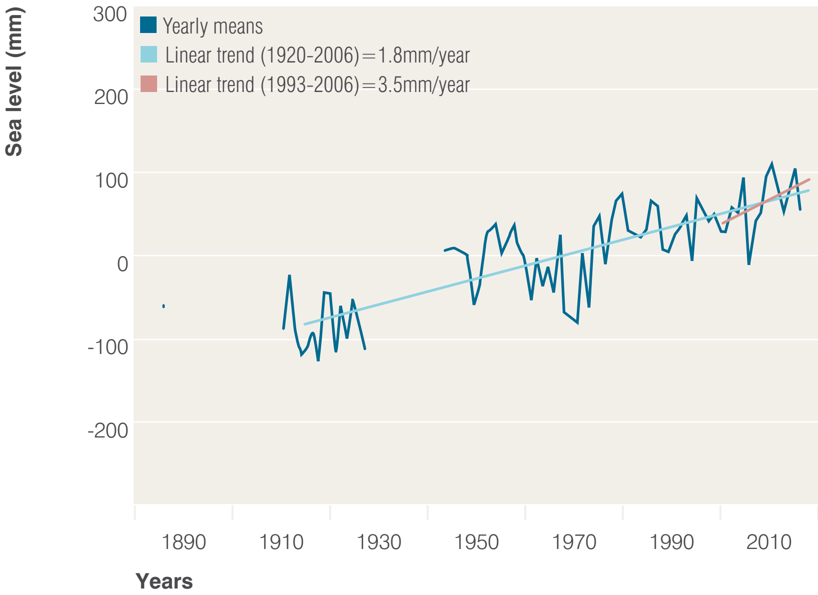
Indicator A10 Projected sea level

IPCC projections indicate that global sea level will likely rise by approximately 20 to 60 cm (relative to 1990 levels) by 2100 due to thermal expansion alone. However, melting of ice sheets from Antarctica and Greenland may add an extra 10 to 20 cm to this, bringing the total projected sea level to somewhere between 20 cm and 80 cm.

Global climate models indicate that mean sea level rise on the east coast of Australia may be greater than the global mean sea level rise[92]. The actual degree of sea level change will be heavily influenced by the global mitigation efforts in the coming years and further contributions from ice sheet melting, which cannot be quantified at this time, may increase the upper limit of sea level rise substantially[93].

The CSIRO has developed projections of the combined impacts of sea level rise and storm surge along the Gippsland Coast. Figure A1.20 shows an example of the impact of inundation resulting from a 1-in-100-year storm surge event in the Gippsland Lakes.

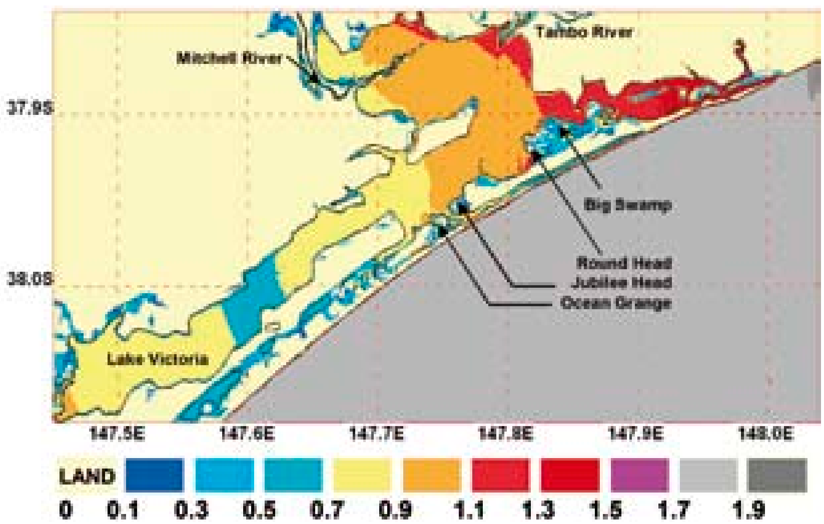
Figure A1.19 Sea level at Williamstown
Data source: CSIRO, 2007



Inundation in the regions of the towns of Port Franklin, Port Welshpool and Port Albert will increase by between 15% and 30% by 2070 under a high wind speed change/high mean sea level rise scenario. Disturbingly, what now appears to be a 1 in 100 year extreme sea level or storm surge could occur around every five years by 2070[94].

More specific analysis of sea-level rise for Victoria is being developed by the Victorian Government through the Future Coasts program. See Part 4.4: Coasts, Estuaries and the Sea for a comprehensive analysis of climate change impacts on Victorian coasts.

Figure A1.20 Flood depth (metres) around the Gippsland Lakes likely to experience inundation during a 1-in-100-year storm tide event estimated for a high wind speed, high mean sea level rise scenario for 2070.
Data source: CSIRO and BOM, 2007



4
Atmosphere
4.1

Indicator A11 Projected Wind Speed

Changes in the frequency and intensity of severe wind due to climate change have only recently been quantified for the Australian region. Changes in extreme wind have the potential to bring about large social, economic and ecological impacts. Extremes in wind contribute directly to hazardous conditions causing damage to the built and natural environment. They also create hazardous conditions over oceans, being responsible for the generation of storm surges and large waves which can cause coastal inundation and increase coastal erosion.

Even modest changes in wind speed can have a major impact on erosion by altering the sea wave climate. Model to model uncertainty in average wind speed change is high, but there is a tendency for increases in most coastal areas in 2030 (range of -2.0% to +7.5% with a best estimate of 2.0-5.0%[95]). By 2070, wind speed for coastal areas is expected to increase by up to 14%[96]. As with the projections of other climate variables, beyond the first few decades of the century the magnitude of the change becomes increasingly dependent on the emission scenario.

The projected wind speed impacts for Victorian regions are shown in Figure A1.21.

Recommendations

A1.1 The Victorian Government should ensure that the data and information required to measure progress against the indicators in this chapter is collected in an ongoing and regular manner and made publicly available, if not done so already.

A1.2 The Victorian Government should sponsor ongoing refinement and development of modelling (by BoM/CSIRO and others) to provide statewide, regional and local climate projection data which is sufficiently precise to underpin policy and capital project decision making with limited risk.

Regional climate change projections

The Victorian Government has published regional climate change projections for a range of climate characteristics. Figure A1.21 shows projected climate values for scenarios in 2030 and 2070 for Victoria's 10 regions.

Figure A1.21 Regional climate change projections 2030 and 2070
Source: DSE 2008

Climate Characteristic	Wimmera		Mallee		North Central		Goulburn-Broken		North East	
Average Temperature	+0.8°C	2.6°C	+0.9°C	2.8°C	+0.9°C	2.8°C	+0.9°C	2.8°C	+0.9°C	2.9°C
Average Rainfall %	-4%	-12%	-4%	-11%	-4%	-11%	-3%	-10%	-3%	-10%
Potential Evaporation %	2%	8%	2%	7%	2%	8%	3%	8%	3%	9%
Relative Humidity %	-0.70%	-2.10%	-0.70%	-2.20%	-0.70%	-2.30%	-0.70%	-2.30%	-0.60%	-2.00%
Wind Speed %	no change	no change	no change	no change	no change	-1%	-1%	-2%	-1%	-2%
Frost Days	23	9	14	5	26	11	35	17	65	40
	Horsham		Mildura		Bendigo		Benalla		Rutherglen	

Climate Characteristic	Glenelg-Hopkins		Corangamite		Port Phillip-Westernport		West Gippsland		East Gippsland	
Average Temperature	+0.8°C	2.4°C	+0.8°C	+ 2.4°C	+0.8°C	+ 2.6°C	+0.8°C	2.6°C	+0.8°C	2.7°C
Average Rainfall %	-4%	-13%	-4%	-12%	-4%	-11%	-4%	-11%	-3%	-9%
Potential Evaporation %	3%	8%	2%	8%	3%	9%	3%	10%	3%	10%
Relative Humidity %	-0.50%	-1.70%	-0.50%	-1.70%	-0.60%	-2%	-0.50%	-1.70%	-0.50%	-1.50%
Wind Speed %	no change	no change	no change	no change	no change	no change	no change	no change	no change	no change
Frost Days	16	5	33	14	2	0	25	10	11	2
	Hamilton		Ballarat		Melbourne		Sale		Orbost	

Indicator A12 Trends in greenhouse gas emissions in Victoria

Victoria emitted 120.3 Mt CO_2-e of greenhouse gas in 2006, accounting for 20.9% of Australia's total net emissions97. The most significant greenhouse gases emitted were carbon dioxide (80.8%), methane (14.3%) and nitrous oxide (4%) in CO_2-e terms.

In 2006, the transport and stationary energy sectors accounted for 85% of the total greenhouse gas emissions in Victoria. Agriculture was also a significant contributor in 2006 accounting for 12.6% of the total emissions.

- Despite a range of programs designed to mitigate greenhouse gas emissions in Victoria, the State's share of national emissions is slightly greater than in 1990 when Victoria's share of national total emissions was 20%. By 2005 this had increased to 22% but in 2006 it fell slightly to just under 21%[98]. Between 1990 and 2006 Victoria's total greenhouse gas emissions increased by 12% but energy-related emissions increased by 27%.

The 12% growth of emissions in Victoria from 1990 (see Figure A1.22) was the second largest in percentage terms of any state, behind only Western Australia. Australia's overall emissions increased by 2.2% during this period, particularly as a result of a reduction in land use change emissions[99]. Victoria's emissions growth rate was heavily influenced by emissions from Victoria's coal-based energy industries.

Indicator A13 Projections of greenhouse gas emissions for Victoria

Australia's annual greenhouse gas emissions are projected to be 108% of the 1990 emissions in the period 2008-2012[100], equal to the level allowable under the Kyoto Protocol target; in absolute terms this projection is 599 Mt (CO_2-e)[101]. For Victoria, this signifies an allowable increase from 120.3 Mt (CO_2-e) in 2006 to 125.8 Mt (CO_2-e) in 2010, assuming a share of national emissions equivalent to 2006 levels (21%).

A recent study of Victoria's emissions profile (see Figure A1.23) suggested that without further action, emissions could trend towards 168 Mt CO_2-e by 2050[102], an increase of about 40% above the 2000 level of 119 Mt CO_2-e (see Figure A1.23). This clearly illustrates the magnitude of the challenge ahead for the State in meeting its nominated emissions reduction target of 60% by 2050, equating to total Victorian CO_2-e emissions of 47.6 Mt in 2050.

Figure A1.22 Total Victorian greenhouse gas emissions 1990–2006
Source: Department of Climate Change

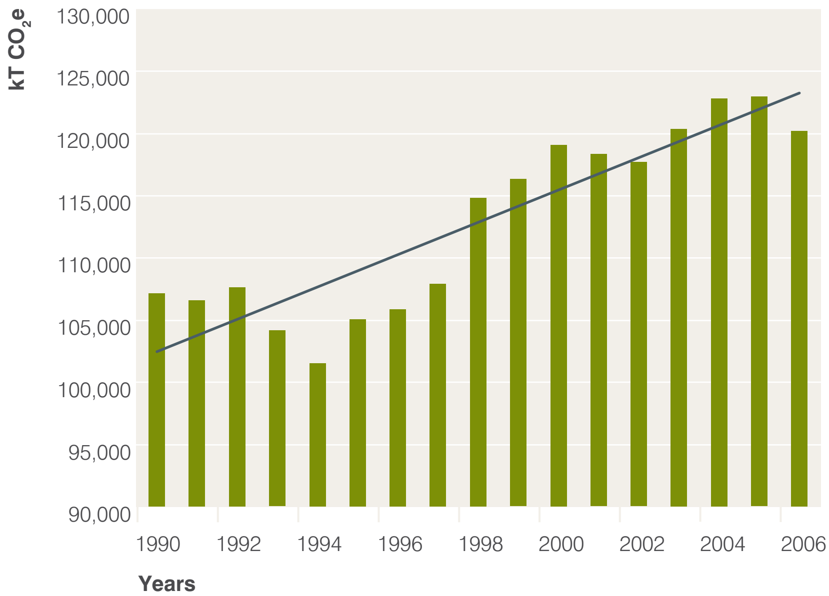
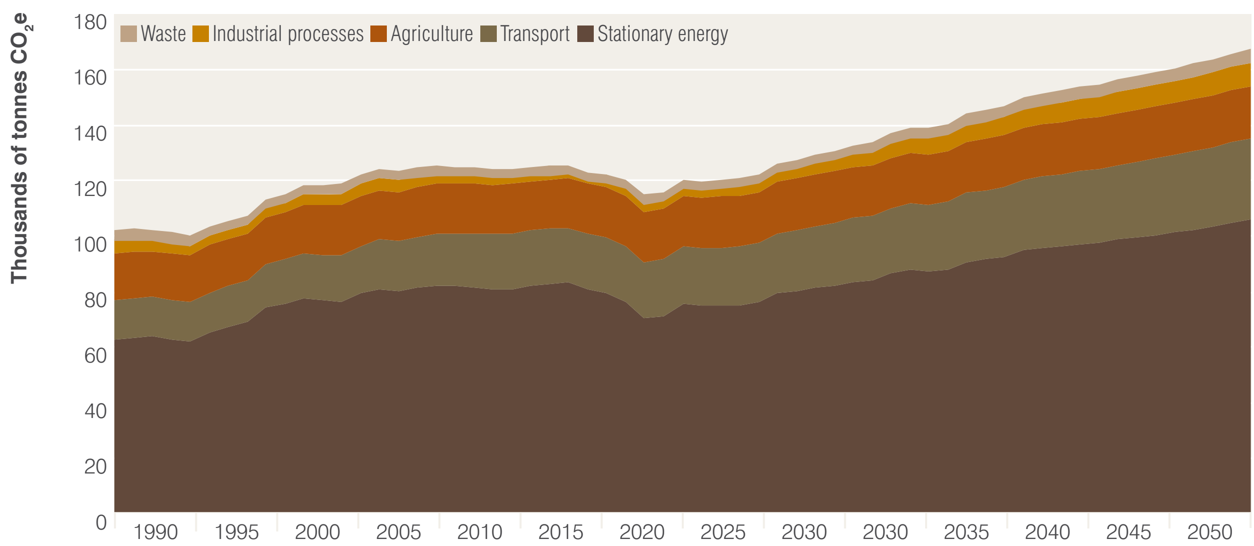


Figure A1.23 Reference case estimates of Victoria's future greenhouse gas emissions
Data source: Victorian Government, Department of Premier and Cabinet[103]
Note: Land use, land use change and forestry emissions considered to be an emissions sink and not shown above shown above.



A1.4 Implications of the state of the climate

The complex interactions between a changing climate system and the natural and built environments introduce a range of impacts which require extensive research, analysis, monitoring and action. The implications of climate change are extensive and far-reaching, and will require committed action by State, Australian and international governments. Table A1.3 shows projections of different levels of global temperature change and their associated impacts.

The following summary of climate change implications for Victorian natural assets and ecosystems need to be supplemented by reference to the detail in other chapters of this State of the Environment Report (see Part 4.2: Land and Biodiversity, Part 4.3: Inland Waters and Part 4.4: Coasts, Estuaries and the Sea). The broad climate change implications for human systems, including health, water availability and coastal development, are canvassed in these sections.

Implications for stratospheric ozone and air quality

The stabilisation and eventual reduction in the size of the stratospheric ozone hole may be threatened as a result of atmospheric conditions associated with climate change. Further, the incidence of dust storms and bushfires associated with climate change is projected to result in more days where the EPA's State Environment Protection Policy (SEPP) objectives are not met.

Implications for land and biodiversity

Climate change poses serious risks to land and biodiversity. Key impacts include warmer temperatures affecting the range of some ecosystems, increased incidence and severity of drought and fire, declining water availability and significant alteration of habitats. Climate change impacts will prompt significant land use change, exacerbate existing pressures on native vegetation and threaten the long-term survival of already endangered species. For example, the alpine ecosystems in Victoria will experience higher temperatures, which will lessen the duration, depth and extent of snow cover, thereby contracting rare alpine habitats and leading to species extinction.

Natural systems have limited adaptive capacity. Projected rates of climate change are very likely to exceed rates of evolutionary adaptation in many species[104]. Habitat loss and fragmentation are very likely to limit species migration in response to shifting climatic zones.

See Part 4.2: Land and Biodiversity for a full discussion of the implications of climate change on land and biodiversity.

Implications for inland waters

Rising temperatures in Victoria, along with less frequent but more intense rainfall events, will result in reduction of stream flows affecting rivers, streams and wetlands. Reduced water availability will jeopardise the subsistence of terrestrial and aquatic ecosystems, and will increase competition from alternative uses, such as agriculture and industry. In addition, increasing fire frequency will have serious implications for water quality.

See Part 4.3: Inland Waters for a full discussion of the implications of climate change on rivers, streams and wetlands.

Table A1.3 Selective summary of outcomes which may occur under the range of temperatures for the three scenarios by 2100
Source: Garnaut Climate Change Review 2008

Outcome / Impact / Sector	No mitigation	550 mitigation	450 mitigation
(a) Percentage of species at risk of extinction	48–100%	8–39%	5–23%
(b) Likelihood of initiating irreversible melt of the Greenland ice sheet	85–100%	12–77%	6–54%
(c) Percentage of mortality in tolerant coral species	90–100%	44–87%	0–79%
(d) Irrigated agriculture in the Murray-Darling Basin	92% decline in irrigated agricultural production in the Basin, affecting dairy, fruit, vegetables, grains	20% decline in irrigated agricultural production in the Basin	6% decline in irrigated agricultural production in the Basin
(e) Natural resource-based tourism (Great Barrier Reef and Alpine areas)	Catastrophic destruction of the Great Barrier Reef. Reef no longer dominated by corals	Disappearance of reef as we know it, with high impact to reef-based tourism. Three-dimensional structure of the corals largely gone and system dominated by fleshy seaweed and soft corals	Mass bleaching of the coral reef twice as common as today

Implications for coasts, estuaries and the sea

Rising sea temperatures and sea levels are projected to have severe repercussions for the marine and coastal environment, such as an increasing acidity, flooding of low lying areas due to storm surge (for example the 2007 East Gippsland flooding), saline water intrusion into estuaries, rivers and embayments, coastal erosion and impacts on mangroves and other fish habitats.

See Part 4.4: Coasts, Estuaries and the Sea for a full discussion of the implications of climate change on these environments.

Implications for human settlements

Impacts of climate change on human settlements will vary between and within settlements. Specific features of the settlement such as size, location and socio-economic characteristics play an important role in determining settlement vulnerability.

Sea-level rise for example could have serious implications and could harm coastal infrastructure and communities.

Climate change and adaptation responses will affect most sectors in Victoria to some extent. Those sectors likely to be most dramatically impacted by climate change include health, infrastructure, services and energy and water supply.

Health

The health of Victorians may suffer due to a range of climate change impacts. These may include direct impacts such as death from heat waves, storms, fire and floods; and indirect impacts related to water quality, food poisoning and air and water-borne diseases[105]. In Australia, it is estimated that there are currently 1,000 heat-related deaths annually in the over 65 age group. Melbourne has a current temperature-attributable death rate of 70 per 100,000 of population[106].

Other implications may include lower human productivity and further required investment in basic health cover. Impacts from climate change will be greater on vulnerable social groups including disadvantaged communities, the elderly and low-income groups[107].

Projected changes to the climate will affect the health of millions of people worldwide. The changes will be most felt by the least able to adapt, such as the poor, the very young and the elderly.

Infrastructure

Infrastructure likely to experience additional pressure as a result of climate change includes roads, bridges, tunnels, drainage, gas and electricity systems and telecommunications networks. The integrity of these and other built structures will deteriorate with higher temperatures, rainfall and extreme weather events.

In terms of infrastructure, adaptive management planning strategies in industry and government will be important in managing for climate change events. This will be especially so if current projections of climate change eventuate, indicating the potential for significant increases in fire weather risk and inundation from higher mean sea levels, more intense weather systems and more extreme precipitation events[108].

Energy and water supply

Higher temperatures will increase the stress on Victoria's energy and water supply. Higher temperatures affect the transmission efficiency in powerlines. Heat waves increase peak demand for electricity due to a greater use of cooling systems[109]. Extreme weather events can disrupt the service by flooding power substations and low-lying water infrastructure such as pipe networks and treatment plants and through wind damage to long lengths of transmission lines.

In terms of water supply, elevated temperatures can affect the quality of water supplies through toxic algal blooms (see Part 4.3: Inland Waters). Toxic algal blooms are likely to become more frequent and to last longer due to climate change[110]. An increase in high intensity rainfall events can cause flooding of sewerage systems and contamination of waterways. Elevated temperatures, along with extreme rainfall events, can increase the likelihood of the transmission of disease.

Emergency services

Demands on Victoria's emergency service organisations will rise as changing climatic conditions progressively increase the number of extreme weather events including bushfires, floods, storms and other natural disasters.

In particular, the fire risk in Victoria is forecast to grow substantially, with the number of very high or extreme fire danger days across south-eastern Australia expected to increase by up to 25% by 2020 and by up to 230% by 2050 as a result of climate change[111]. Metropolitan Melbourne is expected to experience around 15 very high or extreme fire danger days per year by 2050, compared with the current average of nine days per year[112]. More frequent drought conditions may also increase the severity of fires[113]. (See Part 4.2 Land and Biodiversity)

A1.5 Management responses

Responses to the challenge of climate change – by governments, business and industry and by the wider community – are currently dominating international, national and local policy debates. These responses are discussed extensively throughout this report. This section provides an illustrative overview of this dynamic and developing policy environment, from the UNFCCC through to local government action. The focus of the section is on key and emerging developments in the policy environment, and recent climate change advice to governments, such as the development of an Australian emissions trading scheme and the Climate Change Review undertaken by Professor Ross Garnaut.

While climate change action has historically focused on mitigation, governments are becoming increasingly attentive to adaptation imperatives as the reality of unavoidable climate change becomes clear. Victoria's portfolio of responses to climate change incorporate both mitigation and adaptation initiatives.

Victoria's greenhouse gas emission reduction actions are dependent on the Commonwealth Government's aspirations for greenhouse mitigation, including long- and short-term targets, design and coverage of the Carbon Pollution Reduction Scheme (CPRS) and the national and state complementary measures. Urgent action in both mitigation and adaptation is required if both Australia and Victoria wish to make an international contribution to the reduction in global emissions and the avoidance of dangerous climate change.

Due to the impacts of climate change on all ecosystems and economic sectors, specific climate change measures are described in relevant sections throughout this report.

Responses relating to greenhouse emissions in the energy sector are presented in Part 3.1: Energy.

Reducing greenhouse emissions (mitigation responses)

Response Name
United Nations Framework Convention on Climate Change (UNFCCC)

Responsible Authority
Commonwealth Government

Response Type
International Agreement

The UNFCCC was one of three conventions adopted at the 1992 Rio Earth Summit. The central objective of the UNFCCC is to stabilise greenhouse gas concentrations at a level where dangerous human interference with the climate system is prevented.

The 192 signatory nations to the Convention have been divided into three groups, according to differing commitments.

Annex I Parties include the industrialised countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States.

Annex II Parties consist of the OECD members of Annex I, but not the EIT Parties. They are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to adverse effects of climate change. In addition, they have to "take all practicable steps" to promote the development and transfer of environmentally friendly technologies to EIT Parties and developing countries. Funding provided by Annex II Parties is channelled mostly through the Convention's financial mechanism.

Non-Annex I Parties are mostly developing countries.

The main outcome of the UNFCCC to date has been the Kyoto Protocol, negotiated and signed in 1997. Under the Protocol, Annex I countries have been given the initial responsibility for tackling climate change as they are the source of most greenhouse gas emissions to date and have the financial and technological capacity to lead the international response. Developing countries have no immediate restrictions under the Convention. The emergence of commitments for developing countries under the UNFCCC will be an important part of discussions towards a post-Kyoto framework (the 'Bali Roadmap').

Response Name
Kyoto Protocol

Responsible Authority
Commonwealth Government

Response Type
International Agreement

The Kyoto Protocol is an international treaty amongst signatories to the UNFCCC. It sets binding targets for the reduction of greenhouse gas emissions for the developed countries that have ratified the Protocol. It also sets non-binding guidelines for the reduction of emissions by developing countries. The Protocol entered into force in 2005.

While the UNFCCC merely encourages developed nations to stabilise emissions, the Kyoto Protocol goes the next step and commits them to do so. Targets aim for at least a 5% reduction in average global greenhouse gas emissions (for developed nations) relative to 1990 levels.

To help achieve this objective, three market-based mechanisms were included in the protocol: Emissions Trading, Joint Implementation and the Clean Development Mechanism (CDM). These mechanisms help to identify lowest-cost opportunities for reducing greenhouse gas emissions and to attract participation and investment by the private sector.

Australia signed the Kyoto Protocol in 1997 but did not ratify the Protocol until December 2007. Under the Protocol, Australia must limit its emissions to 108% of 1990 levels by 2012. Australia is one of only two developed nations (the other is Iceland) to be granted an increase in emissions under the Protocol. It is estimated that Australia's total emissions will be at 108% of 1990 levels by this time.The United States remains the only developed country not to have ratified the Kyoto Protocol, though it should be noted that both Presidential nominees have stated policy commitments to reduce greenhouse gas emissions (McCain: 60% by 2050; Obama: 80% by 2050).

The UNFCCC Bali Roadmap, agreed in December 2007, establishes a two-year process for the delevoment of a new binding international agreement for the period following 2012. This new agreement is expected to be finalised at the IPCC meeting in Copenhagen in December 2009. A wide range of negotiations is now underway, both under the aegis of the UNFCCC and through other multilateral and bilateral fora. Since the change of the Commonwealth Government in late 2007, Australia is now an active participant in these discussions, where issues of climate equity and the best approach to stronger engagement of the developing world remain central issues.

Recommendation

A1.3 The Victorian Government should encourage, through CoAG and relevant bodies such as the Standing Committee on Treaties, an Australian program of action on climate change which sees effective multilateral and bilateral action and a strong theme of climate ethics and social justice.

Response Name
Australia's Climate Change Response

Responsible Authority
Commonwealth Government
(Department of Climate Change)

Response Type
Policy

The Commonwealth Government has developed a portfolio of policies and programs related to climate change mitigation and adaptation. Many of these programs are jointly administered with the States and territories and some have international elements, for example technology development partnerships with neighbouring countries.

These policies can be viewed through the Commonwealth Government's website http://www.greenhouse.gov.au/

Response Name
Carbon Pollution Reduction Scheme (CPRS) Green Paper

Responsible Authority
Commonwealth Government
(Department of Climate Change)

Response Type
Economic (market-based) instruments

The Commonwealth Government's CPRS Green Paper outlines the Commonwealth's proposed 'cap and trade' emissions trading scheme. The Carbon Pollution Reduction Scheme (CPRS) is a market-based approach to emissions reduction that allows parties to buy and sell permits to emit greenhouse gases. As emissions trading uses the free market to set a price on carbon, it is generally considered to be one of the most efficient ways of reducing greenhouse gases. Funds generated by the permit sales will be used to assist both households and business to adjust to a low carbon economy and to invest in cleaner energy options. The Commonwealth Government has indicated a preferred position regarding the CPRS coverage that would include approximately 75% of Australia's emissions and apply obligations to around 1,000 organisations. A final decision on coverage of Agriculture emissions will be made in 2013, but the sector is not expected to be included within the scheme until at least 2015.

While Australia is yet to commence emissions trading, the Commonwealth Government has committed to a 60% reduction in greenhouse emissions by 2050, with emissions trading being the principal mechanism to achieve this.

While the long-term target of 60% has been set for Australian emissions reduction, this target may be revised upwards as research continues and awareness of the urgency of climate change action increases. The issues of interim targets, reduction trajectories and the initial carbon price, and support for Australia's emissions-intensive industries (both trade-exposed and domestic) are still under consideration. The Commonwealth Government is expected to issue its CPRS White Paper early in 2009.

Response Name
The Garnaut Climate Change Review

Responsible Authority
Commonwealth, state and territory Governments

Response Type
Government review

This landmark independent study was initially commissioned by Australia's state and territory governments and the Commonwealth opposition in mid 2007. The Review, led by Professor Ross Garnaut, conducted a series of public fora around Austalia and has published a number of reports providing medium- and long-term strategic climate change policy recommendations and estimates of the impacts of different scenarios on Australia's economy (September 2008).

A key finding of the Garnaut Climate Change Review is that global greenhouse gas emissions have been growing at a faster rate than previously reported, particularly as a result of the economic growth in key developing countries.

The Review also found that Australia's strong and flexible economy provides the resources to play an important role, with other developed countries, in sharing global leadership and responsibility for mitigation and adaptation. "Australia is ideally placed for this transformation, with its abundant coal, gas uranium, geothermal, solar and other renewable sources and exceptional opportunities for geosequestration and biosequestration of carbon dioxide"[114].

Worldwide emissions allocations per capita provide the only possible (and fair) basis for an international agreement that will bring developing countries into agreed international action.

- Professor Garnaut declared that uncertainty about regional and local aspects of climate change is no cause for delay, especially as Australia is one of the developed countries most vulnerable to climate change impacts. The Review warns that Australia may need to beyond the announced target of 60% emissions reductions by 2050 and notes that Australia is in no danger of leading the world in greenhouse gas mitigation.

Pending international negotiations on post-Kyoto arrangements, the Review suggests a set of possibilities from which the best option should be determined, within an international context. These options create a pathway to an eventual 400 ppm greenhouse gas CO_2-e concentration goal. The suggested possibilities are:

- a 25% (or 40% per capita) reduction on 2000 levels by 2020 within a global agreement aimed at returning emissions to 450 ppm CO_2-e concentration, and 90% emissions reduction by 2050;
- a 10% (or 30% per capita) reduction on 2000 levels by 2020 within a global agreement aimed at stabilising emissions at 550 ppm CO_2-e concentration and 80% emissions reductions by 2050;
- an Australian commitment between the 450 ppm and 550 ppm position, corresponding to a global agreement in between these two;
- if no international agreement is achieved for the post-Kyoto period, a 5% emissions reduction on 2000 levels by 2020 to achieve Australia's existing commitment to achieve a 60% emissions reduction target for 2050.

Professor Garnaut states that the 450 ppm CO_2-e concentration target is in Australia's interests and points out that the economic cost difference between a 450 ppm and 550ppm target equates to just 0.5% of Australian Gross Domestic Product (GDP) by 2020. In both a 450 ppm CO_2-e and a 550 ppm CO_2-e scenario, the overall cost to the Australian economy is manageable and in the order of 0.1 – 0.2% of annual economic growth to 2020. Australian living standards are likely to grow strongly through the 21st century, whether the mitigation goal is 450 ppm CO_2-e or 550 ppm CO_2-e concentration.

"There is a path to Australia being a low-emissions economy within around 40 years, consistently with continuing strong growth in material living standards"[115].

However, Garnaut believes international agreement to target 450ppm CO_2-e concentration is most unlikely to be achieved, and adds "excessive focus on an unlikely goal could consign to history any opportunity to lock in an agreement for stabilising at 550ppm CO_2-e concentration. An effective agreement around 550 ppm CO_2-e concentration would be vastly superior to continuation of business as usual, even if it were to become a final resting point for global mitigation".

However, great caution is required in accepting a revised 'economically acceptable' target for greenhouse gas concentrations. Low targets have the habit of becoming self-fulfilling prophecies[116] and with a 550 ppm CO_2-e concentration comes unacceptably high projected temperature increases and associated environmental, economic and social impacts.

Response Name
Victoria's climate change response

Responsible Authority
Victorian Government (Office of Climate Change, Department of Premier and Cabinet)

Response Type
Policy

Since 2000, the Victorian Government has established a series of climate change policies and programs, with major initiatives since 2006 for which they are commended.

In June 2002, the Victorian Government launched the Victorian Greenhouse Strategy (2002) and started a three-year program of action to reduce growth in Victoria's greenhouse emissions across a range of sectors. Building on this work, the Victorian Greenhouse Strategy Action Plan Update was released in 2005 to acknowledge national and international developments in climate change policy, and build on the actions and commitments initiated in 2002.

In 2006, the Victorian Government released Our Environment, Our Future – Sustainability Action Statement, identifying 150 priority actions aimed at developing environmental sustainability outcomes. Climate change policies and actions were a cornerstone of this action statement. The policies, programs and measures contained in these broad policy statements are the responsibility of a variety of Victorian Government departments and agencies.

In 2006, the Victorian Government established a target of a 60% reduction in Victoria's greenhouse gas emissions by 2050 of 2000 levels.

In 2007, the Victorian Government established the dedicated Office of Climate Change within the Department of Premier and Cabinet. The Office is leading climate change policy across the Victorian Government and with other Australian jurisdictions.

In 2008, the State held a climate change summit and released the paper "A Climate of Opportunity" which heralded a new phase of policy development, noting that:

The Victorian Government is taking this opportunity to be part of the more proactive national emissions reduction effort in Australia by reviewing and updating its climate change policies and programs. In doing so, the Government will exemplify the way in which Victoria can continue to lead the national agenda on climate change by harnessing the opportunities that this economic and environmental shift will bring.

In 2008, the Department of Premier and Cabinet commenced a whole-of-government policy review to ensure that those policies which have a primary focus of reducing greenhouse gases are appropriate to, consistent with and complementary to the proposed national CPRS emission reduction approach.

A Climate Change Green Paper is expected to be released early in 2009, with subsequent climate change legislation proposed for mid-2009. This Green Paper is expected to detail the Government's proposed approach to Victoria's climate change mitigation and adaptation, including the rationale and positioning of Victoria's emissions reduction efforts in the context of the national reduction target(s) and the CPRS. It is expected also to outline how the Government will take climate change into account in its own strategic and operational decision-making.

The Victorian Government also has an opportunity to demonstrate leadership with respect to its own operations. It should be committing to the highest level of greenhouse (and water) performance for its operations, as it makes up around 15% of Gross State Product and employs some 230,000 employees within about 1,800 public sector employing bodies[117]. It should also be leading regular public disclosure of greenhouse, water and waste performance reporting. See Part 5 Living Well for further discussion.

Recommendations

A1.4 The Victorian Government should incorporate in the Climate Change White Paper a strong program of state-based mitigation policy measures which either are required in the lead-up to the CPRS, complement the CPRS (addressing market failures) or relate to sectors not covered by the CPRS.

A1.5 The Victorian Government should build a climate change "test" into all major policy, infrastructure and expenditure decisions, including:

- Development of appropriate assessment tools, methodologies and processes, including consideration of the essential components of strategic environmental assessment methodologies.
- Assessment of climate mitigation and adaptation impacts of budget and Cabinet decisions.
- Assessment of the impact of current policies and programs on Victoria's emissions profile and reduction target.
- Regular public reporting against this measure including building climate assessment and greenhouse gas and water use reduction performance requirements into all Victorian Government department and agency heads performance plans.

A1.6 The Victorian Government should develop strong medium-term greenhouse gas emission reduction targets and a long-term goal of carbon neutrality for its own operations.

A1.7 The Victorian Government monitor and report its own greenhouse gas emissions and water use in annual budget papers and its performance against set targets. A detailed whole of government entity by entity listing of greenhouse gas emissions and water consumption should also be reported.

Adapting to climate change (adaptation responses)

Adaptation responses include those concerned with research into the effects of climate change, risk management, education and awareness, as well as programs which are specific to adaptation in certain areas of the environment and the economy. Adaptation to reduce the impacts of climate change has been identified as a key area which requires research and policy action, in order to cope with the impacts of climate change by both the Victorian and Commonwealth Governments.

Response Name
Victorian Climate Change Adaptation Program (VCCAP)

Responsible Authority
Department of Sustainability and Environment

Response Type
Program

The Victorian Climate Change Adaptation Program is an inter-departmental program with a budget of $14.8 million, designed to coordinate adaptation measures for climate change. The program is chaired by the Department of Sustainability and the Environment, and also involves the Department of Primary Industries, Department of Human Services, Department of Innovation, Industry and Regional Development, and the Department of Premier and Cabinet.

The projects under VCCAP deal with a range of natural resources, economic activities, population settlements and geographical regions in Victoria. The projects are distributed among four main initiatives[118]:

- To help communities through increasing scientific knowledge and technical expertise to help improve the resilience of natural assets to climate change risks, such as fire, coastal erosion and flooding
- To enhance research efforts through the establishment of a research centre in climate change to provide greater and better quality information on climate change to inform government decision-making
- To keep communities informed of climate change vulnerabilities in every Victorian region to help communities develop sound local solutions
- To assess the potential impact of climate change on public health to assist emergency and health care services plan for future demands

Climate Change adaptation: an issue of risk

Given that understanding of elements of climate science is as yet incomplete, and that understanding of and capacity to develop projections of climate is still developing, one of the most effective approaches to prioritising the development of adaptive responses to climate change is through risk analysis and management.

Assessment of priority areas for adaptation involves identification of vulnerable systems (both natural systems and human systems) and the scope of the risk to these systems. At the same time, the capacity of these systems to adapt (either by reducing risk or reducing the likely scale of impact) needs to be considered.

This approach has been adopted already to some extent by the Commonwealth Government, which has undertaken a risk management approach at the national level to identify sectors and regions which would be high priorities for adaptation research, planning and action. The VCCAP has also adopted risk management principles in identifying priority areas of action[119,120].

One advantage of the public presentation of well supported risk management assessments is that these can trigger autonomous adaptation by decision makers in government, business and the wider community. Local government, in particular, needs to develop the capability to ensure that planning approaches in Victoria develop in such a manner as to minimise climate impacts – on the built environment generally, but in particular related to coastal communities and others impacted directly by climate change. This local capability needs to be supported by enhanced State Government research and where needed, action on planning and governance frameworks. Managers of Victoria's natural environment have a similar role in regard to biodiversity and eccosystems.

Box A1.4 presents two examples from the Victorian Climate Change Adaptation Program.

Box A1.4 Some adaptation and research programs under VCCAP

Future Coasts

Future Coasts aims to obtain a sound understanding of the risks associated with climate change on Victorian coasts. The project will develop strategies to help communities and industry respond and adapt to climate change. There are two stages to the project: collecting information and conducting vulnerability assessments. The Future Coasts project is expected to be completed by the end of 2009.

The project will help stakeholders make more informed decisions for the protection and management of the coasts through a better understanding of the potential impacts on Victorian coasts.

Climate Change and Infrastructure – Planning Ahead

This study examined the potential risks of climate change to key infrastructure areas such as water, power, telecommunications, transport and buildings, outlining opportunities for adaptation responses; however more detailed analysis is necessary to develop these responses.

Some short- and long-term outcomes of the study are intended to: reduce risk of significant losses; improve planning for residential and coastal developments; reduce asset maintenance costs; and better inform emergency response and management.

Recommendations

A1.8 The Victorian Government should build on the existing Victorian Climate Adaptation Program to develop and publicly report on a strong and ongoing adaptation research program and suite of actions. Key areas of focus should include long term planning for human systems including electricity infrastructure, and the resilience of agriculture and natural systems, and there should be a clear commitment to business, local government and community engagement and delivery of public good outcomes in the protection of natural systems and resources.

A1.9 The Victorian Government should ensure that Victoria's adaptation and research program supports national and international efforts, through CoAG and relevant Ministerial Councils and CSIRO/BoM.

A1.10 The Victorian Government should conduct and present publicly a regular risk assessment related to climate change within five yearly cycles – looking at risks to both the natural environment and human systems and infrastructure; and its progress in achieving its stated greenhouse gas emissions reduction and climate change adaptation goals.

A1.11 The Victorian Government's proposed Climate Change legislation should incorporate the elements of Recommendations A1.4, A1.5, A1.6, A1.7, A1.8 and A1.10.

Evaluation of climate change responses

The evolving momentum around climate change awareness and government policy responses has developed with the priority assigned to the issue following the election of the new Commonwealth Government in late 2007. It is, however, accurate to describe this policy field as dynamic, currently in a state of flux and still strongly contested.

National commitments to a 60% greenhouse gas emissions reduction target by 2050 from 2000 levels, and the introduction of the Greenhouse Pollution Reduction Scheme (CPRS) in 2010 will be influenced by the outcomes of international climate change negotiations to determine the actions required in the post-Kyoto period.

The national greenhouse gas reduction targets and the CPRS will impact on the plethora of policies and programs that have been established both at the national and state and territory levels over the past decade. Some initiatives, such as State emissions reductions targets may become obsolete in the light of the national target and the annual caps set for the CPRS. Other measures, for example mandatory renewable energy targets, may be reviewed and adjusted as the parameters of the focal initiatives (targets and trajectories and the CPRS) are determined.

What is evident is that across the government, business and community sectors there is an immediate need for action to deliver actual reductions in emissions. The urgency of the situation, as the scientific evidence clearly establishes, dictates that known solutions must be implemented without delay, even as longer term planning and strategies and new technologies are continuously being developed.

Links

Climate change is a prominent issue in all sections of the Report. For specific Victorian policy responses, please refer to the following: Part 2: Driving Forces; Part 3: Production, Consumption and Waste: Energy, Water Resources and Materials; Part 4.1: Atmosphere: Stratospheric Ozone and Air Quality; Part 4.2: Land and Biodiversity; Part 4.3: Inland Waters and Part 4.4: Coasts, Estuaries and the Sea; and Part 5: Living Well within our Environment

For more information

United Nations Framework Convention on Climate Change http://unfccc.int/2860.php

Intergovernmental Panel on Climate Change http://www.ipcc.ch/

CSIRO Climate Change Projects http://www.csiro.au/science/ClimateChange.html

Bureau of Meteorology

http://www.bom.gov.au/lam/climate/levelthree/climch/climch.htm

Commonwealth Government Climate Change Policies & Carbon Pollution Reduction Scheme http://www.climatechange.gov.au/index.html

Victorian Government Climate Change Program http://www.climatechange.vic.gov.au/index.html

Summary of issues

Australia's (and Victoria's) climate change responses must be evaluated against the key issues and challenges that climate change presents to Austalia, as documented throughout this report.

The key issues are:

- The science is established and, through the IPCC, agreed across the world that climate change is unequivocal. To avoid dangerous impacts, temperature increases must be limited through an urgent reduction in global greenhouse gas emissions.
- Globally, between 1970 and 2004, greenhouse gas emissions covered by the Kyoto Protocol have increased by 70% (24% since 1990).
- Without additional policies, global greenhouse gas emissions are projected to increase by 25-90% by 2030, relative to 2000.
- In Bali in late 2007, the IPCC:
  - stated that global CO2 emissions must peak by 2015 and be reduced by 50-85% by 2050 (from 2000 levels) in order for global temperature increases to stay below 2°C;
  - noted that the capacity and leadership required to achieve the emissions reductions lies, both in financial and technological terms, with developed countries; and
  - noted this would indicate emission reductions by developed countries of 25-40% by 2020 and 80-95% by 2050 (from 1990 levels).
- Since 1990, carbon dioxide emissions, global mean temperature and sea level rise have tracked at the upper limit of IPCC projections, indicating that these projections may be underestimates of likely climate change scenarios.
- Amongst developed nations, Australia stands to be amongst the most affected by significant climate change due to our hot, dry and highly variable climate and our highly vulnerable ecosystems.
- On a per capita basis, Australians are the second greatest emitters of greenhouse gases to the atmosphere in the world. However, as fourteenth on the list of the world's 25 largest greenhouse gas emitters, our total contribution overall amounts to just 1.5% of total global emissions.

- There will be little difference to the impacts of climate change worldwide unless the world's largest emitters (both developed and developing nations) all make timely and deep cuts to their greenhouse gas emissions'.
- Urgent global action is required, engaging principles of international and intergenerational equity. However, the world is comprised of sovereign nations which pursue their own interests. Achieving international agreement and action pose a huge challenge to the world community.
- Developing countries, particularly such fast growing economies as China, India and Brazil, are seeking to lift the living standards of their societies in the way that developed countries have done since the industrial revolution. Developed nations have produced most of the greenhouse gases that are changing the climate and as a result must show leadership by committing to significant reductions in their emissions. In reality, the world needs both developed and developing countries to urgently reduce their greenhouse gas emissions.
- The Garnaut Review Report states that Australia's primary interest in mitigation action is to lead developing nations to participate. Australia should do everything possible to foster international agreement and action to mitigate climate change. The Report also points out that over the past 15 years, Australia (and the world) has squandered much of the available time to mitigate emissions and contain climate change impacts.
- The UK Government's Stern Report, the Garnaut Review and Australian industry peak bodies have advised that the sooner action is taken to reduce greenhouse gas emissions, the less costly mitigation will be to economies around the world. Garnaut says that to delay not only increases climate change risks, it also costs more and reduces the flexibility of responses in the long term.
- It is clear the world is facing catastrophic risks to economies, societies and the natural environment from potentially irreversible climate change.

Critical decisions

The state of flux in Australia's and Victoria's climate change policy and programs is reflected in the number of key initiatives in development. These include the Commonwealth Government's response to the final Garnaut Climate Change Review Report, the national Carbon Pollution Reduction Scheme, the Victorian Climate Change Green Paper and subsequent climate change legislation, and research and development of low emissions technologies including the critical Carbon Storage and Capture (CCS) technology for the electricity generation industry and research into non-intermittent renewable energy sources (See Part 3.1: Energy).

In the coming year, critical decisions must be taken that are likely to impact on all Australians and on all sectors of the economy over time. These decisions will also determine Australia's contribution to the reduction of global greenhouse gas emissions and the influence that Australia can exert in getting an international agreement involving developed and developing countries.

Two key national decisions have been announced that form the focal points of Australia's response to climate change mitigation. They are the national 60% target for emissions reductions by 2050 and the establishment of a cap and trade Carbon Pollution Reduction Scheme (CPRS) as the key mechanism to achieve the reductions.

Australia's and Victoria's currently stated targets of 60% reduction of emissions by 2050 needs to be altered to reflect the science and the IPCC's indication of higher reductions (80-95%) required by developed countries.

Recommendation

A1.12 The Victorian Government should support, through CoAG, the adoption of national greenhouse gas emission reduction targets consistent with achieving an initial global 450 ppm CO_2-e concentration. This would require greenhouse gas emission reductions of 25% by 2020 and 90% by 2050.

Australians are the second highest per capita emitters in the world and must demonstrate leadership and responsibility for their contribution to past and projected greenhouse gas emissions. Momentum has built rapidly in terms of public awareness and support for Government action, however, in the context of current global economic instability and concerns about economic competitiveness, strong community support will continue to be required. The international response to current global economic instability is an example of the decisive response, political will and financial resources developed countries can muster when the threat and cost of inaction are made clear[121].

The Garnaut Climate Change Review warns that delayed action involves greater abatement costs, greater risks of dangerous climate change and less flexibility in achieving targets in the longer term.

The Review has provided, for the Commonwealth Government's consideration, three options for greenhouse gas emission reduction targets:

- Australia's full proportionate part in a 450 ppm CO_2-e concentration scenario global agreement equating to a reduction in greenhouse gas emissions of 25% on 2000 levels by 2020, and a 90% reduction by 2050. In line with IPCC projections, a 450 ppm CO_2-e concentration represents an increased temperature range of 2.0–2.4°C. This concentration aligns to a temperature lincrease above the 2.0°C considered to be the limit required to avoid dangerous climate change.
- A global agreement to the 550 ppm CO_2-e concentration option requires an Australian reduction of 10% on 2000 levels by 2020 and 80% by 2050, and in line with IPCC projections, this equates to a global temperature increase of 2.8-3.2°C.
- If no international agreement is achieved for the post Kyoto period, Australia should revert to a 5% emissions reduction by 2020 and maintain the 60% target for 2050. This is referred to as the 'Copenhagen Compromise' option and is Australia's existing unconditional offer for emissions reductions.

Table A1.4 shows the projected economic impacts of these three options. The economic outcomes for the 450 ppm and 550 ppm CO_2-e concentration scenarios are tied to achievement of international agreement for these targets.

Professor Garnaut's Report expresses doubt as to the likelihood of achieving global agreement to a 450 ppm CO_2-e concentration target and 25% reduction by 2020 by developed countries. The Report highlights the crucial nature of a *practical* agreement and finds there are reasonable chances of gaining agreement to a 550 ppm CO_2-e concentration target.

On the basis of the established scientific evidence, it would be of great concern if any option other than the 450 ppm CO_2-e concentration target were initially adopted by the global community as a stepping-stone to an eventual greenhouse gas CO_2-e concentration well below 450 ppm CO_2-e concentrations[122]. Both the 550 ppm conditional and Australia's and Victoria's existing unconditional option delay action significantly and increase the economic, social and environmental risks as a result of climate change. The inevitable result is a reduction in the total amount of carbon abated in the short term, (as represented by the area under the reduction trajectory curve).

The implications of failure to achieve a global agreement are:

- There is a conscious decision to accept the potential risk of eventual irreversible and catastrophic climate change and a belief that adaptation will be manageable.
- There is an implicit acknowledgement that this generation cannot afford to wear the costs of mitigation for the welfare of the world, its ecosystems and future generations.
- It is recognised that the costs of mitigation will increase and flexibility will decrease over time.

Based on the agreed available scientific information, the rationale for a 450 ppm pathway target is strong:

- Climate change is not going to go away, although there is an embedded fallacy in commentaries that this is the case. If anything, the scientific evidence demonstrates that climate change is happening far faster than previously considered likely, escalating the risks involved dramatically.
- There are catastrophic risks involved without early and strong emissions reduction and Australia is one of the most vulnerable to its impacts amongst developed economies.
- The earlier that global mitigation action is taken, the lower the overall cost and the greater the flexibility for management responses as the science and real situation unfold over time.
- A significant reduction in Australian greenhouse gas emissions is achievable now without major technological breakthroughs or lifestyle changes, but this requires prompt action from governments, business and the community. It is estimated that a 30% reduction in Australia's greenhouse gas emissions below 1990 levels can be achieved by 2020 and 60% by 2030 with relative ease[123];
- Australia is ideally placed for this transformation, with a flexible, reformed economy in place.

Australia has the opportunity to benefit economically from the development and commercialisation of low emissions technology and know-how.

Even if there is no international agreement post Kyoto, Australia would be best served by a stronger emissions reduction target. Given the scientific projections and the risks, it is likely the world will have to deliver sharper reductions in due course.

With respect to the proposed Carbon Pollution Reduction Scheme, the Commonwealth Government has indicated a preferred position regarding the CPRS coverage that would include approximately 75% of Australia's emissions and apply obligations to around 1,000 organisations. The CPRS Green Paper has indicated potential exemptions may include the trade-exposed and possibly the domestic energy-intensive sector and at least initally, petrol.

The Garnaut Climate Change Review declared that the emissions trading scheme should have the broadest coverage practicable to ensure its effective operation in achieving the required reductions and spreading the necessary abatement costs widely and fairly.

Rent-seeking behaviour by some industry sectors creates the potential risk of abatement costs being passed on to the community while delaying changes in required capital investment decisions. Distortions within the CPRS will inevitably result in a higher economic burden being placed on non-covered sectors and will undermine the integrity and robustness of the CPRS as the focal mechanism for delivering emissions reductions.

The Commonwealth has indicated that by December 2008, it will announce the national five year trajectory to 2013 (that is, the remaining period under the Kyoto Protocol), including the target reduction range and the approach it will take to setting emissions caps for the CPRS. If an international agreement is reached, Australia's trajectory settings would be changed accordingly.

The announced commitment to commence emissions trading in 2010 is welcome. However, reliance on the market is acknowledged as not being the sole solution. The status of a range of other national responses is unclear and is likely to remain so until the detail of the CPRS and interim targets are announced in mid 2009. Professor Garnaut stresses that a range of complementary measures are essential at the national level to address areas of market failure and least cost abatement; and achieve the reduction targets.

Impacts on the economy

The following table (Table A14) from Professor Garnaut's Final Report demonstrates the impact on GDP of the range of emissions reductions scenarios explored in the Review. It is clear that stronger mitigation by 2020 has a minimal impact, with GDP just half a per cent lower with stronger mitigation (450 ppm) than it would be with the 550 ppm option. Both of these scenarios are dependent on an international agreement.

Table A1.4 Impact on the economy of emissions reductions scenarios
Source Garnaut Climate Change Review, Final Report

	Conditional Offers		Unconditional Offer	
	450 ppm CO_2-e scenario	550 ppm CO_2-e scenario	Copenhagen compromise	Waiting game
Emissions entitlement reduction commitment relative to 2000 (%)				
Reduction in total emissions by 2020	-25	-10	-5	-
Per capita reduction by 2020	-40	-30	-25	-
Reduction in total emissions by 2050	-90	-80	-60	-
Per capita reduction by 2050	-95	-90	-75	-
Deviations from reference case in 2020 (per cent)				
GDP	-1.6	-1.1	-1.3	-0.9
Consumption	-2.4	-1.8	-1.6	-1.2
Carbon Price in 2020 $				
Domestic	60.0	34.5	52.6	29.6

* Price is denominated in 2005 Australian dollars.

Victoria

The key issues outlined above apply strongly to Victoria as well as at the national level, given that this State contributes one fifth of Australia's emissions and has the most emissions-intensive form of stationary energy, derived from brown-coal.

The national CPRS is due to commence in 2010, however, its design is under development and there is uncertainty as to the interim greenhouse gas emissions reduction target and trajectories. Whether these are designed in such a way to drive the capital investment and behaviour change required to reduce emissions in a timely way is currently unclear.

A range of factors underline the risks to Victoria, and Australia, in achieving emissions reduction targets. Implementation of the CPRS is in itself subject to powerful political pressures and partisan platforms on such matters as exemptions and the setting of annual carbon caps and interim emissions targets. As Garnaut declared " These are extraordinarily difficult domestic and international problems of political economy for countries willing to show leadership." Vocal community support for Government leadership on climate change will continue to be required.

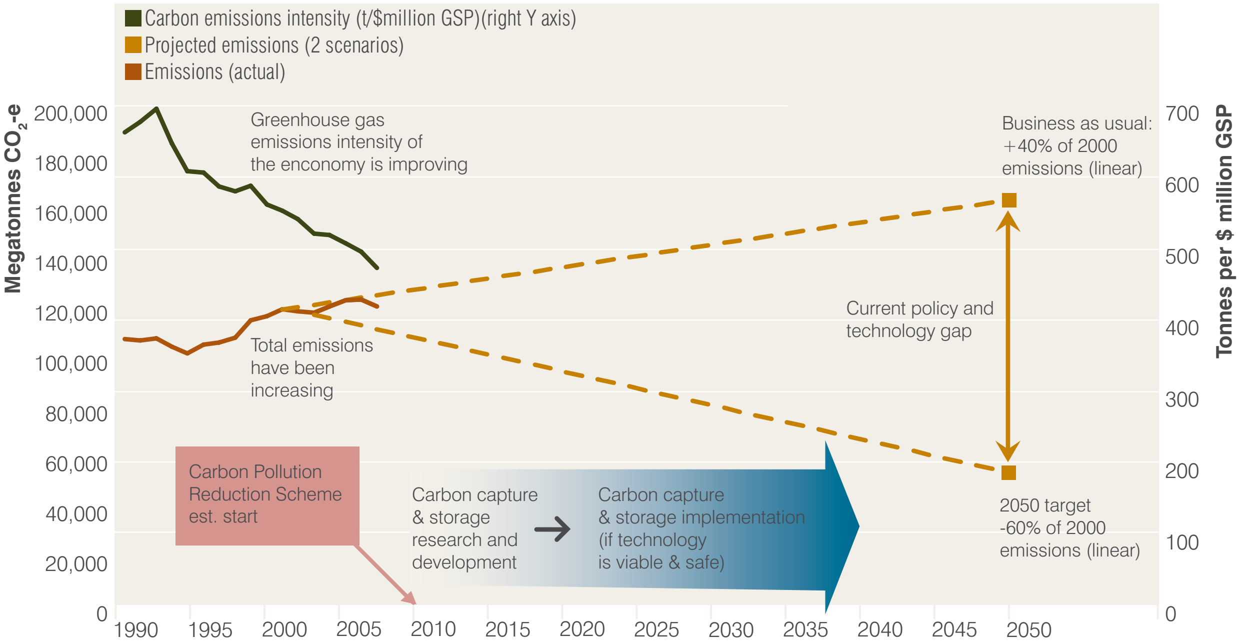
Victoria's faith is invested in an unproven technology, the potential of Carbon Capture and Storage (CCS) to deliver major reduction in emissions. While the benefits of clean coal technologies being successfully developed and operationally deployed are acknowledged, a potential over-reliance on clean coal as a primary means of reducing emissions also presents significant risks. The technology remains unproven, and in any case is not expected to be in place before 2020, with a long ramp-up time after that. Climate change science has stressed the importance of emissions peaking by 2015 and there being significant reductions by 2020. Reliance on a technology that may not be ready by 2030 or later risks emissions continuing to rise for some time. Great care should be taken to adequately encourage investment in renewable energy technologies that will be required and may be more urgently needed if clean coal fails to deliver the expected reductions.

Renewables for baseload power and improved energy efficiency are crucial further parts of the equation. However the current state of policy flux inhibits the certainty required for the capital investment to drive changes in the energy supply mix and in energy use efficiency. There are also huge opportunities in energy efficiencies, but to date they are largely untapped.

The Commonwealth Government's actions will impact on, even overtake, Victoria's current and future responses to climate change. The CPRS will determine where and how the major adjustments will occur to deliver emissions reduction. However, as Professor Garnaut has recommended at the national level, a range of complementary State measures is necessary if greenhouse gas emissions reductions are to be achieved, particularly in unlocking cheaper abatement in situations that are price inelastic or in areas not covered by the CPRS. Research and development into low emissions energy technology, both fossil fuel and renewables are obvious priorities and this should be expanded in scope and investment with support from the Commonwealth and State Governments.

Figure A1.24 below demonstrates the policy and technology action gap that needs to be closed if Victoria is to achieve its stated aim of 60% reduction by 2050, let alone achieve a reduction in the order of 80-95%. This gap must be tackled in the light of the current situation. Victoria's energy efficiency is improving but its total greenhouse gas emissions are still rising and, under business as usual conditions, are projected to increase by 40% (from 2000) to 2050. The State's population and economy are both growing, projections of the former being for an additional one million people in Victoria a decade earlier than expected.

Figure A1.24 Current Victorian policy and technology gap between business as usual greenhouse gas emissions and the 2050 target
Sources: DPC 2007, Department of Climate Change 2008, ABS
Note: Mitigated emissions to 2050 are very unlikely to track evenly (as shown) but rather will decline in steps and at varying rates depending on deployment of policies and abatement technologies as their efficacy is proven.



While climate change action has traditionally focused on mitigation, governments are becoming increasingly attentive to adaptation, as the reality of unavoidable climate change becomes clear. Victoria's portfolio of responses to climate change incorporates both mitigation and adaptation initiatives; however, it is important to note that Victoria's current response repertoire cannot alone prevent severe and dangerous impacts from climate change. It is clear that economic transformation is needed in the face of climate change, a new phase of low carbon industrialisation[124]. Business as usual isn't going to work. Mitigation and adaptation will require involvement of all sectors of the Victorian community, including Government, industry and the general public.

Australia and the world have squandered much of the time available over the past 15 years to seriously address the root cause of climate change –greenhouse gas emissions created by human activities.

The time for much more aggressive and meaningful action on climate change has arrived. Many policies and programs have been put in place at both the Commonwealth and State Government level, however, they have been largely peripheral in the absence of: putting a price on carbon; driving energy efficiency from low-hanging fruit; and being clear as to the magnitude of change required.

Mixed messages, tepid requirements and commitments to short-term economic growth over longer-term sustainability have inhibited the necessary action to both reduce Australia's greenhouse gas emissions and to demonstrate to other countries a viable pathway to a low carbon economy. Demonstrating this viable pathway is desperately needed to increase the likelihood of gaining a global (or series of regional or country) agreement(s) to reduce global greenhouse gas emissions and address the risks associated with climate change.

The urgency for action was underlined by Professor Garnaut declaring:

"What we do now, in time to influence the global mitigation regime from the end of the Kyoto period, is of high importance. What we do later runs the risk of being inconsequential in avoiding dangerous climate change".

"The failure of our generation on climate change mitigation would lead to consequences that would haunt humanity until the end of time".

This point was also re-iterated by a group of eminent Australian academics and climate scientists who recently were moved to co-sign an open letter to Australia's Prime Minister declaring:

"If this trend is not halted soon, many millions of people from around the world will be at risk from extreme events such as heat waves, drought, fire, floods and storms, our coasts and cities will be threatened by rising sea levels, vector-borne, water- and food-borne diseases will spread rapidly, food yields and water supplies will be impaired in many regions, and many ecosystems, plant and animal species will be in serious danger of extinction. Some of Australia's natural assets such as the Great Barrier Reef, Kakadu and the Daintree World Heritage areas, which bring great wealth and recognition to our nation, could be damaged for all time." [125]

"Failure of the world to act now will leave Australians with a legacy of economic, environmental, social and health costs that will dwarf the scale of national investment required to address this fundamental problem."

Now is the time for measured and strong action, not further aspirational policy commitments. Actions to date have simply not been good enough. Australia and Victoria have both the opportunity and the capability to lead this change.

A2: Stratospheric Ozone Depletion

Key Findings

- The anthropogenic emission of chemicals such as chlorofluorocarbons (CFCs) leads to the depletion of stratospheric ozone, exposing both marine and terrestrial life to additional harmful amounts of ultraviolet radiation.
- Global emission of substances that deplete stratospheric ozone peaked in the late 1980s to early 1990s at 2.1 million tonnes per year, and by 2005 had declined by 70% to 0.5 million tonnes.
- Worldwide ozone losses of 4% per decade occurred from the late 1970s until the late 1990s.
- The Antarctic ozone hole reached a maximum area (approximately 30 million km2) and depth (60% ozone losses since the late 1970s) about the year 2000, resulting in 50% to 130% more ultraviolet-B radiation reaching the Earth's surface. It has since stabilised.
- Major ozone losses over Melbourne from the late 1970s until the early 1990s have been 7% - 8% per decade. Ultraviolet levels under clear-sky conditions increased by 10% per decade over southern Australia from the late 1970s to the late 1990s. Since the late 1990s ultraviolet levels have declined by 5%.
- Ozone depletion halted in the late 1990s leaving ozone levels over Melbourne relatively stable, but at a level at least 10% lower than they were in the late 1950s.
- Within this longer-term stabilisation, the lowest ozone level recorded over Melbourne since 1956 was seen last summer (267 DU, 2006/2007). It is believed that this was influenced by solar cycles.
- Stratospheric ozone recovery may have commenced in 2000, but is currently masked by solar cycle effects. Significant ozone recovery is expected over the next five years.
- Full recovery of stratospheric ozone is possible but highly dependent upon adherence of both developed and developing countries to international agreements. In addition, an enhanced greenhouse effect and future atmospheric concentration of nitrous oxide and methane may reverse anticipated ozone recovery.

Description

The depletion of the ozone layer has been accepted as an international concern. Ozone is an important constituent of the atmosphere because it absorbs most of the harmful ultraviolet radiation emanating from the sun, preventing it from reaching the Earth's surface and causing harm to plants and animals, including humans.

Without an adequate ozone layer, solar ultraviolet radiation reaching the Earth's surface can increase to levels unhealthy for humans, potentially causing damage to the eyes, immune system and skin. Excess ultraviolet radiation can also reduce crop yields, affect the growth and reproduction of marine phytoplankton and zooplankton, and degrade synthetic plastics and surface coatings, as well as bio-polymers such as wood, paper, wool and cotton[126]. There is also some evidence to suggest that the dynamic consequences of reduced levels of stratospheric ozone over Antarctica can lead to an exacerbation of certain climate change factors. Reduced ozone levels lead to a contraction and intensification of the Antarctic polar vortex and a series of complex dynamic consequences ensue that impact on the East Australian Current[127] (See Part 4.4 Coasts, Estuaries and the Sea).

Ozone is continuously being produced and destroyed by a number of natural reactions in the stratosphere. Ozone-depleting substances (ODSs) produced as a result of a number of industrial processes play a significant role in increasing the destruction rate of stratospheric ozone and leading to an overall enhanced ozone loss.

In the mid-1970s it was discovered that chlorofluorocarbons (CFCs) (human-produced and released chemicals existing in spray-can propellants, refrigerants, foam-blowing agents and solvents) could deplete the ozone layer[128,129]. In addition to CFCs, there are five other substances used in fire suppression and in industry as solvents and propellants that were also found to deplete ozone[ii]. These ozone-depleting substances release chlorine and bromine, simple chemicals which can act as catalysts to speed up the natural rate of ozone destruction. The emission of ozone-depleting substances such as CFCs that release these catalysts is now limited under the Montréal Protocol on Substances that Deplete the Ozone Layer ('the Montréal Protocol').

Global emissions of ozone-depleting substances peaked in the late 1980s and early 1990s at 2.1 million tonnes per year, and by 2005 had declined by 70% to 0.5 million tonnes. 60% of future ozone depletion will be caused by CFCs yet to be released from stocks (banks) largely in the developed world.

The first evidence that stratospheric ozone levels were declining was published in 1985 based on data collected at Halley Bay, Antarctica[130]. Statistically significant emission rates of ozone-depleting substances occurred until the early 1990s, with global ozone losses of 4% per decade from the late 1970s until the late 1990s. Over Melbourne, the major ozone losses occurred from the late 1970s until the early 1990s (7% - 8% per decade). Global ozone depletion halted in the late 1990s. Since then, ozone levels over Melbourne have been relatively stable and there is some possibility that recovery may have commenced after 2000. As a result of depletion, however, ozone levels over Melbourne are now at least 10% lower than they were in the late 1950s.

On top of this global ozone depletion, a hole in the ozone layer (a pronounced thinning, predominantly in the lower portion of the ozone layer) was discovered over Antarctica in the 1980s. At its maximum, about the year 2000, the hole was approximately 30 million km^2 - almost four times the size of Australia - and its depth was down to 60% of the ozone thickness recorded in the 1970s. It has since stabilised at this size, with significant year-to-year variations largely driven by stratospheric temperature fluctuations.

The Montréal Protocol came into effect in 1989 with the agreement of 55 nations. Strengthened several times since then, the Protocol represents the main worldwide action to control and limit the use of ozone-depleting substances.

Australia has met or exceeded all of its obligations under the Montréal Protocol. Australia will essentially phase out consumption of HCFCs by 2018, thereby consuming some 63% less HCFC in the period to 2020 than permitted under the Protocol.

Objectives

- To continue to contribute to restoration of the depleted global stratospheric ozone layer
- To reduce the hole in the Antarctic ozone layer
- To control and eradicate emissions of ozone depleting substances

ii These are halons, hydrochloroflourocarbons (HCFCs), carbon tetrachloride, methyl chloroform and methyl bromide

A2.1 State of Stratospheric Ozone

Indicator A12: Observed Stratospheric Ozone Concentration

Total ozone over the globe has been measured by satellite since the late 1970s. Under normal conditions, stratospheric ozone in 'the ozone layer' (between about 10 km and 50 km above the surface) exists at an average concentration of around 300 Dobson Units (DU)[iii] depending upon the season and latitude, with ozone levels in Summer naturally lower than in other seasons. For this reason, and due to the implications of increased ultraviolet levels in comparison with other seasons, summertime ozone records are most often used to define ozone changes.

Due to the use of ozone-depleting substances, ozone levels over southern Australia and New Zealand reached their minimum in 1998. Over the 10-year period 1998-2007, mean summertime ozone levels over southern Australia and New Zealand were down to a minimum of 275 DU in 1998/1999, but increased to 286 DU in 2002/2003 before declining again to 276 DU in 2006/2007. The major cause of this reduced concentration is the break-up of the ozone hole (see Indicator A13) and the spreading of ozone-depleted polar air into the ozone-richer air at mid-latitudes.

Significant summertime ozone depletion has been evident over Melbourne for extended periods (Figure A2.1). The first two decades showed summertime ozone losses of 3.1% per decade (1956-1978), then an acceleration in the ozone loss to 7.5% per decade (1978-1992) followed by a 15 year period (1992-2006) when ozone loss is not statistically significant (0.3% decade). Within this apparent stabilisation, the summer of 2006/2007 then recorded the lowest summertime ozone levels for Melbourne since 1956. This is likely due to a solar cycle effect.

Figure A2.1 Summer (December–February mean) total column ozone from the Australian and New Zealand network of Dobson spectrophotometers.
Source: CSIRO, Bureau of Meteorology and the National Institute of Water & Atmospheric Research

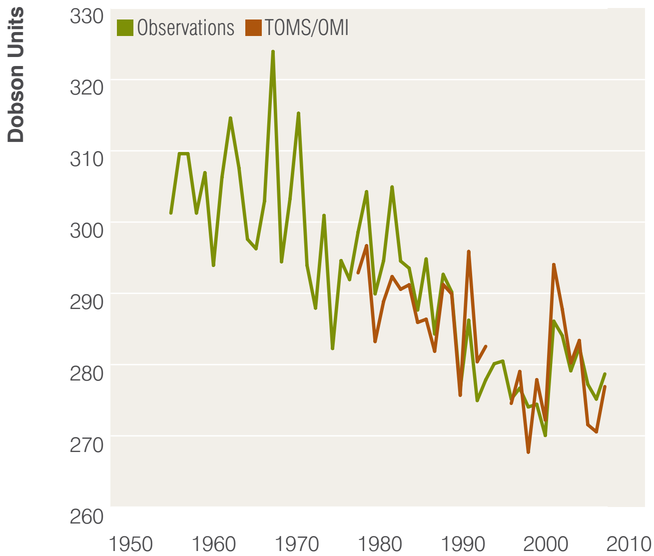
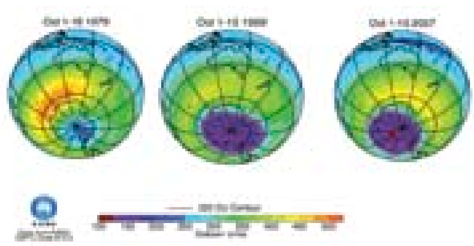


Figure A2.2 Total ozone levels over the southern hemisphere October 1979, 1989 & 2007. The edge of the ozone hole is shown as a red line
Source: CSIRO & NASA



Indicator A13: Average size of the ozone hole over Antarctica

An ozone hole is defined as a region poleward of 60° (or in polar regions) where total ozone levels are less than 220 DU (regions of ozone less that 220 DU in the tropics are not ozone holes). The value of 220 was chosen because total ozone values of less than 220 DU were not found in the historic observations over Antarctica prior to 1979. Figure A2.2 shows southern hemisphere ozone data during October 1-15 from 1979 to 2007. A progressive loss of ozone was observed at mid- and polar latitudes with a rapid reduction in ozone over Antarctica occurring from the mid-1970s until the mid-1990s, leading to an overall ozone loss in that region of about 60%. During the 1990s, ozone loss over Antarctica appears to have stabilised.

The area of the Antarctic ozone hole grew rapidly at about 2 million km² per year during the 1980s and about 0.5 million km² per year during the 1990s (see Figure A2.3). The ozone hole became larger than the Antarctic continent by 1985 and larger than the southern polar zone by 1992. The data suggest that the area of the Antarctic ozone hole is currently at a maximum or may be in slow decline.

iii Ozone is measured in Dobson Units. 100 DU is equivalent to a 1 millimetre thick layer of pure ozone at sea level temperature and pressure.

Figure A2.3 Area (million km²) within the 220 DU contour of the Antarctic ozone hole from 1979 to 2007
Source: CSIRO

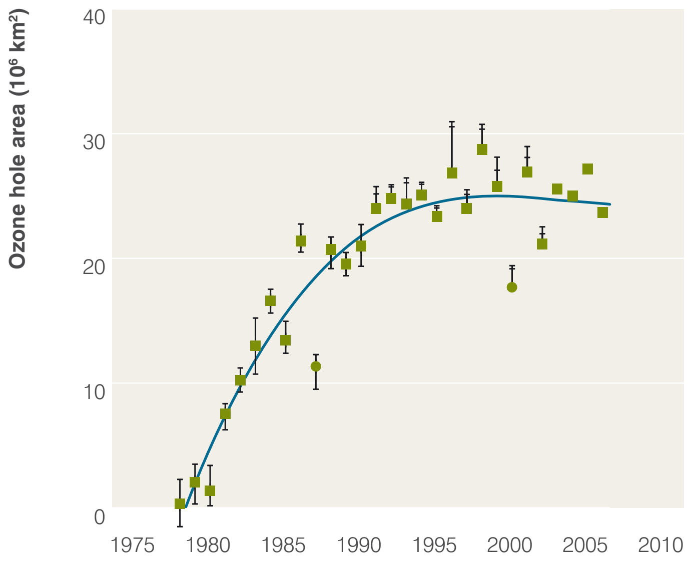
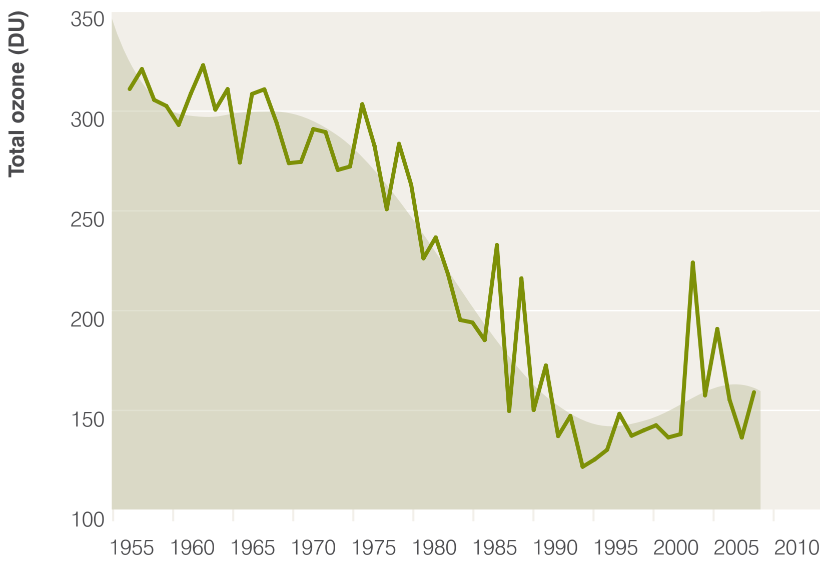


Figure A2.4 October mean total ozone (DU) observed at Halley Bay (66°S), Antarctica
Source CSIRO



Since 2001, springtime ozone levels over Halley Bay, Antarctica, have been variable, but higher on average (160±20 DU) than in the 1991-2001 period (see Figure A2.4).

Relatively high ozone values in 1986, 1988 and 2002 resulted from warmer than normal stratospheric temperatures. The recent trend shown in Figure A2.4 is consistent with the onset of ozone recovery driven by reductions in concentrations of stratospheric ozone-depleting substances (measured in Effective Equivalent Stratospheric Chlorine (EESC)).

Indicator A14: Ultraviolet radiation flux at the surface

Of the three broad groups of ultraviolet radiation, the type that is most dependent on stratospheric ozone levels is ultraviolet-B radiation (solar radiation with a wavelength of between 280 and 315 nanometres). Excessive exposure to this type of ultraviolet radiation, as well as ultraviolet-A (solar radiation with a wavelength of between 315 and 400 nanometres) can cause negative health effects (see Implications).

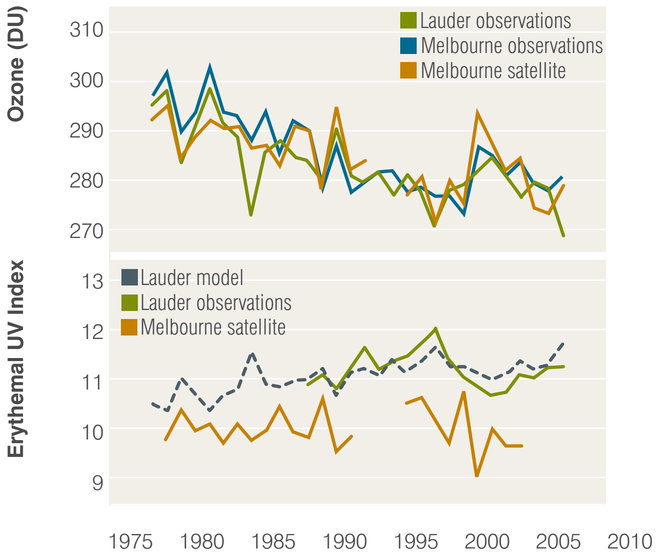
Although the level of ultraviolet radiation reaching the ground is primarily dependent upon latitude, it is also affected by the amounts of ozone and particulate matter in the atmosphere. The degree of cloud cover also has an effect. Data from various locations around the world show a clear correlation between decreased stratospheric ozone and increased ultraviolet radiation under clear sky conditions.

An analysis of satellite-based radiation data from 1979 to 1992 found statistically significant increases of erythemal[iv] (skin-reddening) ultraviolet radiation of 5% per decade for the Australian continent in summer[131]. Analyses also found that summer ultraviolet radiation in the tropics increased 10% per decade due to a simultaneous depletion of ozone and a decrease in cloud cover. However, for regions in Australian mid-latitudes (between the Antarctic Circle and the Tropic of Capricorn) including Victoria, no significant annual ultraviolet-B radiation trends were found because of increases in cloud cover during the same period[132].

Lauder, operated by the National Institute of Water and Atmospheric Research (NIWA) on the central highlands of the South Island of New Zealand (45°S), is a key research station for measuring both ozone and erythemal ultraviolet radiation. In addition, the Lauder ozone data have been used to derive a record for a 30-year ultraviolet index. Results from Lauder show that on days of clear sky there is a strong correlation between decreasing ozone levels and rising ultraviolet radiation levels (see Figure A2.5).

iv The clear-sky erythemal ultraviolet Index (1 unit = 25 mW m-2) is the erythemal ultraviolet dose at local noon under clear-sky conditions.

Figure A2.5 Top: Mean Summer (Dec-Feb) total ozone (DU) for Melbourne and Lauder, New Zealand, 1979-1993. Bottom: Summer (Dec-Feb) clear-sky Ultraviolet Index for Melbourne and Lauder 1979-1993
Source: Bureau of Meteorology and the National Institute of Water & Atmospheric Research



This model shows that the ultraviolet radiation increased 5% per decade from the late 1970s to the late 1990s, followed by a decrease of 3% per decade since the late 1990s. There is good agreement between this model and the measured Ultraviolet Index from 1989 to 2006, suggesting that the modelled trends prior to 1989 are also accurate[133,134]. In contrast, the satellite ultraviolet data over Melbourne do not show a long-term trend of any significance. Generally speaking, because of calibration stability issues, NASA advise that satellite data should not be used for long-term trend studies.

Record low ozone values (but not record high UV) were observed at Lauder in New Zealand in the summer of 2007/2008; but, unusually, these were not reflected in the Melbourne or satellite data. The last time this finding was obvious was in the summer of 1985/1986, and has been interpreted as a meteorological anomaly (a persistent blocking high pressure system over the South Island of New Zealand)[135].

A2.2 Pressures

Indicator A15: Concentration of ozone depleting substances

Atmospheric observations over the past 50 years, either direct (see Box A2.1) or from air trapped in ice cores and other 'archives', have shown that the sources of the chlorine and bromine catalysts that enhance the degradation of ozone have increased sevenfold, whereas the levels of nitrogen and hydrogen catalysts, predominantly generated from natural sources, have remained approximately constant. It is the increasing levels of chlorine and bromine in the stratosphere that have resulted in enhanced ozone destruction, leading to the global losses of ozone.

Box A2.1 Air pollution station at Cape Grim, NW Tasmania

The most important station for the measurement of ozone-depleting substances in the Southern Hemisphere is located at Cape Grim, on the north-west coast of Tasmania.

Photo: Photo: CSIRO Marine and Atmospheric Research

Hemispherically-representative atmospheric observations of ODSs have been made over the past three decades either in situ at Cape Grim or by analysis of the Cape Grim air archive, which dates back to 1978[136]. The station is a joint activity of the Bureau of Meteorology and CSIRO.

Concentrations of ozone-depleting substances are expressed as 'equivalent effective stratospheric chlorine' or EESC, which is a way of representing the ability of the substances to destroy stratospheric ozone. Data from Cape Grim shows the historic and projected trend in stratospheric ozone-depleting substance levels (see Figure A2.6).

The level of EESC, including that attributable to methyl chloride (which is largely natural in origin), observed at Cape Grim and in Antarctic firn (compressed ice) air rose from 1 part per billion in 1970 and peaked at around 3.1 parts per billion in 1998 before beginning to decline (see Figure A2.6).

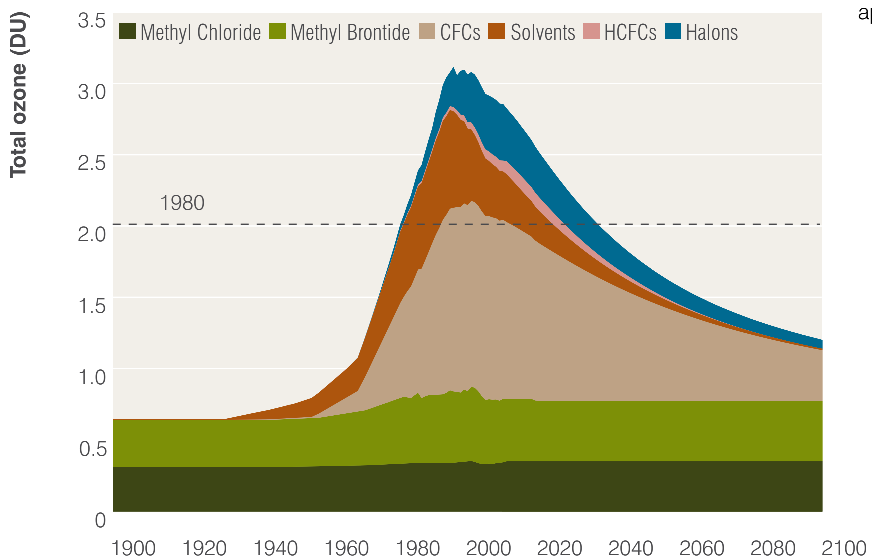
Atmospheric concentrations of ozone-depleting substances have followed closely that predicted by the models, both in terms of the increase and in the post-Montréal Protocol decline. It takes between three and five years for the changes that are occurring in the lower atmosphere to affect the upper atmosphere, and this includes expected future reductions in the level of EESC. In conjunction, the accuracy of the models and the reductions in use and emission of ozone-depleting substances that have occurred and continue to occur as a result of the Montréal Protocol therefore indicate that the concentration of stratospheric ozone-depleting substances over Australia and Antarctica will continue to decline.

Ozone recovery is expected to follow the long-term removal of anthropogenic ozone-depleting substances from the atmosphere. However, stratospheric ozone levels exhibit large natural variability such that it may take up until 2010 to determine when ozone recovery actually commenced. Ozone recovery will be relatively slow over the next 15 years because of emissions of ozone-depleting substances from large 'banks' in the developed world and their continuing use in the developing world, which is allowed under the Montréal Protocol. After 2015 ozone recovery is expected to accelerate, as global consumption of ozone-depleting substances should be close to zero and emissions from the global banks should be in decline. The continued use of ozone-depleting substances in the developing world allowed under the Montréal Protocol should continue for between 10 and 20 years after phase-out in the developed world (see Table A2.1).

Ozone recovery is commonly defined to be near complete when the levels of chlorine and bromine in the stratosphere fall back to 1980 levels (approximately 2 parts per billion), the same level that marked the onset of the Antarctic ozone hole. Based solely on the estimated future global levels of ozone-depleting substances, ozone recovery, as measured by the virtual disappearance of the Antarctic ozone hole, should be complete by 2040.

Figure A2.6 Historic and projected stratospheric chlorine levels attributable to the major ozone depleting substances. Ozone depletion was first detected about 1980 and ozone recovery is anticipated by about 2040

Source: CSIRO



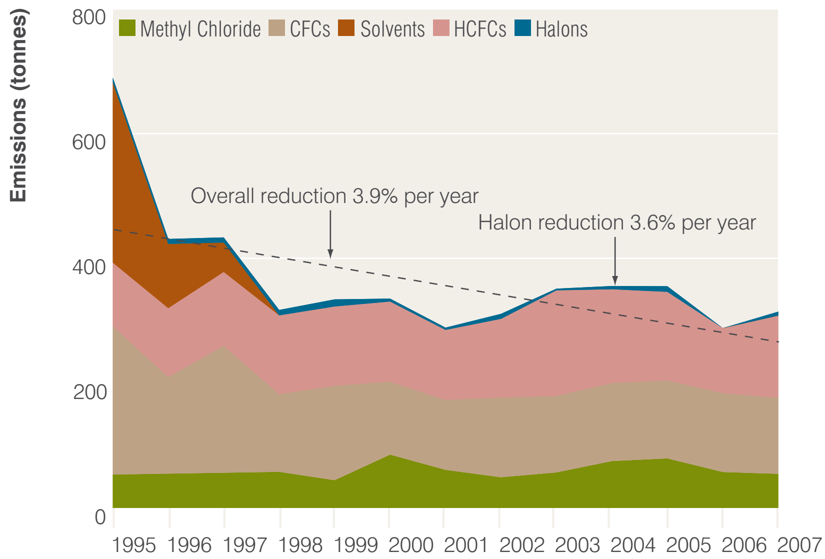
However, additional factors may mean that ozone recovery may not occur by 2040. One of the consequences of climate change (see Part 4.1 Atmosphere, Climate Change) is that as the lower atmosphere warms, the upper atmosphere cools. A cooler stratosphere means more polar stratospheric clouds and more ozone depletion for a given amount of chlorine and bromine attributable to ozone-depleting substances in the stratosphere. Climate change may delay full ozone recovery (i.e. complete disappearance of the Antarctic ozone hole) by as much as 50 years[137].

In addition, the long-term growth of nitrous oxide (N_2O) in the atmosphere may cause significant ozone depletion after about 2060, when the amount of chlorine and bromine in the atmosphere is reduced substantially. This is because oxides of nitrogen (NO, NO_2) from nitrous oxide, which can catalytically destroy ozone, are most effective when chlorine/bromine levels are low.

Indicator A16: Victorian emissions of ozone depleting substances

Overall emissions of ozone-depleting substances from the Melbourne and Port Phillip region have declined from 700 tonnes in 1995 to 300 tonnes in 2007, an overall rate of 3.9% per year. Given that the emission of ozone-depleting substances is roughly population dependent, these emission rates are estimated to account for 80% of the Victorian total (approximately 375 tonnes in 2007). Most of the decline in ODS emissions occurred in the mid-to-late 1990s, when the phase-outs of CFCs and methyl chloroform were completed. Since 2000, ozone-depleting substance emissions have been approximately constant (see Figure A2.7).

Figure A2.7 Emission of ozone-depleting substances for Melbourne/Port Phillip from 1995 to 2007
Source: CSIRO



Emissions of carbon tetrachloride and methyl chloroform ceased in the late 1990s, while CFC and halon emissions are declining by about 4% per year. However, emissions of HCFCs and methyl bromide are increasing by 1-2% per year.

Use of methyl bromide for fumigation of soil and structures is controlled by the Montréal Protocol; however, its use in quarantine for fumigation of grains, timber and containers is not. Methyl bromide (CH_3Br) emissions from quarantine/pre-shipment uses in the grain and other commodity ports of Melbourne and Geelong are about 50-60 tonnes per year. CFC emissions (120-140 tonnes per year) are likely from old refrigeration and air conditioning equipment that is still in use, or buried in landfills with CFC-emitting foams and aerosol cans. Most HCFC emissions (100-160 tonnes per year) are from operational refrigeration and air conditioning equipment. Halon emissions (5-9 tonnes per year) are somewhat episodic.

Victoria is performing well against its Montréal Protocol obligations. However, further opportunities exist for Victoria to accelerate the recovery and reclamation rate of ozone-depleting substances. Industries of particular importance are the strawberry runner industry and grain handling facilities at Melbourne and Geelong ports. Exploring these opportunities could play an important role in contributing to an even greater rate of ozone layer repair.

A2.3 Implications

Indicator A17: Incidence of skin cancer

Compared to other types of radiation, ultraviolet-B, the type of ultraviolet radiation that is relevant under a scenario of depleted ozone, does not penetrate far into the skin[138]. Fortunately, this means that the negative effects of increased exposure to ultraviolet radiation are limited to the skin and eyes, rather than all vital organs. Nevertheless, there is little dispute that chronic exposure to solar ultraviolet A & B radiation is the most significant cause of skin cancers, both melanoma[139] and non-melanoma. Skin cancer is the most common human cancer, and recent data shows an increase in the incidence of melanoma[140] and non-melanoma. Incidence of melanoma increased from about 14 cases per 100,000 people in 1982 to about 26 cases per 100,000 people in 2004[141]. During that period the death rate remained steady at less than 4 per 100,000 people[142], though the death rate is beginning to decline[143].

The recent increases in diagnoses of skin cancers cannot be attributed entirely to ozone depletion. Other factors such as sun height and changes in cloud cover appear to have more influence on levels of ultraviolet radiation reaching the ground than do stratospheric ozone levels. In addition, there are likely to be behavioural factors that also account for a significant proportion of the trend.[144]

Marine ecosystems

Ozone depletion over Antarctica results in 50% to 130% more ultraviolet–B radiation reaching the Earth's surface. This type of ultraviolet radiation reduces growth, production and survival of marine protists - microscopic marine organisms[145]. There is evidence to suggest that substantial changes to the structure and function of marine microbial communities in Antarctica occur at ozone concentrations less than 300 DU[146]. Given that the concentration of ozone at the Antarctic ozone hole is 220 DU or less, Antarctic ecology may be particularly vulnerable to the effects of ozone depletion.

In addition, an increase in ultraviolet-A radiation causes most of the ultraviolet-induced reduction of photosynthesis by phytoplankton in the ocean. The implications of these changes and a reduction in protist populations can affect the food chain, with flow-on effects to larger animals such as fish, seabirds, seals and whales[147].

Other implications of ozone depletion include summer surface wind changes affecting oceanic currents[148]. This issue is covered in more detail in Part 4.4 Coasts, Estuaries and the Sea.

Terrestrial vegetation and agriculture

The responses of plants to ultraviolet irradiation have mainly been determined through agricultural studies. The effects occur at several levels and include physiological, biochemical, morphological and anatomical changes. In general, ultraviolet radiation negatively affects plant growth, reducing leaf size and limiting the area available for photosynthesis[149]. Under a scenario of increasing ozone destruction, these findings would have implications for crop production, especially due to the dependence of global food supply on a small number of agricultural species. Apart from the effect of ultraviolet radiation on agricultural plants, little is known of its effects on other natural terrestrial vegetation species and communities[150].

The deleterious effects of natural ultraviolet radiation on plants can be further exacerbated by other stressors such as drought, mineral deficiency and increased concentrations of carbon dioxide. In contrast, while increased ambient levels of CO_2, due to climate change for example, can have a beneficial effect on plants (see Part 4.1 Atmosphere, Climate Change), this may not necessarily compensate for the anticipated negative effects of increased ambient ultraviolet-B radiation due to ozone depletion[151].

Unintended consequences of phasing out ozone depleting substances

Chlorofluorocarbons (CFCs) were formerly used widely in industry as refrigerants, propellants, and cleaning solvents until their use was prohibited by the Montréal Protocol, because of effects on the ozone layer. They have in part been replaced by hydrofluorocarbons (HFCs) which have no known effect on the ozone layer. However, HFCs are a known greenhouse gas that are much more potent than carbon dioxide in terms of climate change.

A2.4 Management responses

Response Name
Montréal Protocol on Substances That Deplete the Ozone Layer

Responsible Authority
Department of the Environment, Water, Heritage and the Arts

Response type
International Treaty

The Montréal Protocol is the principal mechanism responsible for the decrease in global atmospheric concentrations of ODSs since 1998. This international treaty was created under the Vienna Convention for the Protection of the Ozone Layer. The Montréal Protocol came into force in 1989 and its main purpose is to protect the ozone layer by phasing out the use and production of ozone depleting substances (ODS) over a limited period. It has been signed by 191 countries and, based on its results, is considered a very successful international agreement. The Multilateral Fund for the Implementation of the Montréal Protocol has been established to help developing countries in their efforts to phase out ODSs.

In Australia, the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* was developed to put into practice the commitments made under the Montréal Protocol. As a result, Australia has met its phasing-out targets and it is expected that by the end of 2015 there will be no further HCFC consumption in Australia apart from a small 'tail' (0.5%, 2.5 ODP tonnes) for servicing existing, long-lasting chillers[153]. The Act is also designed to help achieve faster reductions of ODSs and their synthetic greenhouse gas replacements. The Department of the Environment, Water, Heritage and the Arts is the authority responsible for implementation.

Response Name
Ozone Protection and Synthetic Greenhouse Gas Management Act 1989

Responsible Authority
Department of the Environment, Water, Heritage and the Arts

Response Type
Legislation

In Australia, the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* puts into practice the commitments made under the Montréal Protocol. As a result, Australia has met its phasing-out targets and it is expected that by the end of 2015 there will be no further HCFC consumption in Australia apart from a small 'tail' (0.5%, 2.5 ODP tonnes) for servicing existing, long-lasting chillers[154]. The Act is also designed to help achieve faster reductions of ODSs and their synthetic greenhouse gas replacements. The Department of the Environment, Water, Heritage and the Arts is the authority responsible for implementation.

Response Name
Australian Chlorofluorocarbon Management Strategy

Responsible Authority
Department of the Environment, Water, Heritage and the Arts

Response Type
Strategy/policy

The strategy was developed in 2001 by Environment Australia to report on Australia's efforts in managing CFCs and to provide an ongoing framework for the management and use of CFCs in Australia. The strategy aims at minimising the impact of CFCs on the ozone layer by restricting the use of CFCs to essential uses (some pharmaceutical and laboratory uses) and by ensuring the maintenance of infrastructure for CFC recovery and disposal.

Indicator A18
Quantity of ozone depleting substances destroyed or reclaimed

Program Name
Refrigerant Reclamation Australia

Responsible Authority
The Australian refrigeration and air conditioning industry

Refrigerant Reclamation Australia (RRA)[155] is the product stewardship organisation for Australian refrigeration and air conditioning industries. It is an industry/government partnership model established in response to the need to control ODSs and the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*. RRA is a not-for-profit organisation created to work nationally with industry to share the responsibility for, and costs of, recovering, reclaiming and destroying surplus and unwanted refrigerants. RRA's aim is to improve the industry's environmental performance by reducing the level of emissions of refrigerants through its take-back program. To date, the RRA has collected 2 million tonnes of potentially ozone-depleting substances. A further increase of 20% is expected in 2007-08.

Response Name
Victoria's Ozone Protection Framework

Responsible Authority
EPA and the Department of the Environment, Water, Heritage and the Arts

Response Type
Legislation and policy

Victoria's ozone protection framework has been in place since the late 1980s and has enabled Victoria to minimise release of ozone depleting substances and meet its obligations under the Montréal Protocol. The framework provides for recycling and reuse of ozone depleting substances, improved handling and work practices, and managing safe destruction. The Industrial Waste Management Policy (Protection of the Ozone Layer) partly duplicates some requirements of the Commonwealth regulations the Industrial Waste Management Policy (Protection of the Ozone Layer).

Table A2.1 Year of phase out for developed and developing countries under the Montréal Protocol
Source: Anderson & Sarma[152]

Ozone depleting substance (ODS)	Year of phase-out for developed countries under the Montréal Protocol	Developing countries
Halons	1994	2010
HBFCs	1996	1996
CFCs, carbon tetrachloride	1996	2010
Methyl chloroform	1996	2015
Bromochloromethane	2002	2002
Methyl bromide	2005	2015
HCFCs	2020	2040

A2.5 Evaluation of stratospheric ozone responses

Since implementation of the Montréal Protocol ozone depleting substances have been removed from use around the world. This has led to a reduction in the size of the ozone hole, though it is not yet certain if and when the hole will disappear. Whilst Australia has effected its obligations under the Protocol by implementing the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989 the broader* success of the Protocol is still subject to further action required by developing nations.

The strategies and policies described above have had a good degree of success, though there remain a limited number of permissable uses for ODSs in Victoria. It is important that CSIRO and others continue to monitor ODSs, particularly atmospheric changes that may occur with climate change.

For further information

Global ozone protection - http://www.epa.vic.gov.au/air/monitoring/pub409.asp

Ultraviolet radiation – www.sunsmart.com.au/downloads/resources/info_sheets/ultraviolet_radiation.pdf

Recommendations

A2.1 That the Government monitor emissions of HCFCs and methyl bromide to inform a management strategy to reduce emissions.

A2.2 That a strategy be developed to ensure that methyl bromide used for quarantine purposes in shipping ports be recaptured from freight containers then recycled or destroyed.

A2.3 That the Government further encourages the processes that are currently in place to recall equipment currently in use and reclaim the ozone-depleting substances they contain, including CFCs and HCFCs, from refrigeration and air conditioning systems and halons from fire-fighting equipment.

A2.4 That the Victorian Government continues with its control and limitation on the use of ozone-depleting substances and assists in further reduction of emissions from industrial sectors of particular importance, specifically the strawberry runner industry and grain handling facilities at Melbourne and Geelong ports.

A2.5 That the Australian or Victorian Government further investigate the feasibility of salvaging refrigeration systems currently discarded in landfills so that the ozone-depleting substances they contain can be reclaimed.

Issue A3: Air Quality

Key findings

- By international standards, Victoria has good air quality.
- Air quality has been relatively stable over the last decade despite increased pressures from a growing population and economy.
- Levels of fine particles and ozone do not always meet the objectives set out in Victoria's ambient air quality policy.
- Bushfires and dust storms resulting from a prolonged drought have recently affected air quality across Victoria.
- Air quality was poor in 2003 and 2006 due to the impact of severe bushfires.
- Increased frequency and severity of bushfires and drought associated with climate change will compound existing air quality pressures. The higher temperatures may also lead to a greater potential for ozone formation.
- Current air pollution levels are associated with adverse health impacts.

Description

Clean air is one of the essentials of life. Like land and water, air is a resource that must be managed wisely to ensure a healthy living environment. Air quality is primarily of concern in urban areas due to the concentration of population, transport and industrial activities. This is not to say that regional Victoria does not experience air quality issues at times (for example, dust storms or smoke from bushfires), simply that problems are greater in Victoria's more populated regions.

Air pollution is a problem that no major city in the world has avoided although Melbourne is more fortunate than many other cities of comparable size. Melbourne's geography, climate, industry types and its dispersed population mean that air quality is relatively good by international standards. During the 1970s and 80s Melbourne was a smoggy city, frequently affected by days of high ozone levels and poor visibility. However, air quality has improved significantly since the 1970s. This has occurred despite significant increases in population, car fleet and economic activity. Emission reduction actions (particularly in relation to industry, motor vehicles and banning of backyard burning) are the key reasons for this success.

There are three main groups of pollutants that come from human activities. The first and most significant group of pollutants come from burning fuel to run motor vehicles, factories, power stations and wood heaters. The second group of pollutants come from industrial manufacturing processes. Some of these pollutants are more toxic than others and include chemicals, solvents and other process materials emitted from industrial facilities. The third group of pollutants come from other sources such as evaporative losses, and dust or leaks from industry, agriculture and construction work.

High levels of fine particles can also occur as a result of bushfires and dust storms. Climate change is likely to increase the frequency and severity of bushfires and dust storms (leading to more particle pollution) and may lead to more smog events.

Emissions of nuisance pollutants such as odour also affect many local communities and can impact on our enjoyment of the environment.

The common air pollutants – ozone, particles, nitrogen dioxide, carbon monoxide, lead and sulfur dioxide – are associated with a range of health effects, including premature mortality, increased hospital admissions and emergency room attendances, doctors visits, use of medication, and reduced lung function. Air toxics have been associated with cancer, respiratory irritation, and developmental and reproductive problems.

The statutory framework for protecting the air environment in Victoria is set by two State Environment Protection Policies (SEPPs):

- The State Environment Protection Policy (Ambient Air Quality)[156] or SEPP (AAQ),
- The State Environment Protection Policy (Air Quality Management)[157] or SEPP (AQM).

The SEPP (AAQ) contains the national indicators, standards, goals and monitoring and reporting protocol of the National Environment Protection Measure for Ambient Air Quality (AAQ NEPM)[158]. The SEPP (AAQ) also includes an ambient air objective for visibility reducing particles. The SEPP (AQM) sets the framework for managing emissions into the air environment. These emissions are managed to ensure that the air quality objectives of the SEPP (AAQ) are met. In addition Victoria monitors for air toxics under the National Environment Protection (Air Toxics) Measure (AT NEPM)[159].

Objective

- Improve Victoria's air quality, including meeting the air quality objectives and goals specified in the National Environment Protection Measures (NEPMs) and State Environment Protection Policy (SEPP)

Photo: Jane Tovey

A3.1 State of air quality

Indicator A18: Status and trends in particle levels

Particle pollution is the most significant air quality issue facing Victoria. The specific effect of a particle on health depends on its size, composition and concentration. Particles are associated with increased respiratory symptoms, aggravation of asthma, increased mortality and hospital admissions for heart and lung diseases. Particles are sourced from both human (eg. industry, motor vehicles, wood heaters) and natural (e.g. bushfires, dust storms, sea salt) activities.

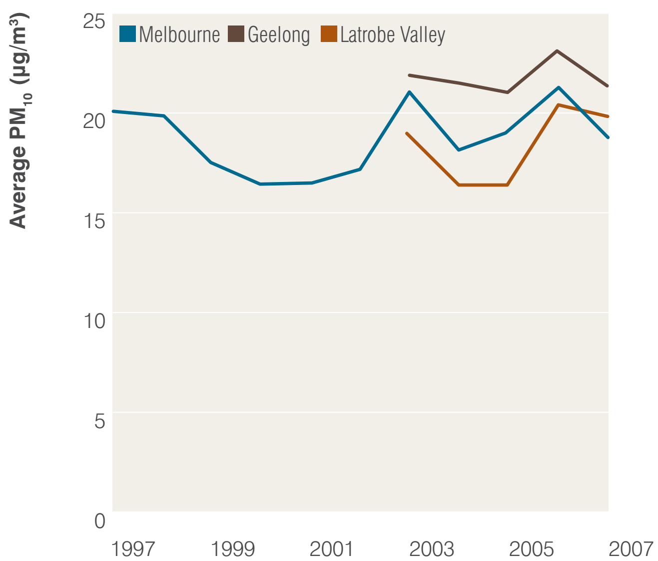
In Melbourne and Geelong, extended periods of light winds associated with persistent high pressure systems can result in accumulation of particle emissions in winter and autumn. Also, with extended periods of dry weather, strong wind gusts can lead to dust storms. There is also significant potential for smoke from fires (both bushfires and planned burns[v]) to impact on populated areas of Victoria.

Particles smaller than 10 micrometres (PM_{10})

Average particle levels[vi] have remained relatively unchanged over the last 10 years (see Figure A3.1), though elevated particle levels occurred during the bushfires of 2003[160] and 2006/07[161]. Geelong's average levels are higher than Melbourne's averages due to the impact of wind blown dust from areas to the west where soils are prone to wind erosion (see Part 4.2 Land and Biodiversity, Soil Structure and Erosion).

The Ambient Air Quality NEPM and Victoria's SEPP (Ambient Air Quality) specify that particles smaller than 10 micrometers should not exceed a concentration of 50 $\mu g/m^3$ on more than five days per year. Figure A3.2 shows that Victoria continues to experience days when the PM_{10} objective is not met. The goal for particles as PM_{10} (i.e. no more than five days per year with levels above the objective) is met at most stations in Melbourne and the Latrobe Valley, except in years with significant bushfires or dust storms. The Geelong station has recorded frequent dust events, preventing this area from meeting the particles goal. Rural centres in Victoria (such as Mildura[162]) are also known to experience frequent dust storms and days when the PM_{10} objective is not met.

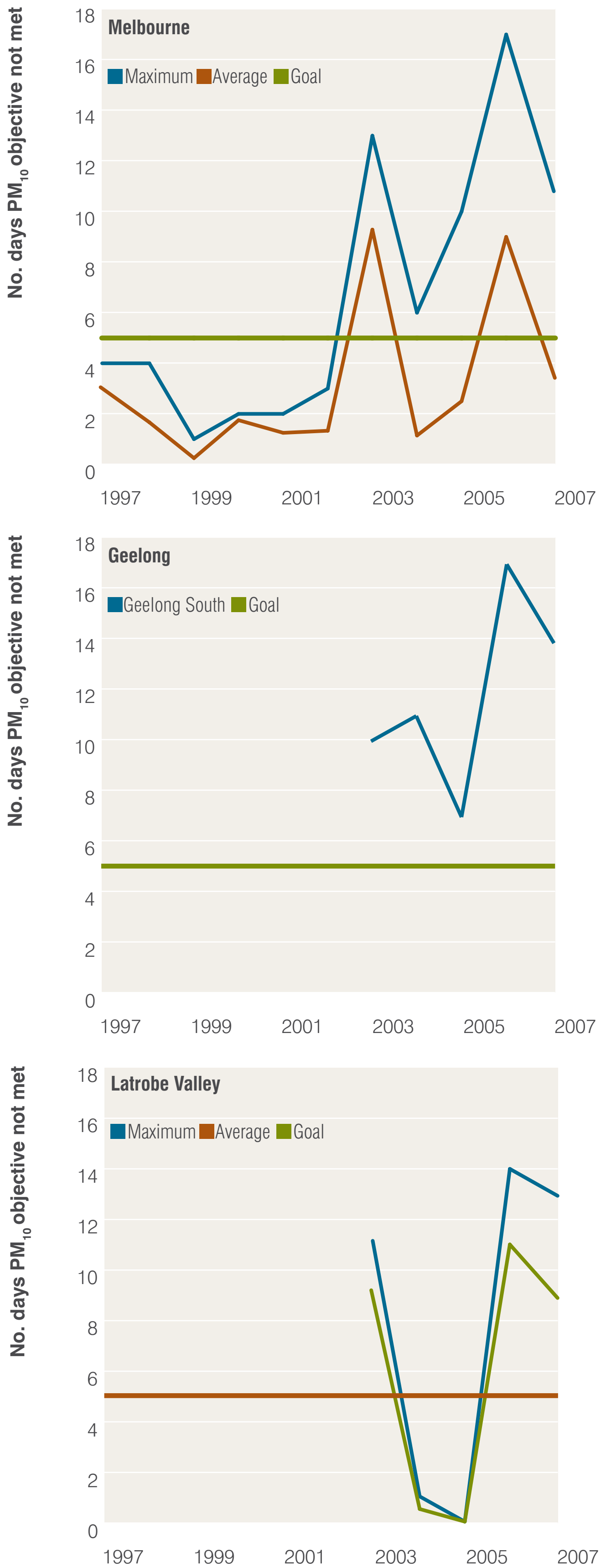
Figure A3.1 Average particle levels (PM_{10})
Data source: EPA



v Planned burns are used for fuel reduction to reduce the risk and severity of bushfires, and for ecological purposes.

vi Average levels are calculated by averaging the pollutant level at each station in a region.

Figure A3.2 Number of days when the objective for particles (PM10) was not met[vii]
Data source EPA



vii Both a maximum and average number of days not meeting the objective have been calculated for regions with more than one monitoring station. The maximum number gives the value for the station recording the highest number of days not meeting the air quality objective each year (that is, the worst performing station that year). The average number (calculated by averaging the number of days at each station in a particular region) is a better indicator for how the region is performing overall rather than simply looking at an individual station.

Particles smaller than 2.5 micrometres ($PM_{2.5}$)

Particles smaller than 2.5 micrometres ($PM_{2.5}$) are considered to have more significant health effects than PM_{10} due to their deeper penetration into the lungs. Monitoring of $PM_{2.5}$ as part of the ambient air quality NEPM has been conducted in Melbourne since 2003 (at Alphington and Footscray), with measurements occurring on a 1-day-in-3 basis. The NEPM specifies advisory reporting standards for $PM_{2.5}$. Levels are not to exceed a concentration of 25 $\mu g/m^3$ per day or an average of 8 $\mu g/m^3$ per year.

There is not currently sufficient data to comment on trends, however, Figure A3.3 shows that the daily reporting standard has been exceeded up to five times a year. The measured levels to date (see Figure A3.4) suggest that the annual reporting standard will be difficult to attain, especially during bushfire affected years. Reasons for days not meeting the reporting standard included both bushfires and the accumulation of urban pollution on calm autumn and winter days.

Visibility reducing particles

Reduced visibility due to fine particles is often the community's main measure of air quality. People comment being unable to see clearly or the presence of a visible brown haze. In addtion to their visual impact, these fine particles also constitute a health risk.

Figure A3.5 shows that the poorest visibility[ix] of the last 10 years was experienced during the bushfire-affected year 2006. Other than in bushfire years, the average visibility level has remained relatively stable over the last 10 years.

Victoria's SEPP (Ambient Air Quality) specifies that visibility should be no less than 20km and that this objective should not be exceeded more than three days per year. Whilst there was a significant improvement in meeting the visibility objective during the 1980s in recent years the improvement has slowed (see Figure A3.6). Figure A3.6 also clearly shows the effect of bushfires in 2003 and 2006.

Figure A3.3 Number of days when the advisory reporting standard for $PM_{2.5}$ was not met
Data source: EPA

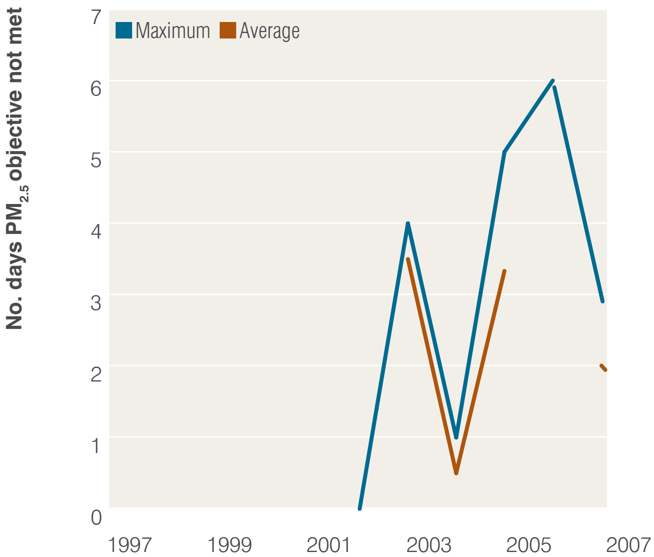


Figure A3.4 Maximum and average PM2.5 levels[xiii]
Data source: EPA

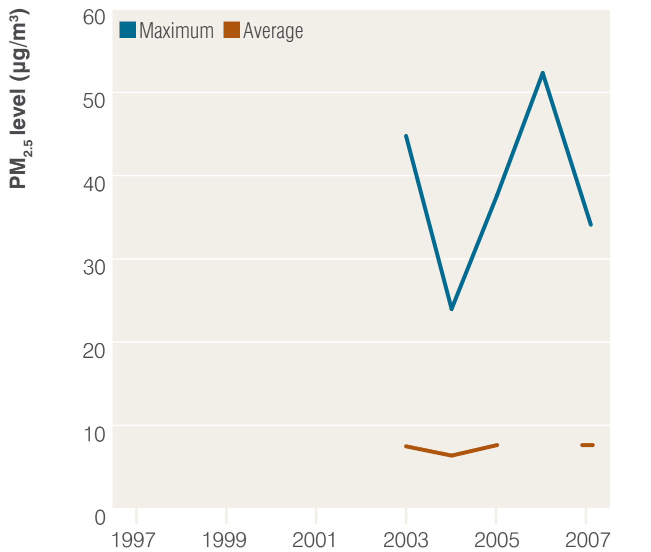
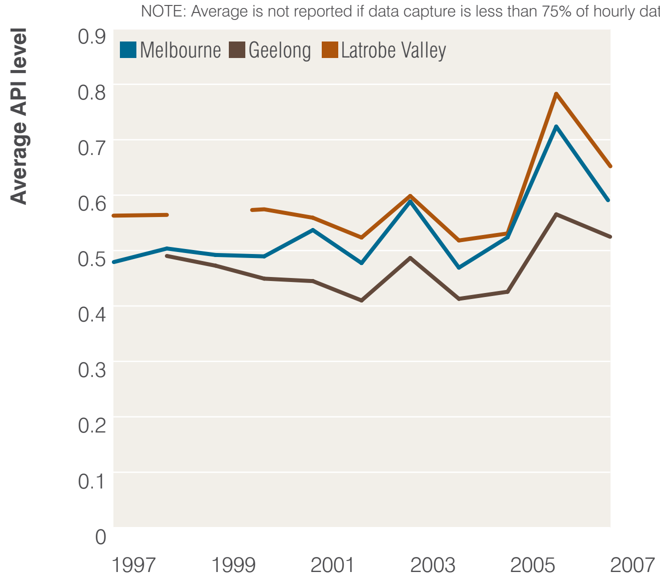


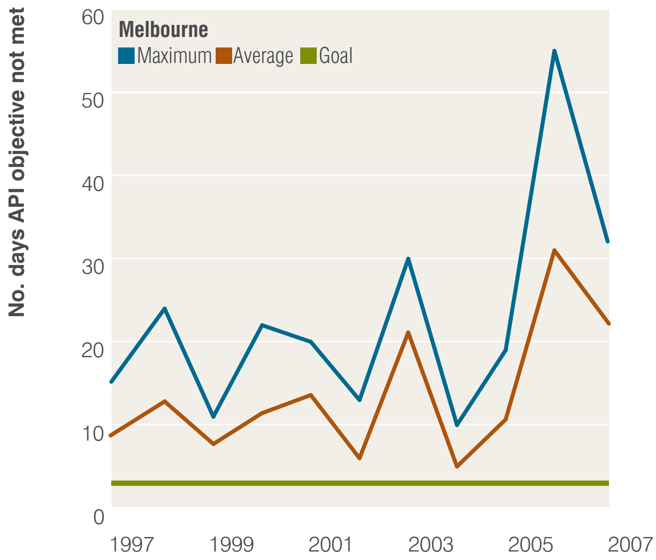
Figure A3.5 Average visibility reduction based on the airborne particle index (API)
Data source: EPA
NOTE: Average is not reported if data capture is less than 75% of hourly data in a year

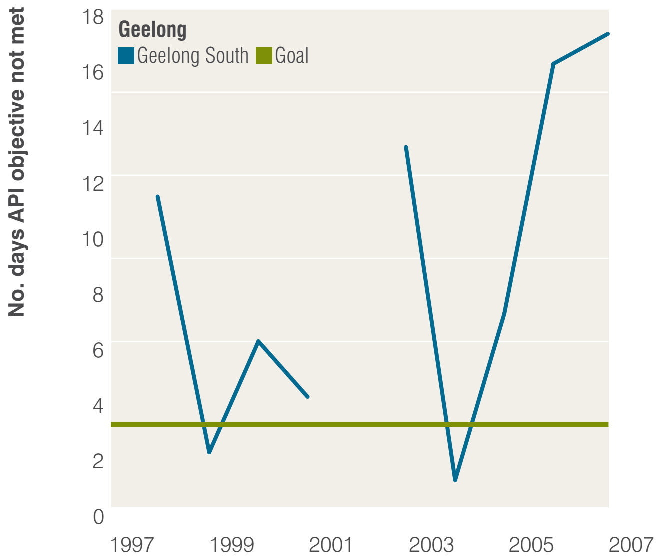


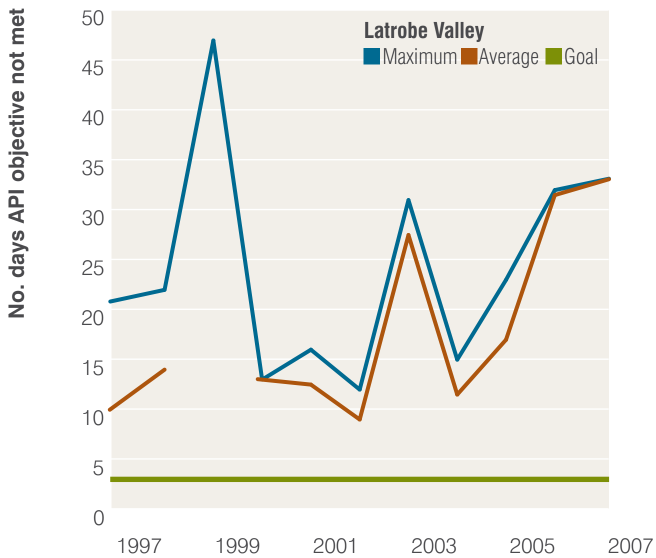
viii The maximum level is calculated by averaging the maximum pollutant levels at each monitoring station in a region over any one year.

ix Visibility is presented as an Airborne Particle Index (API), where the 20 km objective corresponds to an API value of 2.35. Note that visibility decreases as API increases.

Figure A3.6 Number of days where the visibility objective was not met
Data source: EPA
NOTE: Average is not reported if data capture is less than 75% of hourly data in a year







Historically, reduced visibility has been mainly an autumn/winter problem, where pollutants build up under stable atmospheric conditions. In Melbourne, the sources were mainly industry, motor vehicles and domestic wood heaters. In the Latrobe Valley, the topography promotes build up of pollutants, especially from wood heaters and during the burning season (whether by local landholders or from planned burning of vegetation to reduce the risk and severity of bushfires). More recently, many days of poor visibility have been caused by events such as bushfires in 2003 and 2006.

Visibility problems have also been observed during campaign monitoring performed in Ballarat and Bendigo[163], although the frequency of exceedences was not as high as in Melbourne or the Latrobe Valley. Typically these problems are experienced in rural towns that have high wood heater usage.

Indicator A19: Status and trends in ambient ozone levels (an indicator of summer smog)

Ozone is found naturally in low concentrations in the air we breathe. Ozone in air is distinguished from ozone in the stratosphere, commonly known as the ozone layer which has the beneficial effect of absorbing harmful radiation (see Part 4.1 Atmosphere, Stratospheric Ozone). Ozone in air is used as an indicator of summer smog, which is a mixture of gases and particles, with ozone being the largest component. Higher concentrations of ozone are formed when chemical reactions between pollutants (volatile organic compounds and oxides of nitrogen) take place in the presence of sunlight. In Victoria summer smog may appear on hot afternoons between November and March, mostly around Melbourne and Geelong[164]. It is usually seen on the horizon as a white or grey haze.

Ambient ozone levels

Maximum ozone levels in Melbourne over the last 10 years have typically remained low. High levels, however, were recorded during the 2003 and 2006 bushfires. Annual average ozone levels have recently tended to slowly increase, reversing the downward trend observed in the previous decade. EPA is investigating the reasons for this upward trend. Figure A3.7 presents trends for ozone levels from 1997 to 2007.

The Ambient Air Quality NEPM and Victoria's SEPP (Ambient Air Quality) specify both 1-hour and 4-hour ozone objectives. The 1-hour average level of ozone should not exceed 0.10 ppm and the 4-hour level should not exceed 0.08 ppm. The goal is that these levels should not be exceeded on more than one day per year.

Over the last 10 years the number of days in Melbourne on which ozone concentrations exceeded the 4-hour objective ranged from zero to four (see Figure A3.8, which presents trends for Melbourne, Geelong and the Latrobe Valley).

In recent years, with the exception of the bushfire-affected years 2003 and 2006, Melbourne has met the SEPP goal for ozone (i.e. to have no more than one day not meeting the objective). This marks a significant improvement since the early 1980s, when exceedences were common in Melbourne, typically returning more than 10 days each year. Since that time there have been significant improvements in pollution control, mainly through vehicle emission standards, the introduction of catalytic converters for cars, and reductions in industrial emissions.

While Geelong also experiences days not meeting the ozone objective, these days are less frequent than in Melbourne. As a result of bushfires in 2006 the Latrobe Valley recorded its first ever days when the ozone objectives were not met. Campaign monitoring in other parts of Victoria indicates that the ozone objectives are being met.

Figure A3.7 Maximum and average ozone levels (1997-2007)
Data source: EPA

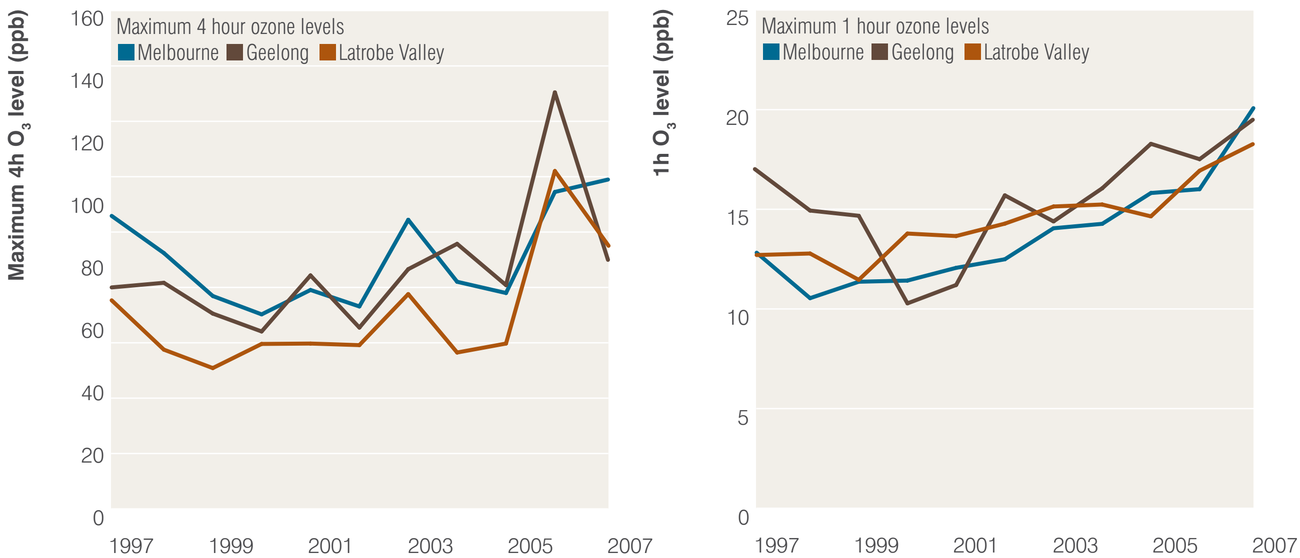


Figure A3.8 Number of days where the four-hour ozone objective was not met
Data source: EPA

Indicator A20: Status and trends in levels of other pollutants

The Ambient Air Quality NEPM specifies four other pollutants that have the potential to affect human health. These pollutants - carbon monoxide, nitrogen dioxide, sulfur dioxide and lead each remain within the objectives specified in the NEPM.

The Air Toxics NEPM specifies monitoring for benzene, polycyclic aromatic hydrocarbons, formaldehyde, toluene and xylene. Monitoring has indicated that concentrations of these air toxics are generally low. Further details on Victoria's air toxics monitoring program can be found on EPA's website[165].

Table A3.1 Air quality objectives for other pollutants

Pollutant	Air quality NEPM objective
carbon monoxide	9 ppm, 8-hour objective
nitrogen dioxide	0.12 ppm, 1-hour objective
sulfur dioxide	0.20 ppm, 1-hour objective
lead	0.50 $\mu g/m^3$, annual objective

Carbon monoxide and nitrogen dioxide

In Victoria, motor vehicles are the dominant source of both carbon monoxide and nitrogen dioxide and as a consequence concentrations tend to be higher in urban areas. With improvements in motor vehicle design, both carbon monoxide (see Figure A3.9) and nitrogen dioxide (see Figure A3.10) levels have decreased over the last 10 years in Melbourne. Although there is no clear trend in Geelong and the Latrobe Valley, these pollutants remain at levels lower than in Melbourne.

Sulfur dioxide and lead

Sulfur dioxide comes mainly from industries such as oil refining and coal-fired power generation. Sulfur dioxide levels tend to be higher near these sources such as the industrial regions of Geelong and the Latrobe Valley (see Figure A3.11). Sulfur dioxide levels are very low in Melbourne, except where influenced by specific industrial sources.

Figure A3.12 shows the annual average lead concentrations in Melbourne from 1984 to 2004. Due to the removal of lead from petrol, lead levels have decreased to such an extent that on-going monitoring is no longer undertaken in Victoria (see Part 3.1 Energy).

Figure A3.9 Maximum 8-hr carbon monoxide levels (1997-2007)
Data source: EPA

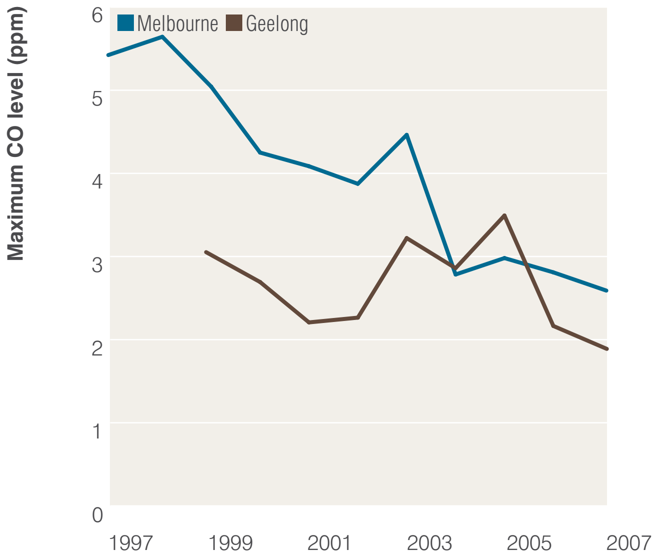


Figure A3.10 Maximum 1-hr nitrogen dioxide levels (1997-2007)
Data source: EPA

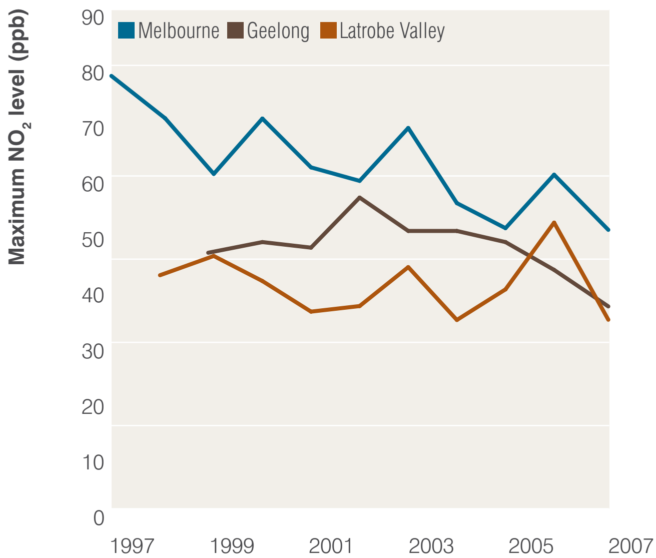


Figure A3.11 Maximum 1-hr sulfur dioxide levels (1997-2007)
Data source: EPA

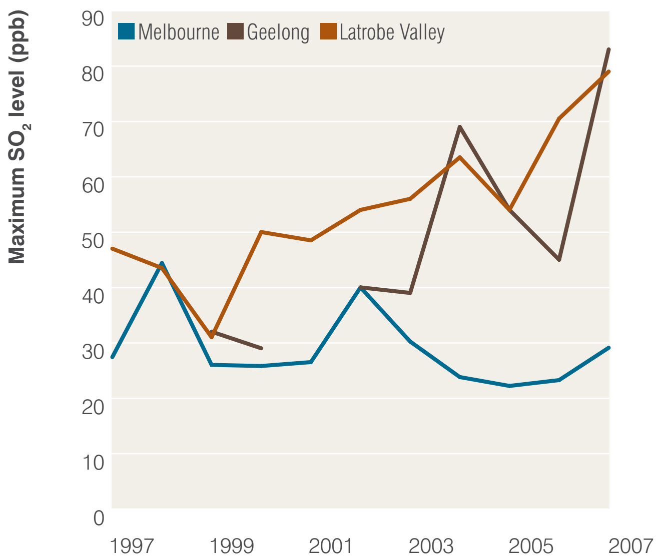
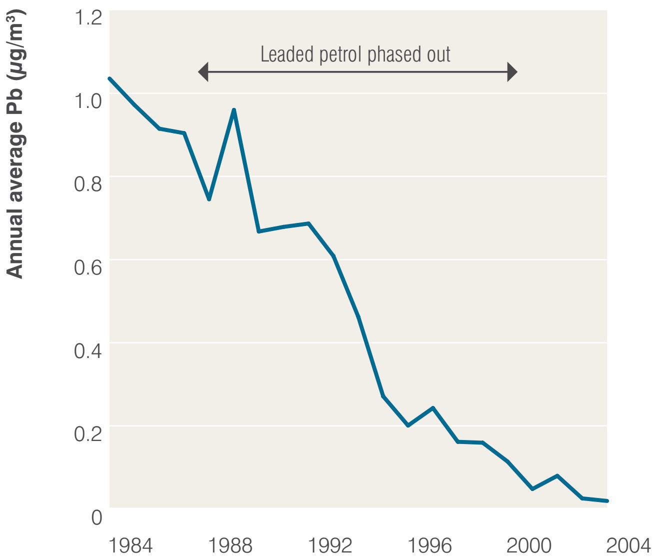


Figure A3.12 Annual lead levels in Melbourne (1984-2004)
Data source: EPA



A3.2 Pressures

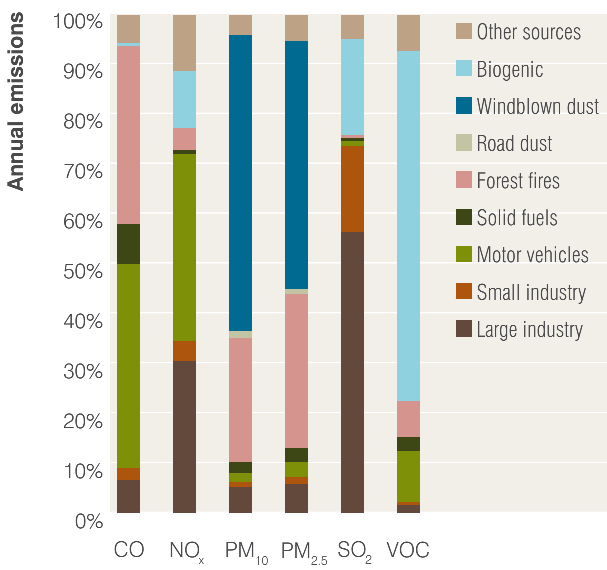
While Victoria's air quality is relatively good, the pressures on the air environment are increasing with time. Pollutants are emitted into the air environment through everyday activities and, with Victoria's growing population and economy, these emissions have the potential to increase. Factors such as climate change are also adding a further threat to air quality. Active management of the sources of pollutant emissions will be required to maintain good air quality in Victoria. For example, in the absence of other strategies, increased vehicle use could eventually offset the improvements gained from stronger new vehicle emission standards and cleaner fuels.

The EPA compiles an emissions inventory for Victoria as a stocktake of the mass of pollutants emitted into the air environment by different sources. The most significant sources of fine particle emissions in Victoria are natural phenomena such as dust storms, bushfires and sea salt. The most significant anthropogenic sources are industry and motor vehicles (particularly diesels). Wood heaters and planned burning can also constitute a significant source of particles.

Motor vehicles are a major source of the pollutants that lead to the formation of smog. Smog can also form downwind of bushfires, as bushfire smoke contains some of the same smog-forming pollutants contained in motor vehicle exhaust fumes.

As Victoria's climate changes average temperatures are predicted to increase (see Part 4.1 Atmosphere, Climate Change). With a dustier and more fire-prone Victoria[166] predicted, particle emissions will increase. Higher temperaturers will also cause greater emissions of ozone precursors and an increase in the speed of the chemical reactions that form ozone. There is also a slow increase in background ozone being observed in many parts of the world, including Australia[167]. These factors may increase summer smog in the future.

Figure A3.13 Contributions to annual emissions, Victoria 2002
Data source: EPA



Indicator A21: Emissions of major air pollutants by sector

Figures A3.13 and A3.14 show the contributions from different sources to annual emissions of major air pollutants in Victoria and the Port Phillip Region (covering Melbourne and Geelong) respectively.

For Victoria as a whole (see Figure A3.13):

- motor vehicles contribute most of the carbon monoxide and oxides of nitrogen (the sum of NO and NO_2)
- large industry contributes most of the sulfur dioxide and significant amounts of oxides of nitrogen
- wind-blown dust contributes most of the particle emissions
- bushfires also contribute large amounts of particles, as well as carbon monoxide
- biological sources contribute most of the volatile organic compounds.

The dominant sources of emissions in urban areas are motor vehicles and industry (see Figure A3.14 for the Port Phillip Region). Commercial and domestic activities also make a significant contribution to some pollutants. The amount of pollutants emitted into the atmosphere is influenced by many factors including trends in population, economic activity, prosperity, mobility and personal behaviour.

Motor vehicles are important sources of oxides of nitrogen in all regions, except in the Latrobe Valley where most oxides of nitrogen come from industry. In the Port Phillip Region motor vehicles contribute 72% of the oxide of nitrogen emissions.

The Port Phillip Region contributes about 40% of carbon monoxide, oxides of nitrogen and sulfur dioxide in Victoria from sources such as motor vehicles and industry. The Latrobe Valley Region contributes about 30% of oxides of nitrogen and sulfur dioxide in Victoria, most of which come from industry.

On the whole, wind-blown dust contributes most of the PM_{10} emissions in Victoria. In the Port Phillip Region, most of the PM10 particle emissions come from industry, motor vehicles, solid fuel combustion and road dust. In the Latrobe Valley, the dominant source of PM_{10} particles is industry (predominantly from electricity generation). In the northwest of Victoria, wind-blown dust is the primary particle source. In some parts of rural Victoria, forest fires are important sources of PM_{10} particles.

Emissions vary by season and day. PM_{10} particle emissions are highest in autumn in Victoria due to wind-blown dust from agricultural lands. PM_{10} particle emissions are also high in summer due to both wind-blown dust and forest fires.

Total PM_{10} particle emissions in the Port Phillip Region do not vary as much seasonally. Industry, motor vehicles, other combustion sources and dust always constitute part of the background PM_{10} particle emissions throughout the year. In winter, solid fuel combustion from wood heaters contributes approximately 30% of the PM_{10} emissions. In summer, dust emissions increase.

EPA's emissions inventory also tracks pollutants specified in the Air Toxics NEPM (benzene, polycyclic aromatic hydrocarbons, formaldehyde, toluene and xylene). These compounds are found in petrol and some solvents and produced as a by-product of combustion processes which include exhaust from cars and trucks, wood heaters and other solid fuel burning, and industry.

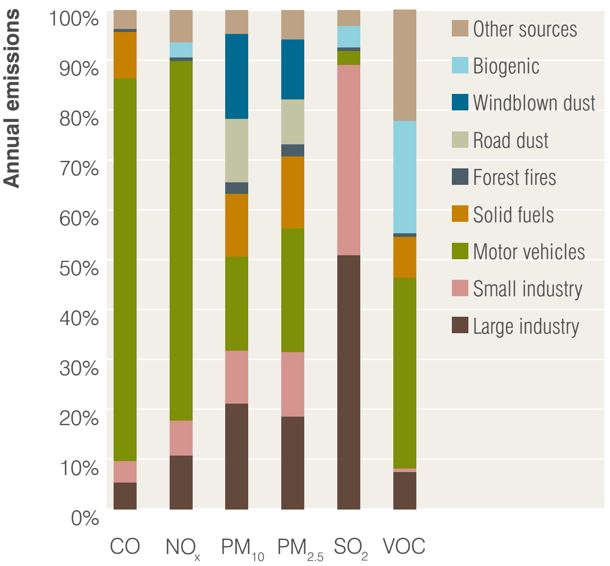
A3.3 Implications

Good air quality has a range of benefits including human health and well-being; ecosystem protection; clear visibility; useful life and aesthetic appearance of buildings, structures, property and materials; aesthetic enjoyment and local amenity.

Even at current air pollution levels, with most pollutants meeting the air quality objectives, there is still a significant health burden for the Victorian population. The common air pollutants – ozone, particles, nitrogen dioxide, carbon monoxide and sulfur dioxide – are associated with a range of health effects. Although maintaining air quality since the 1990s is a positive result, improving Victoria's air quality into the future will be a challenge in the context of expected continued population growth and the impacts of climate change.

Particle pollution is the most significant air quality issue facing Victoria. Particles can aggravate existing respiratory and cardiovascular disease resulting in increased hospital admissions, emergency room visits and increases in daily mortality. Children, the elderly and those with existing respiratory illnesses (asthma, for example) may be more vulnerable to the effects of particle pollution.

Figure A3.14 Contributions to annual emissions, Port Phillip Region 2002
Data source: EPA



Human exposure to high concentrations of ozone in air can result in increases in asthma attacks, decreases in lung function and increases in admissions to hospitals for people with heart and lung conditions. Ozone is also known to affect some healthy individuals who spend prolonged periods of time outdoors during summer. The effects of ozone are strongest in children, the elderly and those with chronic lung conditions such as asthma.

The health costs of air pollution

Epidemiological studies indicate that our current levels of air pollution contribute to approximately 300 deaths and 1,000 hospital admissions per year in Melbourne[168]. Children with asthma, and the elderly were found to be most strongly impacted by air pollution. Australia (including Victoria) has the highest asthma rates in the world with 20-25% of children under 5 years of age diagnosed with asthma. Predictions are that the Australian population is living longer and the impact of air pollution on the elderly poses a problem for public health that is likely to increase into the future unless air pollution levels decline.

The monetary costs associated with the health effects attributable to air pollution are significant. Although costs have not been calculated specifically for Melbourne, the NSW Department of Environment and Climate Change has estimated the health costs of ambient air pollution in the greater Sydney region from $1 billion up to $8.4 billion per year[169]. These estimates include the cost of premature deaths as well as hospital admissions.

The Bureau of Transport and Regional Economics estimates that particle pollution from motor vehicles alone costs the Australian economy up to $3.8 billion per year in premature deaths and direct medical costs (the estimate for Victoria is up to $1 billion per year)[170]. This estimate does not account for lost productivity and restricted activity days.

A recommendation of the Environment and Natural Resources Committee Inquiry[171] into the Impact of Public Land Management Practices on Bushfires in Victoria is that the number of planned burns to reduce the risks associated with major bushfires should be increased. There is a need to better understand and balance the health risks of reduced air quality associated with planned burning versus the benefits obtained in meeting bushfire, biodiversity and other land management goals.

Air quality and regional Victoria

Air pollution has always been considered an issue that affects urban areas, particularly large cities such as Melbourne. Although this is true for pollutants arising primarily from the use of motor vehicles, air pollution in regional Victoria can also be significant. Wind-blown dust and smoke from fires (bushfires, planned burning and woodheaters) can lead to significant deterioration of air quality across Victoria.

The recent Victorian bushfires and drought have shown that natural events impact significantly on air quality across the State. With climate change projections indicating that the frequency and severity of such events is likely to increase, the impacts experienced during 2006/07 may become more common. This poses a significant challenge to ensure that the health of the population is protected from these adverse impacts.

Box A3.1 Planning for new roads

When planning or assessing new road developments VicRoads are required to show that air quality will not be compromised. This is undertaken in reference to the intervention levels set by EPA. For some road developments monitoring is required as part of the Environmental Effects Statement process. The results of such studies inform EPA in its assessment of the impact of vehicle emissions on air quality.

A3.4 Management responses

The Environment Protection Authority (EPA) is responsible for monitoring Victoria's air quality. Air quality has been monitored in Victoria since the 1970s. More detailed information on Victoria's air monitoring network and air quality can be found in the annual air monitoring reports produced by EPA[172].

Two State Environment Protection Policies (SEPPs), Ambient Air Quality and Air Quality Management, provide the framework for protecting Victoria's air environment. These SEPPs aim to safeguard beneficial uses of the air environment from the effect of pollution and waste. The SEPPs establish the uses and values of the environment that the community wants to protect, define the environmental quality objectives to protect these uses, and describe the attainment and management programs that seek to work towards ensuring the necessary environmental quality.

In addition to these statutory responses, EPA undertakes a range of education activities and partnerships to improve air quality and reduce emissions.

Response Name
State Environment Protection Policy (Ambient Air Quality)

Responsible Authority
Victorian Environment Protection Authority

Response Type
Policy

The Ambient Air Quality SEPP contains the national indicators, standards, goals and monitoring and reporting protocol of the National Environment Protection Measure for Ambient Air Quality (AAQ NEPM). These relate to particles (PM_{10} and $PM_{2.5}$), ozone, nitrogen dioxide, carbon monoxide, sulfur dioxide and lead. The SEPP also includes an ambient air objective for visibility reducing particles.

Currently there are 16 EPA operated air quality stations (12 in Melbourne, two in Geelong and two in the Latrobe Valley) that monitor the common air pollutants and some air toxics. Site-specific monitoring is also undertaken via mobile monitoring stations to better understand local or sub-regional air pollution (such as in 'hot spot' locations near busy roads or industrial areas or near major incidents such as bushfires).

The data provided by the monitoring network provides important information on whether air quality objectives are being met, and allows trends in air quality to be tracked. This information is used to guide the development of Government policies and strategies to improve Victoria's air quality.

Response Name
State Environment Protection Policy (Air Quality Management)

Responsible Authority
Victorian Environment Protection Authority

Response type
Policy

The Air Quality Management SEPP sets the framework for managing emissions to the air environment. These emissions are managed to ensure that the air quality objectives of the SEPP (AAQ) are met.

The SEPP provides a framework for management of the emissions of pollutants from industry, greenhouse gas emissions, ozone depleting substances, vehicles and fuel, planned burning, wood heaters, burning of waste and activities such as mining and road construction.

The Waste Management Policy (Solid Fuel Heating)[173] is an example of a policy supporting the aims of the Air Quality Management SEPP. It covers burning of wood (solid fuel) for home heating, which is a significant source of air pollution in Victoria in the winter months. It requires that all solid fuel heaters manufactured and sold in Victoria be certified to comply with the Australian Standard (AS/NZS 4013). When installed and operated correctly, solid fuel heaters that comply with this standard produce significantly less emissions than non-compliant heaters.

The policy also contains measures to improve the use and operating practices of solid fuel heating appliances already installed in homes. This includes community information and education campaigns that are aimed at assisting householders with these appliances to reduce their smoke emissions.

Response Name
National Environment Protection Measure (Air Toxics Measure)

Responsible Authority
Commonwealth Government and the Victorian Environment Protection Authority

Response type
Intergovernmental agreement

The EPA implements the Air Toxics NEPM in Victoria as part of a national process. It is currently collecting data to assist in development of a national objective for air toxics.

The aim of the air toxics NEPM is to provide a framework for monitoring, assessing and reporting on ambient levels of five air toxics (benzene, formaldehyde, toluene, xylenes and polycyclic aromatic hydrocarbons) within the Australian environment. This will then be used for the development of air quality standards for these pollutants. Air toxics are found in petrol and some solvents and are produced as a by-product of combustion processes which include exhaust from cars and trucks, wood heaters and other solid fuel burning, and industry. The NEPM requires that monitoring for air toxics be undertaken at locations where emissions from cumulative sources are likely to give rise to elevated levels and where there is likelihood of significant population exposure.

Response Name

Environment Protection (Vehicle Emissions) Regulations 2003

Responsible Authority

Victorian Environment Protection Authority

Response type

Legislation

Motor vehicles are a major source of air pollution in urban areas. Improvements to the design of motor vehicles and the quality of fuel can have a big impact on reduing air pollution. The process of tightening emission standards in Australia began in the 1970s for passenger cars, and is scheduled to continue through to the end of this decade reflecting European design standards. At the national level EPA is involved in the development and implementation of new Australian Design Rules for new vehicles and national fuel quality standards.

The Environment Protection (Vehicle Emissions) Regulations 2003[174] specify standards and test methods for motor vehicle emissions. The regulations define petrol quality parameters, set construction, maintenance and labeling requirements, set requirements for the sale and operation of vehicles on unleaded petrol, prescribe vehicle emission standards and establish offences relating to modification and tampering with vehicle fuel, emission control and noise control systems.

Reductions have been made to the benzene content of petrol in Australia from about 3% to 1%. The sulfur content of diesel fuel was significantly reduced in 2006 and will be cut further in the coming years. These reductions will cut air pollution (sulfur dioxide and fine particle levels) and also make it possible to fit new emission control technologies to diesel vehicles. The fuel standards have also reduced petrol volatility over the summer cutting the volatile organic compounds lost during the supply and use of petrol. This has reduced the potential for petrol use to contribute to the formation of summer smog (ozone).

Box A3.2 Low emission buses

The Victorian Government, with support from the Commonwealth, has initiated a trial of two hybrid-electric buses to take place over 2009 and 2010. The trial is designed to assess the economic, environmental and social implications of hybrid-bus operation within the Victorian public transport context. Hybrid-electric buses use an on-board battery system to store energy for an electric motor that either supplements or provides the complete propulsion force for the vehicle. The battery system allows energy otherwise lost as heat during braking to be retained, reducing the amount of fuel energy used by the diesel engine. According to manufacturer's data, the fuel economy improvement may be anywhere from 20 to 54%, translating to a significant reduction in the amount of harmful NOx and particle pollutants introduced into the atmosphere. Should the trial prove a success, hybrid buses may become the mainstay of the Victorian fleet in future years.

Evaluation of air quality responses

EPA has been working to improve Victoria's air quality for over 35 years. Victoria established its first statewide policy framework for the management of air quality in 1981, with the development of the State Environment Protection Policy (SEPP) (The Air Environment). The current regulatory framework for protecting Victoria's air environment is provided by the Ambient Air Quality and Air Quality Management SEPPs.

In 1998, consistent national objectives to protect the air environment were introduced with the development of the first National Environment Protection Measure (NEPM) in relation to air quality. Responsibility for development of these NEPMs rests with the Environment Protection and Heritage Council, of which Victoria is a member. Victoria has implemented the NEPMs and continues to develop its own State Environment Protection Policies (SEPPs), which either mirror the NEPMs or build on them. These tools have been highly successful in guiding EPA's monitoring and reporting on air quality. That knowledge enables EPA to work with the community, industry and government to tackle the sources of pollution.

The present suite of management responses that directly target air quality are effective, with Victoria experiencing improvements or stabilisation of air quality levels despite increased pressures from a growing population and economy. However, there are some areas where improvements could potentially be made. This is likely to require action from a range of agencies across Government. These actions include limiting the smoke that arises from bushfires, planned burns and wood heaters; reducing emissions from transport; and improving land management practices to reduce the potential for wind blown dust.

It is important to note that the targets are stringent, establishing a benchmark for good air quality. This means that the targets are sometimes difficult to achieve, providing a focus for continued improvement. The NEPMs include an allowance for natural events such as bushfires and dust storms; however due to the impacts of climate change the incidence of natural events is becoming more frequent leading to more days when the air quality objectives are not met.

Trend: Air quality has stabilised against increased pressures.

For further information

Air quality in Victoria - http://www.epa.vic.gov.au/air/

Recommendations

Improve Victoria's air quality

Ways to improve air quality are many and varied. Some methods directly target the cause of reductions in air quality; others may have a different primary purpose, such as reducing greenhouse gas emissions, that may also carry a benefit for air quality. The recommendations provided are focussed on management actions that will lead to an improvement in air quality, either through a reduction in health burden or through minimising the impacts of events. As many pollutants lead to different types of reductions in air quality the recommendations are not all separated out under the air quality objectives. Reducing emissions of pollutants and greenhouse gases should be an important consideration in land use and transport planning decisions.

A3.1 To reduce emissions of greenhouse gas and pollutants from motor vehicles, Government should shift transport investment priorities towards less energy intensive modes such as public transport, walking and cycling.

A3.2 Government should investigate the best means by which to improve community awareness of the impacts of transport and heating choices on air quality which might include an eco-labelling system whereby passenger cars and heaters or heating systems are supplied with a label stating the potential pollutants that will be produced through their use.

A3.3 Government should consider the findings of the Environment and Natural Resources Committee Inquiry into the Impact of Public Land Management Practices on Bushfires in Victoria and revise the Code of Fire Management on Public Land if necessary to better manage air quality in relation to bushfires and planned burns.

A3.4 Government should investigate how alternative fuels (including diesel) will affect air quality whilst continuing to support improved emissions standards for motor vehicles.

A3.5 The Victorian Government should continue to work through the Environment Protection and Heritage Council to develop a National Environment Protection Policy to set goals and objectives for very small particles ($PM_{2.5}$).

A3.6 The Victorian Government should continue to assess and understand how Victoria's air quality may be impacted by pressures from urban growth and climate change.

A3.7 EPA should continue to issue smog and pollution alerts (including smoke and dust alerts) and work with the media to improve community access to practical information and advice on what to do on days when air quality is poor.

A3.8 Government should investigate options to further reduce the impacts of wood heaters on air quality, especially in the areas of Victoria where alternatives are readily available (e.g. metropolitan Melbourne). The impacts of restricting or phasing out the sale and use of wood heaters and encouraging householders to switch to alternative and more sustainable heating options, such as natural gas should be investigated.