Victoria:
STATE OF THE
ENVIRONMENT

2013

PART A

TRENDS AND ANALYSIS

INTRODUCTION PART A: TRENDS AND ANALYSIS

In *Part A: Trends and Analysis*, we report on environmental indicators that inform us of the current condition, and accompanying trends, of Victoria's natural environment. The indicators also provide insight into the effectiveness of environmental management policies and activities.

However, it should be noted that since the last State of the Environment report 2008, there have been a number of significant events that have affected Victoria's environment. These include the continuation and end of the Millennium Drought (1997 to 2009),[1] record breaking floods between September 2010 to February 2011,[2, 3] the devastating Black Saturday bushfires in February 2009,[6] and the occurrence of extreme heatwaves in early 2009 and the spring and summer of 2012–13.[8]

Such events have implications for a range of Victorian environments regardless of management. For example, drought conditions significantly reduced water availability for both terrestrial and aquatic ecosystems.

It is also important to note that environmental assessment is dependent on the availability, quality and comprehensiveness of data. This was found to be variable across the reporting themes, limiting the ability to determine environmental condition and trends for some indicators.

CONTENTS

Numurkah floods, 2012

DETAILED CONTENTS CHAPTER **ONE**

CHAPTER **ONE** CLIMATE CHANGE AND AIR QUALITY

A CLIMATE CHANGE

BACKGROUND

Climate change and its impact on Victoria is discussed in detail in Foundation Paper One, *Climate Change Victoria: The Science, Our People, and Our State of Play*.[1]

Climate change is considered to be the greatest environmental challenge facing Australia and Victoria. It has the potential to have significant natural, social and economic impacts both here and globally.

Solid scientific evidence supports the position that climate change is occurring now, and is caused by elevated concentrations of greenhouse gases in the atmosphere. Climate change in Australia has been reported by pre-eminent climate science scholars and reporters, CSIRO and the Australian Bureau of Meteorology.[2–5] This research shows that temperatures, sea levels and sea-surface temperatures are all rising in Australia.

Such changes will lead to significant ecosystem changes and biodiversity impacts, and will expose Victorians to increased droughts, fires, large storm events and coastal inundation (Figure A.1.1).

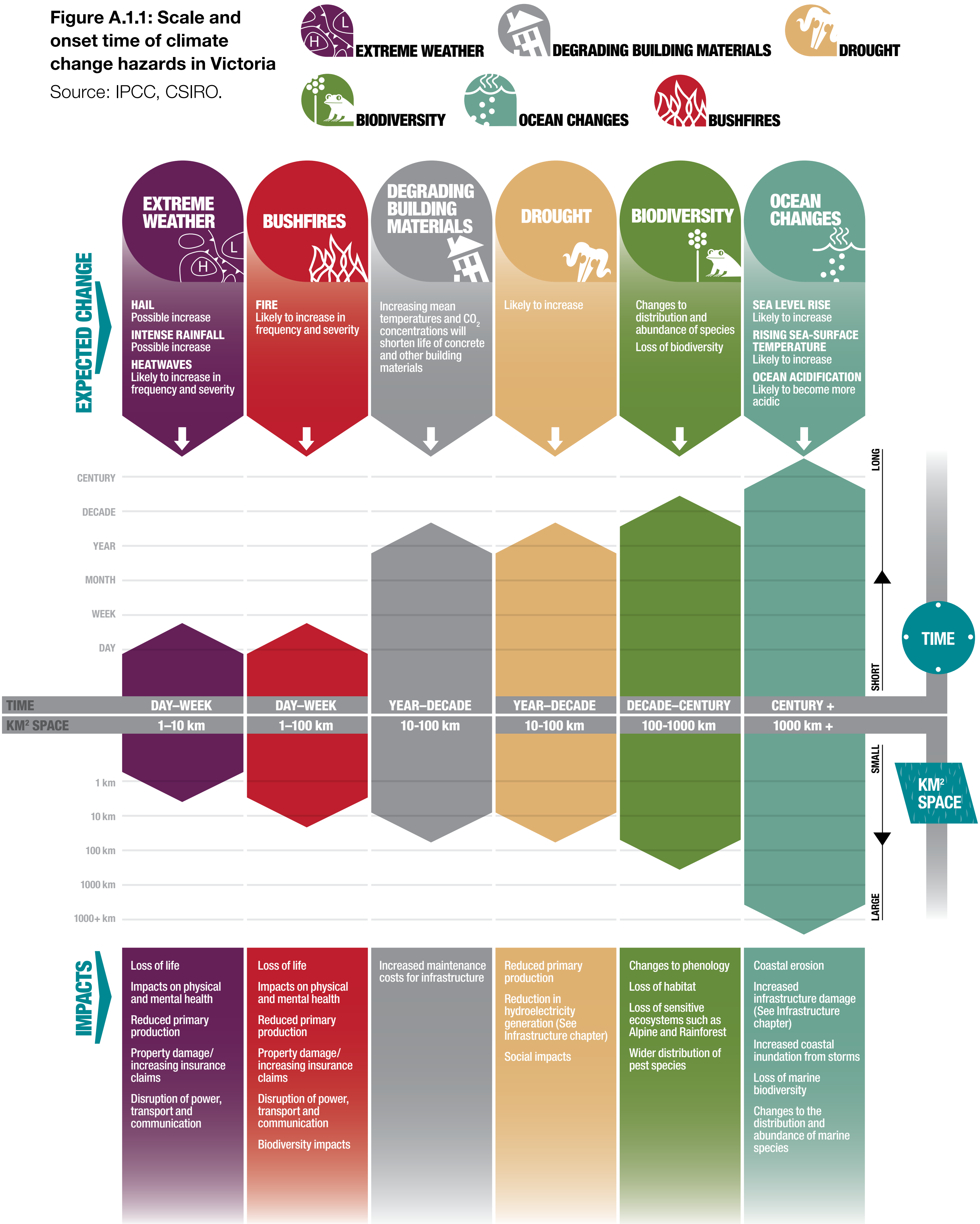
Some level of climate change is already unavoidable due to existing levels of greenhouse gases in the atmosphere.

To minimise the severity and impacts of climate change, emissions of greenhouse gases need to be reduced. Despite this, annual emissions are increasing both globally and in Victoria. Under current policies, the Organisation for Economic Co-operation and Development (OECD) estimates a rise in global greenhouse gas emissions of 50% by 2050.[6]

The opportunities to reduce greenhouse gas emissions and limit the severity of climate change are rapidly diminishing. However, action on climate change is proving to be a difficult global challenge. This is especially because climate change is hard to visualise; it happens slowly, almost imperceptibly; and impacts may have long lead times. However, strong action has to occur now if risks and their associated costs are to be avoided – the greater the warming, the greater the risk of irreversible climate change.

Figure A.1.1: Scale and onset time of climate change hazards in Victoria

Source: IPCC, CSIRO.



MAIN FINDINGS

Greenhouse gas emissions

- Victoria's greenhouse gas emissions continue to rise. In 2010–11, Victoria emitted a total of 118 million tonnes (Mt) CO_2-e of greenhouse gas, or 124 Mt CO_2-e when land use, land-use change and forestry are excluded. Between 1989–90 and 2010–11, total emissions increased by 12%, or 23% excluding land use, land-use change and forestry.
- Per capita greenhouse gas emissions decreased from 24 tonnes in 1989–90 to 21 tonnes in 2010–11. However, this decrease has been offset by population growth. Victoria's per capita emissions continue to place us among the world's highest polluters.
- Victoria is responsible for 21% of Australia's total net emissions.
- The stationary energy and transport sectors accounted for 68% and 14% of the total greenhouse gas emissions respectively. Agriculture was also a significant contributor, accounting for 11% of the total emissions.
- Emissions from the stationary energy sector increased by 42% between 1989–90 and 2010–11.
- Between 2000 and 2009, fires released 70 million tonnes of carbon dioxide, around 6% of the total emissions over the period. Large fires in 2007 released the equivalent of 20% of the total greenhouse gas emissions for that year.
- Passenger vehicles are the greatest contributor to greenhouse gas emissions in the transport sector. In 2008–09, passenger vehicles were responsible for 36% of all transport emissions in Victoria, 61% of all road-based transport emissions, and 96% of emissions from commuting.
- Passenger vehicle emissions increased by 21% between 1987–88 and 2008–09.
- In 2008–09, international air travel accounted for 21% of the total Victorian transport emissions. International air travel increased by 26% between 1987–88 and 2008–09.
- In 2010, Victoria's carbon stock for publicly managed forested land was estimated at between 680 and 775 Mt of carbon (or up to 2.8 billion tonnes of CO_2-equivalent). This represents roughly 25 years of Victoria's total annual greenhouse gas emissions.
- Carbon stocks in Victoria are vulnerable to climatic variation and the occurrence of bushfires.

Climate trends

- Average temperatures in Victoria have risen by approximately 0.8°C since the 1950s.
- The severity, duration and frequency of heatwaves have increased.
- Between 1997 and 2009, Victoria experienced a record-breaking 13-year drought, the longest recorded period of rainfall deficits on record.
- Over the past two decades, there has been a large decline in autumn rainfall, a small decline in winter and spring rainfall, a small increase in summer rainfall, and reduced frequency of very wet years.
- Victoria experienced its highest summer rainfall on record in 2010–11. The record rainfall led to major flooding that affected a third of Victoria.
- Since 1993, Victoria's sea level has been similar to global averages of 3 mm per year.
- Annual sea-surface temperatures in south-eastern Australia increased at a rate of 0.023°C per year, approximately four times the global ocean-warming average.

Climate change projections

- 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.
- Runoff is projected to decrease between 5% and 45% by 2030 and between 5% and 50% by 2070.
- Fire risk is forecast to increase substantially, with the number of very high or extreme fire danger days 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.

INDICATOR ASSESSMENT

Indicator Summary

Indicator	Summary	Status and trends Good / Fair / Poor / Unknown	Data quality
CC1 Trends in greenhouse gas emissions in Victoria	Between 1989–90 and 2010–11, total emissions increased by 12%, with stationary energy emissions increasing by 42%.		
	Per capita greenhouse gas emissions decreased from 24 to 21 tonnes between 1989–90 and 2010–11. However, this decrease was offset by population growth. With per capita emissions high compared to the global average, Victorians are among the world's largest greenhouse gas emitters.		
CC2 Victorian ecosystem contribution to global greenhouse gas balance and carbon storage	Victoria's forests store a considerable amount of carbon but are vulnerable to the occurrence of bushfires, which have temporarily decreased carbon storage in some areas. Carbon stocks are likely to be impacted by climate change with increased periods of drought and fire risk. Knowledge of Victoria's carbon stocks is improving but is mainly limited to forested public land.		
CC3 Climate trends in Victoria	Average temperatures in Victoria have risen by approximately 0.8°C since the 1950s and the severity, duration and frequency of heatwaves have increased. There has been a decline in autumn, winter and spring rainfall over the past two decades.		
CC4 Projected climate trends in Victoria	Victoria's future climate is projected to become hotter and drier with an increased risk of bushfire and drought, decreased availability of water resources, and more frequent extreme weather events. These will have severe environmental, social and economic consequences.	NA	NA
CC5 Sea-surface temperature and sea-level rise	Annual sea-surface temperatures in south-eastern Australia increased at a rate of 0.023°C per year, approximately four times the global ocean-warming average. Since 1993, Victoria's sea-level rise has been similar to global averages of 3 mm per year.		

Indicator Assessment Legend

Status

Good | Fair | Poor | Unknown

- Environmental condition is healthy across Victoria, **OR** pressure likely to have negligible impact on environmental condition/human health.
- Environmental condition is neither positive or negative and may be variable across Victoria, **OR** pressure likely to have limited impact on environmental condition/human health.
- Environmental condition is under significant stress, **OR** pressure likely to have significant impact on environmental condition/ human health.
- Data is insufficient to make an assessment of status and trends.

Data Quality

- Good — Adequate high-quality evidence and high level of consensus
- Fair — Limited evidence or limited consensus
- Poor — Evidence and consensus too low to make an assessment

Trends

Deteriorating | Improving | Stable | Unclear

NA Assessments of status, trends and data quality are not appropriate for the indicator.

Indicator CC1: Trends in Greenhouse Gas Emissions in Victoria

Annual greenhouse gas emissions

There has been a dramatic growth in global greenhouse gas emissions since 1750, mainly through the combustion of fossil fuels and widespread land clearing. As concentrations of these gases have increased, global temperatures have risen, causing changes to weather conditions worldwide.

In Victoria, carbon dioxide is the most significant greenhouse gas, contributing over 80% of total emissions in 2009.[7] The majority of carbon dioxide emissions come from industry, transport and energy generation. Emissions of methane and nitrous oxide, mainly from land management and agriculture, also make significant contributions of 12% and 4% respectively. Other greenhouse gases include manufactured gases such as sulfur hexafluoride, chlorofluorocarbons (CFCs) and some of their replacements.[8, 9]

Australia's greenhouse gas emissions

Compared to the rest of the world, Australians (per capita) make a disproportionately high contribution to global warming. Although Australia only generates about 1.5% of the total global greenhouse gas emissions, our per capita emissions make us among the world's largest polluters. In 2012, Australia's emissions per capita were 25 tonnes of carbon dioxide equivalent (CO_2-e) per person, although this has declined by 24% since 1990.[10] This is nearly twice the OECD average and more than four times the world average.[11]

Victoria's greenhouse gas emissions

Victoria's greenhouse gas emissions are reported annually in the *Australian National Greenhouse Accounts*.[12] In 2010–11, Victoria emitted a total of 118 Mt CO_2-e of greenhouse gas, or 124 Mt CO_2-e when land use, land-use change and forestry (LULUCF) is excluded (Figure A.1.2).[13] Victoria is responsible for 21% of Australia's total net emissions.[12]

The stationary energy and transport sectors accounted for 68% and 14% of the total greenhouse gas emissions in Victoria respectively (Figure A.1.3). The stationary energy sector is heavily influenced by Victoria's reliance on coal-based energy industries. Agriculture was also a significant contributor, accounting for 11% of the total emissions.

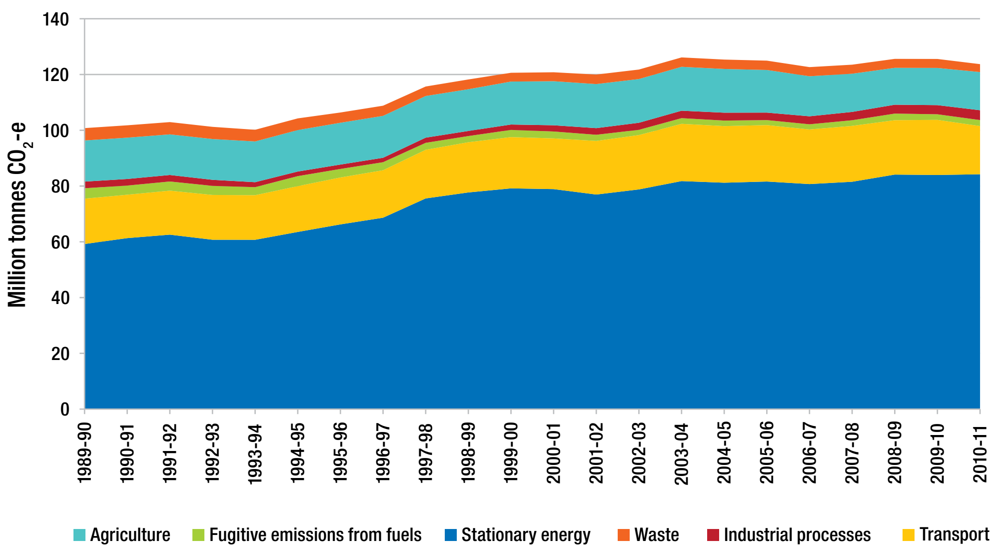
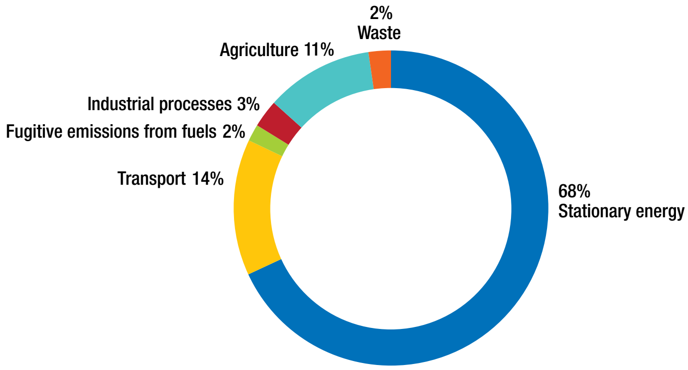


Figure A.1.2: Victorian greenhouse gas emissions by sector (excluding LULUCF), 1998–90 to 2010–11

Source: Australian Government Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education.

Figure A.1.3: Sector contributions to Victorian greenhouse gas emissions (excluding LULUCF), 2010–11

Source: Australian Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education.



Victoria's greenhouse gas emissions continue to rise. Between 1989–90 and 2010–11, total emissions increased by 12%, or 23% excluding LULUCF (Figure A.1.2).

The largest increases were 42% from the stationary energy sector, 48% from the industrial processes sector and 6% from the transport sector. Fugitive emissions from fuels, agriculture, waste and LULUCF emissions have all decreased since 1989–90 (Figure A.1.4).

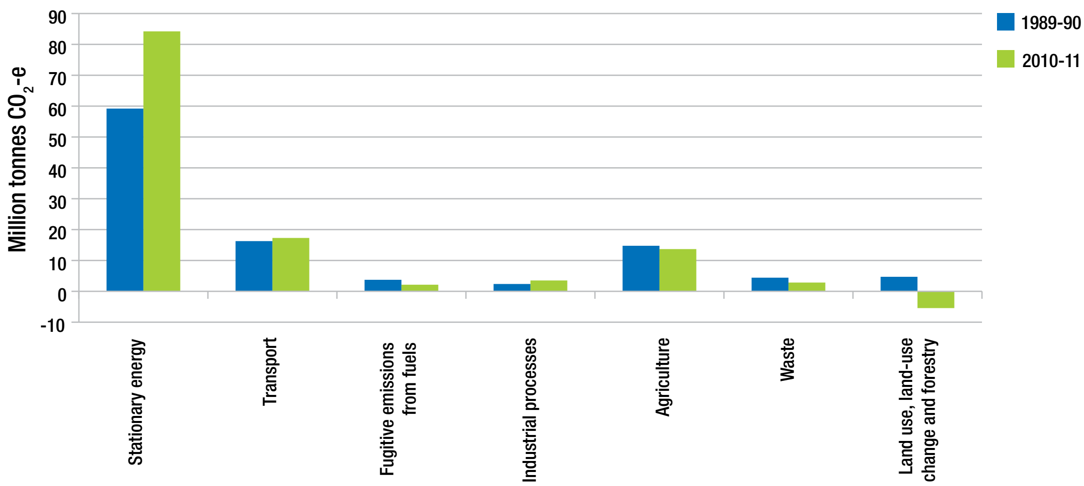


Figure A.1.4: Victorian greenhouse gas emissions by sector, 1989–90 and 2010–11

Source: Australian Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education.

Notes: **'Stationary energy'** emissions from the production of electricity and other direct combustion of fossil fuels in industry; **'Transport'** emissions from air, road, rail and shipping transportation; **'Fugitive emissions from fuels'** emissions from the extraction and distribution of coal, oil and natural gas; **'Industrial processes'** direct emissions from the chemical and/or physical transformation of materials and the consumption of synthetic greenhouse gases; **'Agriculture'** emissions of methane and nitrous oxide from livestock, crops, agricultural and forest soils, and agricultural burning; **'Waste'** emissions from the disposal of solid waste to land, the treatment of domestic and industrial wastewater and the incineration of municipal and clinical waste; **'Land use, land-use change and forestry'** includes afforestation and reforestation (emissions and removals from forests established on previously cleared land since 1990), and deforestation (emissions and removals from the clearing of forest and replacement with other uses on land that was forest on 1 January 1990).

Despite the growth in total emissions, per capita greenhouse gas emissions have decreased from 24 tonnes in 1989–90 to 21 tonnes in 2010–11 (Figure A.1.5). However, this per capita decrease has been offset by population growth in Victoria.

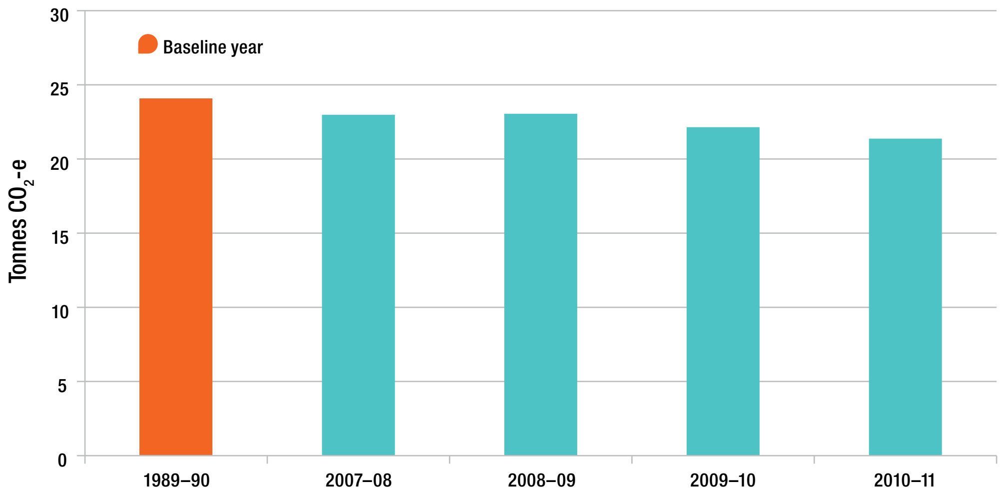


Figure A.1.5: Victorian per capita greenhouse gas emissions, 2010–11

Source: Australian Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education.

Carbon dioxide emissions from fire

Fires are another source of greenhouse gas emissions in Victoria. It is estimated that nearly 70 million tonnes of carbon dioxide was released to the atmosphere as a result of fires between 2000 and 2009,[7] around 6% of the total emissions over the period.

Large fires can also be significant in terms of annual emissions – for example, fires in 2007 were equivalent to 20% of the total greenhouse gas emissions for that year.

For impacts of fires on carbon stocks see Indicator CC2: Victorian Ecosystem Contribution to Global Greenhouse Gas Balance and Carbon Storage.

Transport emissions

Passenger vehicles are the greatest contributor to greenhouse gas emissions in the transport sector. In 2008–09, passenger vehicles were responsible for 36% of all transport emissions in Victoria (Figure A.1.6). In terms of road-based transport, passenger vehicles contributed 61% of total transport emissions and 96% of total emissions from commuting (Figures A.1.7 and A.1.8). Passenger vehicle emissions increased by 21% between 1987–88 and 2008–09.[14]

Other significant trends in transport emissions include the following.[14]

- Buses and light rail only contribute 3% of commuting emissions in Victoria.
- Trucks and light commercial vehicles contributed 37% of road-based emissions and 21% of total travel emissions in 2008–09. Emissions from trucks and light commercial vehicles increased by 48% between 1987–88 and 2008–09.
- In 2008–09 international air travel accounted for 21% of the total transport emissions.
- Domestic air travel emissions increased by 34% between 1987–88 and 2008–09, with international air travel emissions growing by 26% over the same period.

Figure A.1.6: Greenhouse gas emissions from all transport in Victoria

Source: A. Pekol, *Victorian Transport Facts 2011.*[14]

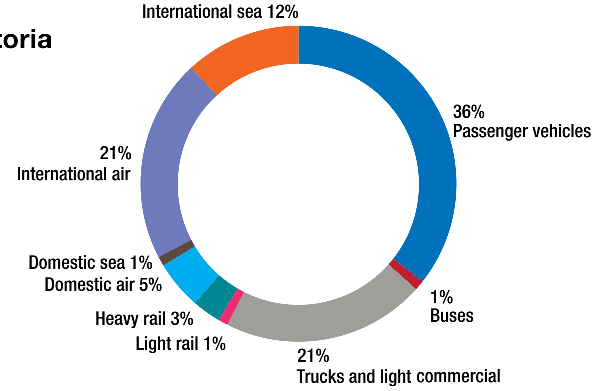


Figure A.1.7: Greenhouse gas emissions from road-based transport in Victoria

Source: A. Pekol, *Victorian Transport Facts 2011.*[14]

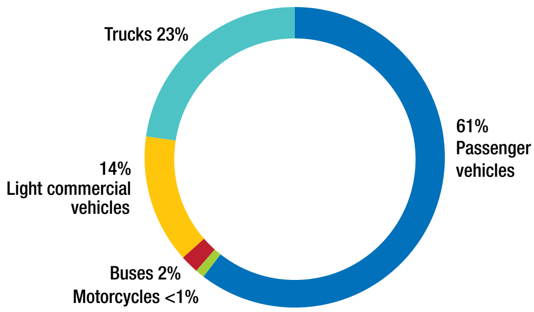
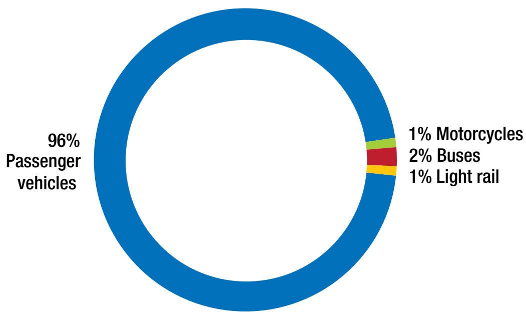


Figure A.1.8: Greenhouse gas emissions by commuting type in Victoria

Source: A. Pekol, *Victorian Transport Facts 2011.*[14]



Indicator CC2: Victorian Ecosystem Contribution to Global Greenhouse Gas Balance and Carbon Storage[15]

Forest ecosystems play an important role in the global carbon cycle and global greenhouse gas balance by storing carbon in both trees and soil.

Carbon storage is dependent on a range of factors that are impacted by climate change, such as rainfall, soil moisture, nutrient availability, and disturbances such as bushfire.

Land-use change (permanent clearing) and forest harvesting also affect carbon storage.

Victoria's forests store a considerable amount of carbon. In 2010, Victoria's carbon stock for publicly managed forested land was estimated at between 680 and 775 million tonnes of carbon (or up to 2.8 billion tonnes of carbon dioxide equivalent). This represents approximately 25 years of Victoria's total annual greenhouse gas emissions (Figure A.1.9).

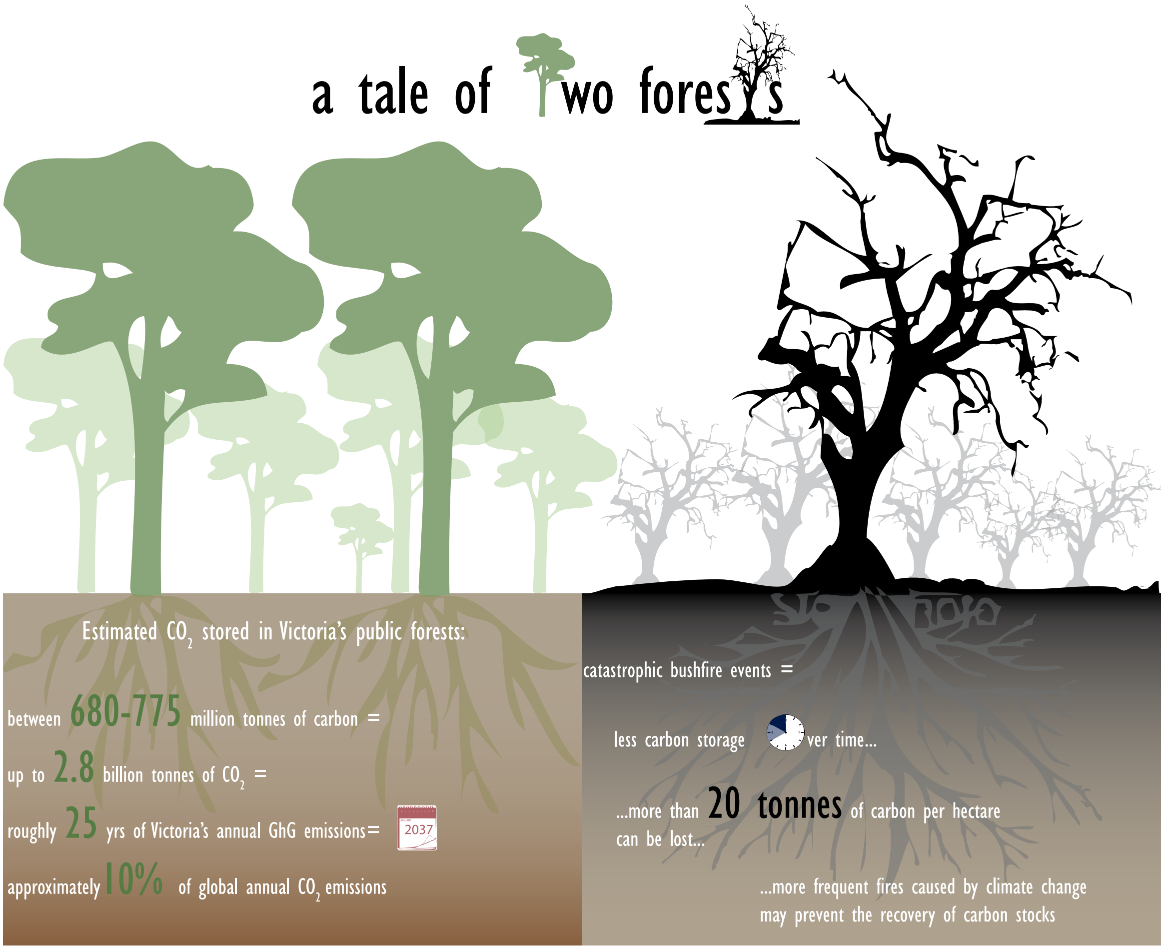


Figure A.1.9: Impacts of bushfire on carbon storage in Victorian forests

Source: Infographic based on DEPI information.

Figure A.1.10 shows the changes in the modelled total above-ground carbon stock for Victoria's public land estate between 1970 and 2010. A strong west to east and north to south trend is evident. This largely follows the rainfall gradient. In addition, the impact of recent fires appears across the Central Highlands and Alps, which have relatively low carbon stocks compared to the largely unburnt areas of the state in East Gippsland and the Strzelecki Ranges.

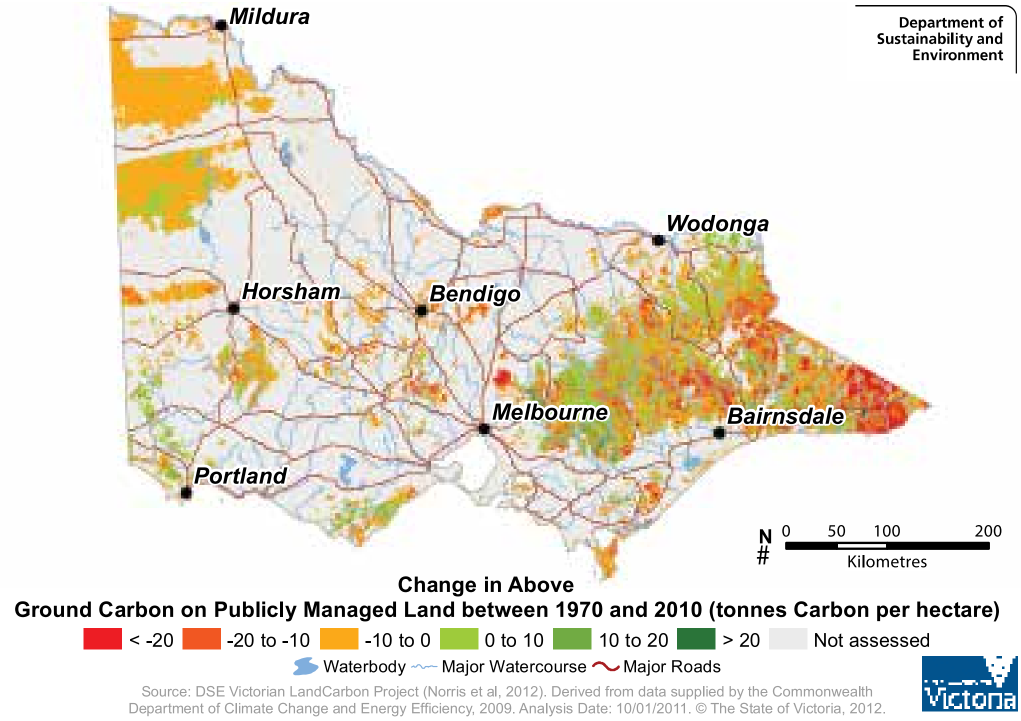


Figure A.1.10: Change in above-ground carbon on publicly managed land between 1970 and 2010 (tonnes carbon per hectare)
Source: DEPI.

Impact of fire on carbon stocks

Figure A.1.11 shows the area affected by the 2009 Black Saturday bushfires. The effect of the fires on carbon storage is shown by the change in carbon stocks between 2008 and 2010. Results show that catastrophic bushfire events can have considerable impacts on carbon stocks, with a change of more than 20 tonnes of carbon per hectare in some areas.

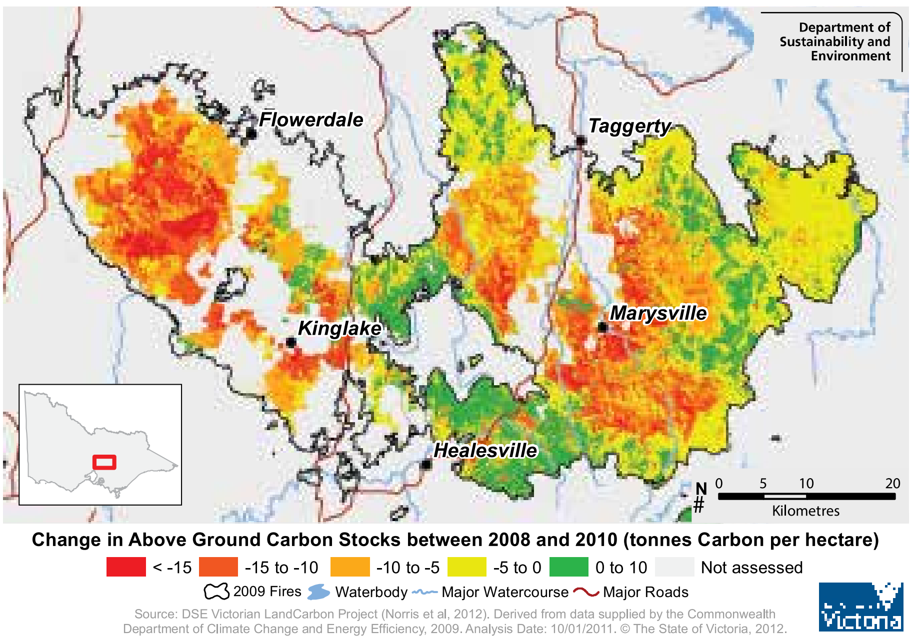


Figure A.1.11: Change in above-ground carbon stocks between 2008 and 2010 (tonnes of carbon per hectare)
Source: DEPI.

While the post-fire recovery of forests will increase carbon stocks, the projected increase in the occurrence and severity of fire as a result of climate change is of particular concern.

It is unlikely that Victoria's forests can remain resilient to the impacts of increased fire frequency.

Exceeding ecological fire tolerances is likely to result in forests being altered in terms of structure, dominant species and function – potentially storing less carbon over time.

Carbon stocks in Victoria are vulnerable to climatic variation and the occurrence of bushfires. This has important implications for the management of Victoria's carbon stocks with the ability of forests to take up carbon vital for the mitigation of climate change.

Indicator CC3: Climate Trends in Victoria

Victoria's climate is influenced by a range of factors, including atmospheric conditions (the Southern Oscillation) and changes in sea-surface temperatures (El Niño and La Niña cycles). These drivers of climate lead to large natural year-to-year variations in temperature and rainfall. However, long-term climate change caused by increasing greenhouse gas emissions is occurring at global scales and is cumulative over many years.

Climate change is now reported widely and the global warming trend is unequivocal. In south-eastern Australia, research has determined both the Millennium Drought (1996–2010) and the record-breaking rainfall in the summer of 2010–11 were found to be at least partly linked to climate change.[4]

Climate change is discussed in detail in Foundation Paper One, *Climate Change Victoria: The Science, Our People, and Our State of Play*.[1]

Observed surface temperature

Victoria's climate has been getting warmer since the 1950s (Figures A.1.12 to A.1.15).

There has been an increase in both the frequency and severity of hot temperatures and a decrease in cold temperatures. Average temperatures in Victoria have risen by approximately 0.80°C since the 1950s.[16] Annual maximum temperatures rose by 0.85°C from 1910 to 2010, slightly greater than the Australian average of around 0.75°C. Victorian minimum temperatures have increased by approximately 0.90°C between 1910 and 2010.[7]

Heatwaves are the most significant natural hazard in Australia in terms of loss of life. In January 2009, Melbourne experienced three consecutive days at or above 43°C. There were 980 heat-related deaths during this heatwave, which preceded the Black Saturday bushfires.

Over the period 1971–2008, the severity, duration and frequency of heatwaves have increased. In Melbourne, the long-term average number of days per year above 35°C was 9.9, but between 2000 and 2009, the average number rose to 12.6 days. This increase is quicker than climate model projections.[16]

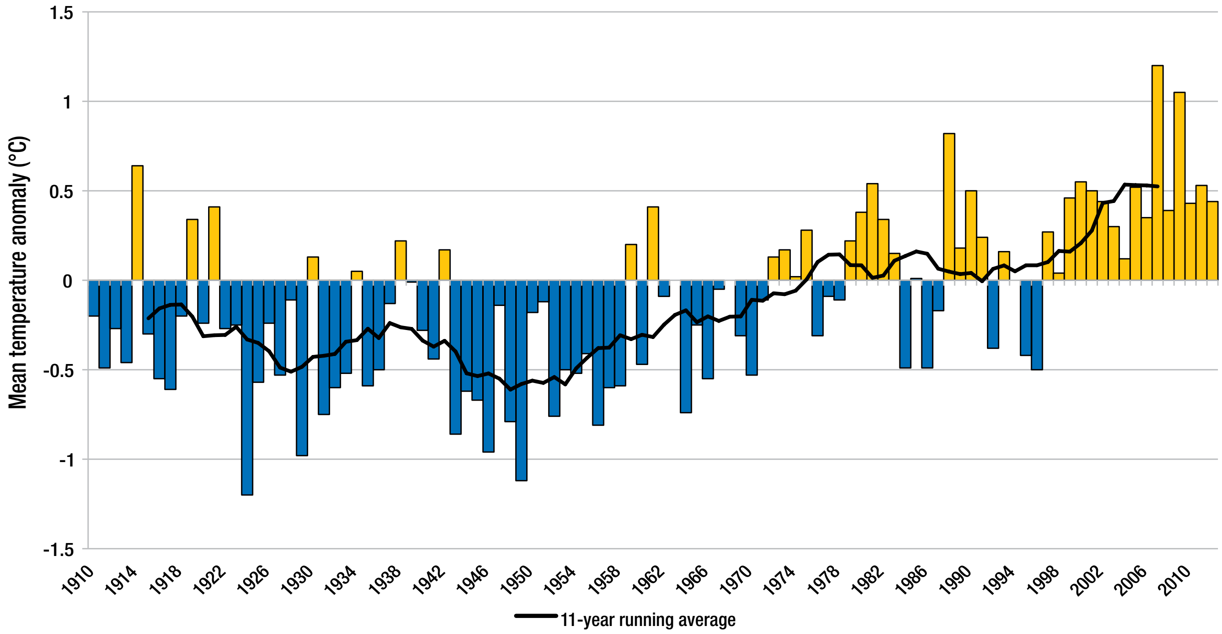


Figure A.1.12: Victorian mean temperature anomaly, 1910 to 2012

Source: BoM.

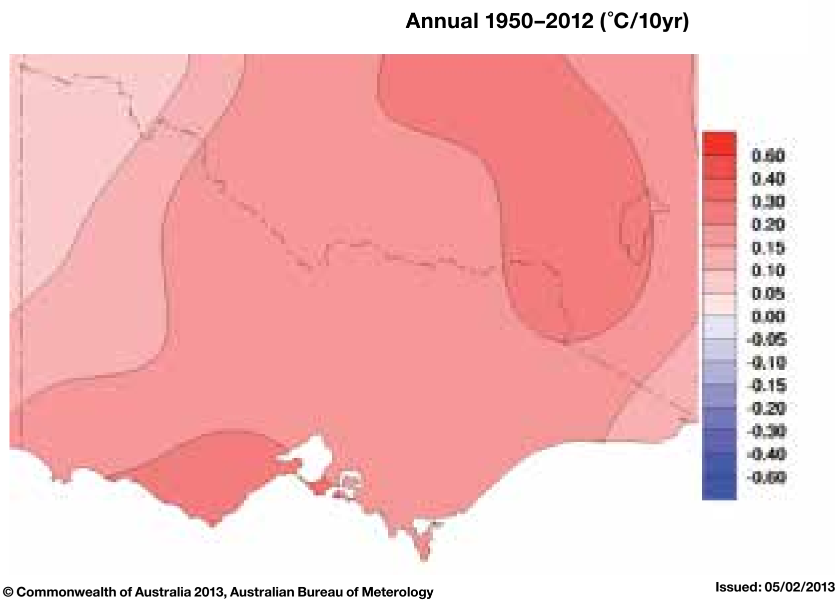


Figure A.1.13: Trend in Victorian mean temperature, 1950 to 2012

Source: BoM.

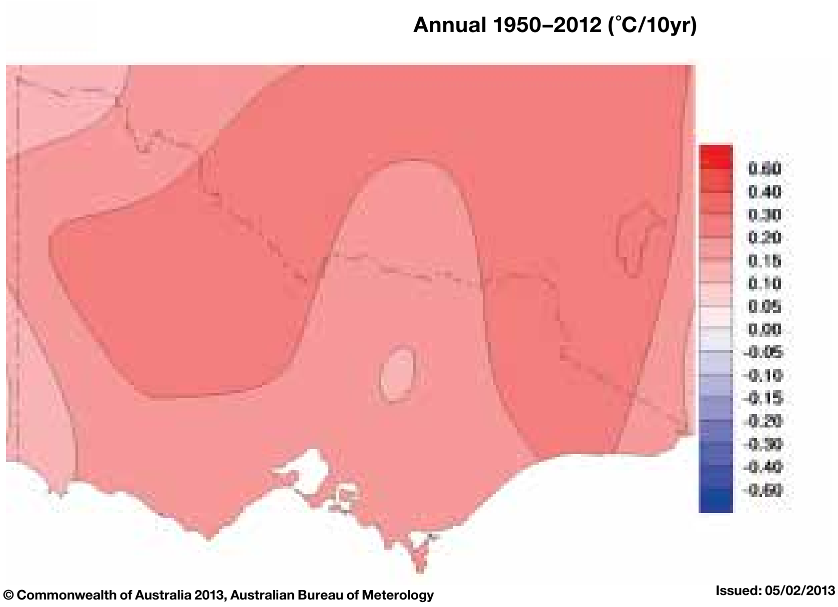


Figure A.1.14: Trend in Victorian maximum temperature, 1950 to 2012

Source: BoM.

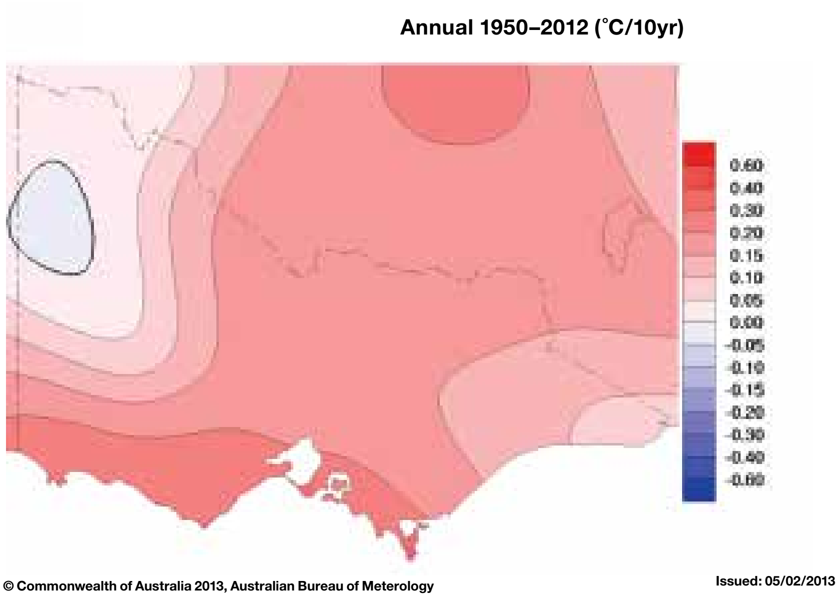


Figure A.1.15: Trend in Victorian minimum temperature, 1950 to 2012

Source: BoM.

Observed average rainfall

Annual rainfall in Victoria experienced large variations over the past century with no long-term trend (Figures A.1.16 to A.1.18). However, over the past two decades there has been a large decline in autumn rainfall, a small decline in winter and spring rainfall, a small increase in summer rainfall, and reduced frequency of very wet years.[7, 16]

Between 1997 and 2009, Victoria experienced a record-breaking 13-year drought – the longest recorded period of rainfall deficits on record. During this period, the annual inflow into Melbourne's dams dropped by almost 40%, and total water storage was down to 17% in 2009. In the Wimmera Southern Mallee region, drought conditions resulted in an 80% reduction in grain production and a 40% reduction in livestock production.[16]

Despite the drought ending in 2010 with two above-average rainfall years (2010 was the fifth-wettest year on record), ongoing declines in autumn rainfall persist, leaving large areas of Victoria with below-average rainfall.

Victoria experienced its highest summer rainfall on record in 2010–11. Record levels of rainfall were recorded across most of the state, with western, central and north-eastern Victoria particularly affected.

The high rainfall was the result of a combination of weather phenomena, including one of the strongest La Niña events ever observed and record high sea-surface temperatures to the north of Australia, which are associated with high rainfall in Victoria[7] The record rainfall led to major flooding that affected a third of Victoria.

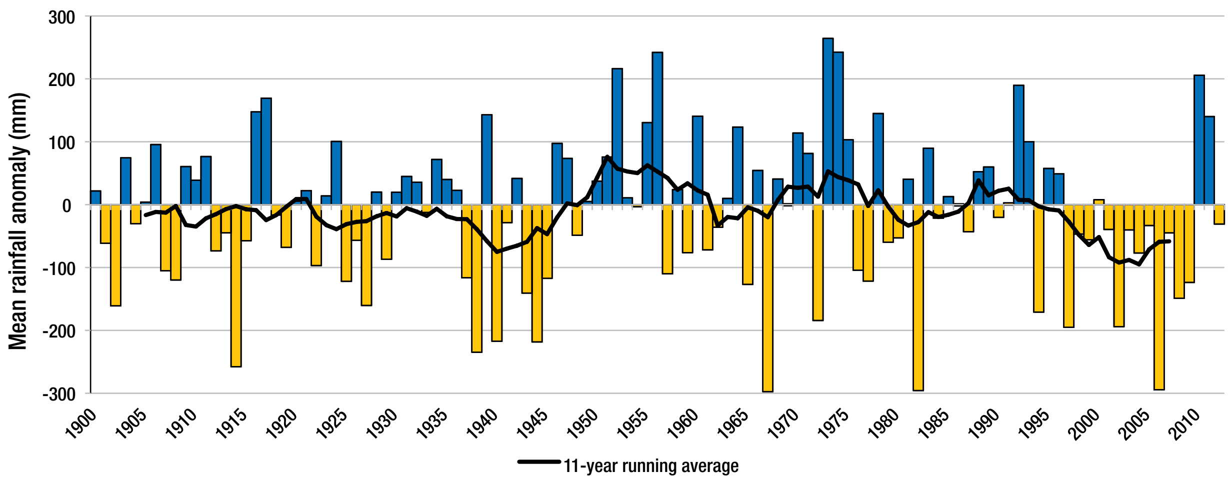


Figure A.1.16: Victorian annual rainfall anomaly, 1900 to 2012

Source: BoM.

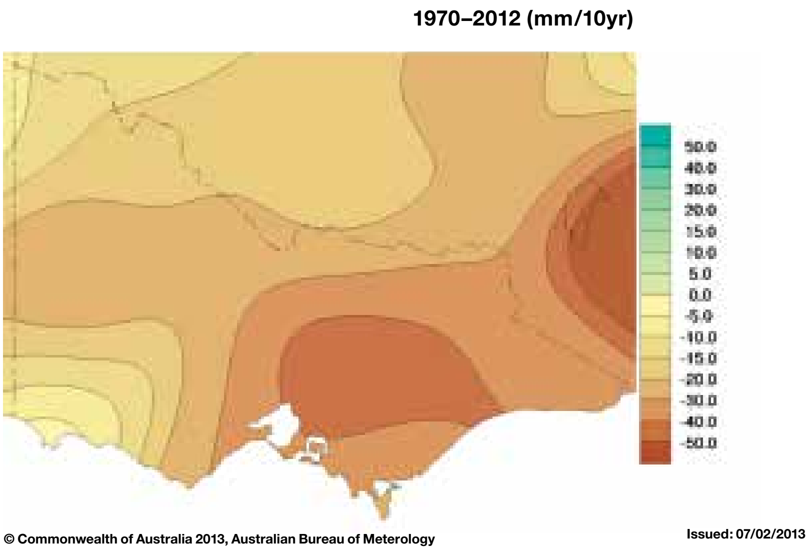


Figure A.1.17: Trend in Victorian annual total rainfall, 1970 to 2012

Source: BoM.

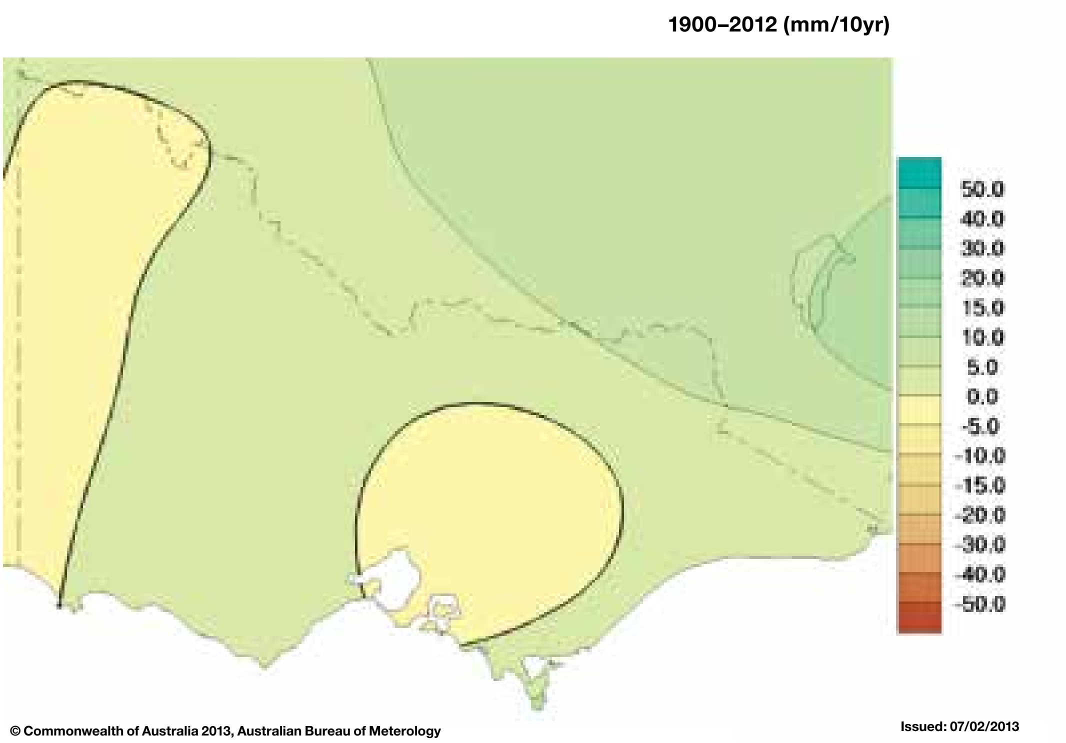


Figure A.1.18: Trend in Victorian annual total rainfall, 1900 to 2012

Source: BoM.

Snow cover

Snow cover in alpine areas is critical to Victoria's ecosystem resilience, water supply, biodiversity and recreation. It is also an important indicator of climate change extent and impacts.

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.[9] Between 1962 and 2001, the Australian Alps warmed by 0.2°C per decade with snow depth (measured at Spencers Creek in NSW) decreasing by 40% over roughly the same period.[17, 18]

In a recent study, Victorian snow measurements from 1954 to 2011 (taken from Rocky Valley Dam) showed a decrease in maximum snow depths and an earlier end to the snow season.[2] These changes were due to higher maximum temperatures and reduced snowfall from June to August.

CSIRO temperature and precipitation projections indicate that the length of the snow season will be reduced in the future with lower maximum snow depths.[2] The average snow-covered area of north-east Victoria is also likely to decline. Although natural year-to-year variability is projected, the number of good snow seasons is expected to decline while the number of poor seasons is likely to increase.*

* J. Bhend et al., *Climate Change Impacts on Snow in Victoria, 2012*, 2012, The Centre for Australian Weather and Climate Research.

Indicator CC4: Projected Climate Trends in Victoria

The range of climate projections in Australia was examined in detail by CSIRO in the 2007 analysis *Climate Change in Australia*.[9] The outcomes for Victoria were discussed in detail in the previous State of Environment report in 2008. Main findings include:

- 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.
- Runoff into most of our 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 five years by 2070. Projected sea-level rises will further exacerbate these problems.
- An updated analysis of the implications of global climate change projections for Australia, using the most recent modelled data, is currently being undertaken by CSIRO and will be available to the public in 2014.

Future Climate Zones in South-East Australia

The effects of changing patterns of rainfall and temperature were assessed in Foundation Paper One, *Climate Change Victoria: The Science, Our People, and Our State of Play*. This analysis used global model data to estimate potential southward movement of climate zones in south-east Australia by 2050 compared to the 1975–2004 baseline climate.

Based on a 'business as usual' scenario (IPCC A1FI),[19] some of the key outcomes were:

- decrease in the area covered by temperate climate from 55% to between 32 and 37% in 2050
- increased area of desert climate in south-east Australia from 5% to between 11 and 24% of the analysed area in 2050
- the emergence of a persistently drier climate in the western districts
- rising temperatures across Victoria leading to hotter summers.

Modelled outcomes were also examined under a lower emissions scenario (SRES B1).[19]

In this case, the most severe changes were often avoided in southern Victoria but substantial changes in climate were still seen in the north-west.

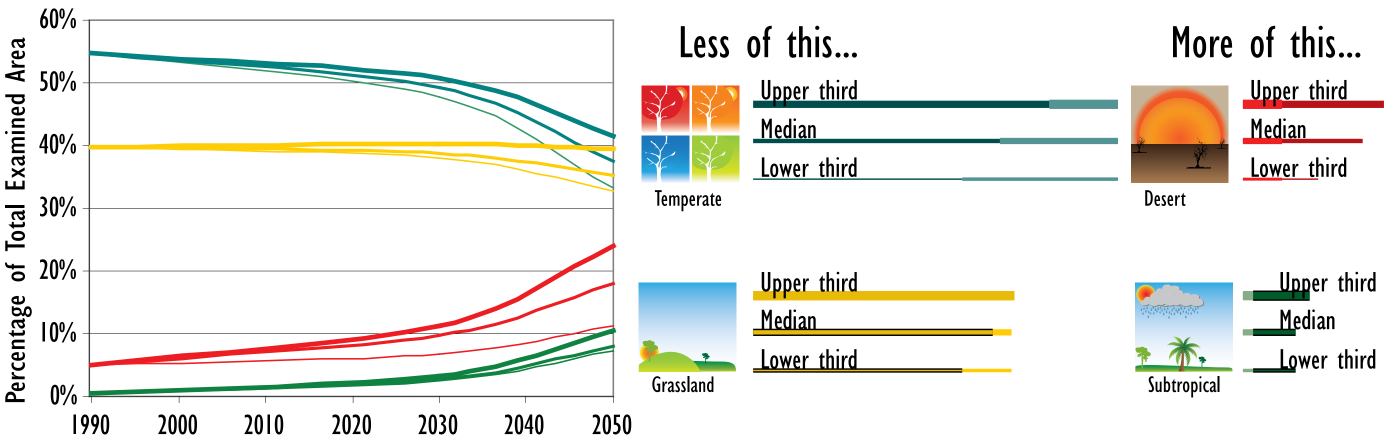


Figure A.1.19: Projected change in area covered by Subtropical, Temperate, Grassland and Desert climate zones in south-east Australia in 2030 and 2050 compared to 1990 under an unabated use of fossil fuels scenario (A1FI)

Note: The plots summarise the output of 23 global climate change models and show the median change across all models and the range of the middle 33% of changes.

Source BoM.

Indicator CC5: Sea-Surface Temperature and Sea-Level Rise

Sea-surface temperature

Victorian waters are getting warmer, with annual sea-surface temperatures increasing by around 0.8°C since 1910 (Figure A.1.20).

Southern Australia has experienced some of the fastest increases in ocean temperatures globally.

This rise in temperature is mainly due to the southern extension of the East Australian Current (Figure A.1.21). Changes in climactic conditions have strengthened the current by 20% in the last 50 years, increasing its southward penetration by 350 km.[20] The current brings warmer and saltier waters from north-east Australia down the east coast and its strengthening has caused warming at a rate of 0.023°C per year, approximately four times the global ocean-warming average.[21]

The changes in current strength and rising sea temperatures are likely to have severe consequences for marine ecosystems in Victoria.

In 2010, sea-surface temperatures in the Australian region were the highest on record, with nine of the months during 2011 ranked in the top 10 warmest months on record. Ocean temperatures around Australia were warmer during 2010–11 than for any previously identified La Niña event. This outcome was probably caused by the long-term warming trend of the past century.[5]

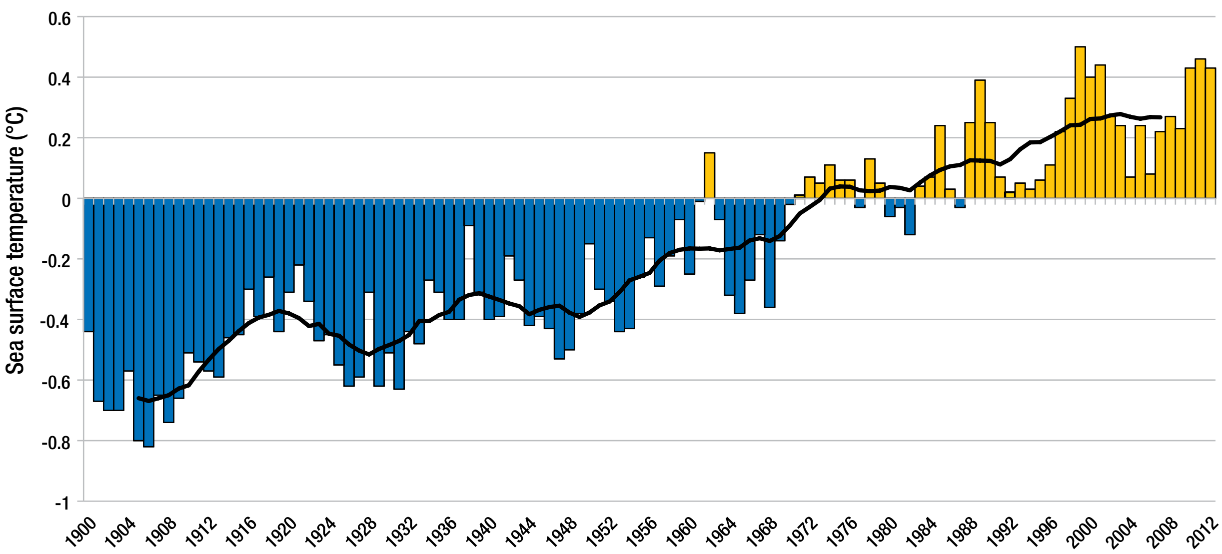


Figure A.1.20: Annual sea-surface temperature anomaly, southern region 1900–2012
Source: BoM.

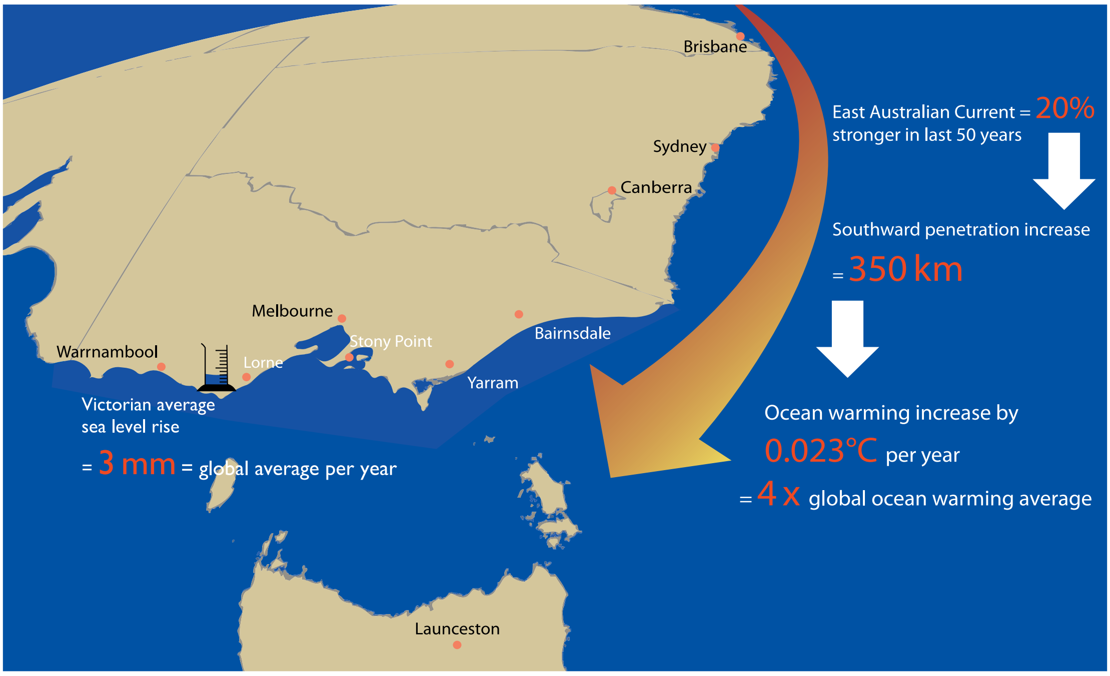


Figure A.1.21: Changes to the East Australian Current [20, 21, 22]

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 rates of sea-level rise are not uniform and vary from year to year, and by region. This is because of differences in conditions such as ocean currents and prevailing winds.

Global average mean sea level rose 210 mm (± 30 mm) between 1880 and 2011 (1880 is the earliest year for which robust estimates are available). Sea-level rise was faster between 1993 and 2011 than during the 20th century as a whole. Global average sea level rose at a rate of 3 mm per year between 1993 and 2011, compared to 1.7 mm per year during the 20th century as a whole, placing it at the high end of current projections.[5]

Victorian sea-level recording stations Lorne and Stony Point have shown an annual rise of 2.7 mm and 2.6 mm respectively since 1993.[23] Averaged annual sea-level rise across all Victorian waters is considered to be similar to the global average of 3 mm over the same period (Figure A.1.21).[5] Sea-level rise in Australia is highly variable, with the north and north-west regions showing a rise of 7 to 11 mm per year, two to three times the global average.

B AIR QUALITY

BACKGROUND

Good air quality is essential for human health and the environment. Air quality is primarily of concern in areas with high concentrations of population, transport and industrial activities. Such areas can experience localised air-quality problems, which have the potential to cause adverse health impacts. The common air pollutants – ozone, particles, nitrogen dioxide, carbon monoxide and sulfur dioxide – are associated with a range of health effects.

Currently, the main sources of air pollution in Victoria are industry, wood heaters, windblown dust, bushfires, planned burning activities such as fuel reduction burns, and motor vehicles (especially diesel exhaust).

Climate change will compound existing threats, with higher temperatures likely to increase the risk of more frequent and severe fires and dust storms, as well as an increase in summer smog formation.

EPA Victoria monitors air quality at 14 sites across Victoria (Figure A.1.22), with 12 in metropolitan Melbourne (11 long-term and one short-term), one in Geelong and one in the Latrobe Valley. EPA Victoria also receives data from industry-operated stations such as the Alcoa site at Point Henry.

Figure A.1.22: EPA Victoria air-quality monitoring sites in Melbourne and Geelong
Source: EPA Victoria.

MAIN FINDINGS

- Victoria has good air quality by international standards, although areas of poor air quality exist.
- Current air pollution levels can cause adverse health impacts.
- Levels of some gaseous pollutants, especially carbon monoxide and nitrogen oxides (emitted by cars and trucks), have significantly decreased in Melbourne since 1996.
- Levels of particle pollution (PM_{10} and $PM_{2.5}$ and visibility reduction) have been relatively stable since 1996, except for very high levels during fire and dust events.
- Bushfires and dust storms linked to prolonged below-average rainfall are the main causes of poor air quality across Victoria.
- Particle pollution is the most significant air-quality issue in Victoria.
- Levels of fine particles and ozone do not always meet the objectives set out in Victoria's ambient air-quality policy.
- Odour is a significant issue in Victoria, with around 4,000 complaints made to the Environment Protection Authority Victoria (EPA) each year.
- Climate change is likely to increase the frequency and severity of bushfires and drought leading to greater smoke and dust impacts on Victoria's air quality. Planned burning measures to reduce the severity of bushfires is also likely to increase smoke impacts in many areas. In addition, higher temperatures are likely to increase summer smog formation.

INDICATOR ASSESSMENT

Indicator Summary

Indicator	Summary	Status and trends (Good / Fair / Poor / Unknown)	Data quality
AQ1 Status and trends in levels of air pollutants	Victoria's air quality has improved significantly over the past decades and remains good by international standards. Fires and dust storms continue to be responsible for the most severe air pollution events. However, some localised problems occur from the accumulation of urban pollution sources, including wood heaters, transport exhaust and industrial pollution. While air quality monitoring is good in Melbourne, regional monitoring is limited.		Melbourne Regional Victoria
AQ2 Emissions of major air pollutants by sector	Future air-quality projections show a net reduction in total vehicle exhaust emissions due to better vehicle exhaust controls. In contrast, road dust is expected to increase in line with traffic growth. Industrial emissions will remain relatively stable over time, although some increases are predicted due to growth in economic activity. Emissions linked to domestic and business activity are expected to grow in line with population growth.	NA	NA
AQ3 Health impacts of air pollution	Although no recent comprehensive data are available for Victoria, previous studies suggest that there are relationships between human health and air pollution. Current air pollution levels are known to impact on the health of sensitive people.		

Indicator Assessment Legend

Status Good | Fair | Poor | Unknown

- Pressure likely to have negligible impact on environmental condition and/or human health.
- Pressure likely to have limited impact on environmental condition and/or human health.
- Pressure likely to have significant impact on environmental condition and/or human health.
- Data is insufficient to make an assessment of status and trends.

Data Quality

- Good: Adequate high-quality evidence and high level of consensus
- Fair: Limited evidence or limited consensus
- Poor: Evidence and consensus too low to make an assessment

Trends Deteriorating | Improving | Stable | Unclear

NA Assessments of status, trends and data quality are not appropriate for the indicator.

Current knowledge

Melbourne

Air quality in Melbourne has improved significantly since the 1970s and remains relatively good by international standards. This has occurred despite the pressures from a growing population and increased economic activity. Air-quality improvements are the result of Victoria's regulation of pollution sources, particularly in relation to industry, vehicle exhaust and backyard burning.

For example, gaseous motor vehicle exhaust pollutants such as carbon monoxide have significantly reduced over the last decade. In addition, particle pollution levels have remained relatively stable, except for periods of severe impact due to major fire and dust events.

Melbourne's air quality is considered to be relatively good for a major metropolitan centre.[24] Despite this, air pollution problems still exist in Melbourne because of localised sources such as industry and high-density traffic. For example, the EPA has found that Brooklyn in Melbourne's west has experienced ongoing air-quality problems (see Case Study: Air Quality Monitoring in Brooklyn, Melbourne).[24]

EPA Victoria has also undertaken air toxics monitoring at residential sites in Tullamarine beside the old Tullamarine landfill, and at residential sites surrounding the Dandenong South industrial precinct. The majority of the air toxics were detected at low levels or not at all.

Case Study: Air Quality Monitoring in Brooklyn, Melbourne[25, 26]

In late 2009, EPA commenced an air-quality monitoring program in Brooklyn, a suburb 10 km west of the Melbourne city centre. The area had been subject to high levels of particle pollution with the suspected cause being the Brooklyn Industrial Estate.

Particle pollution can have significant health impacts, particularly for young children, the elderly, and people with respiratory (such as asthma, bronchitis and emphysema) and heart conditions. Main health impacts include:

- increased allergic reactions and asthma attacks in people with these pre-existing conditions
- increased breathing-related problems in people with respiratory conditions
- increased symptoms of existing heart problems
- in severe cases, hospitalisation.

Monitoring results show that particle pollution (PM_{10} – particles smaller than 10 micrometres in size) in Brooklyn is much higher than other regions of Melbourne and Geelong (Figure A.1.23). Between November 2009 and April 2013, the PM_{10} air-quality objective was exceeded on 95 days, including on 38 days between November 2009 to October 2010.

Annual exceedences in Brooklyn are significantly higher than the Ambient Air Quality National Environment Protection Measure for particles, which states levels should not exceed the PM_{10} air-quality standard on more than five days a year.

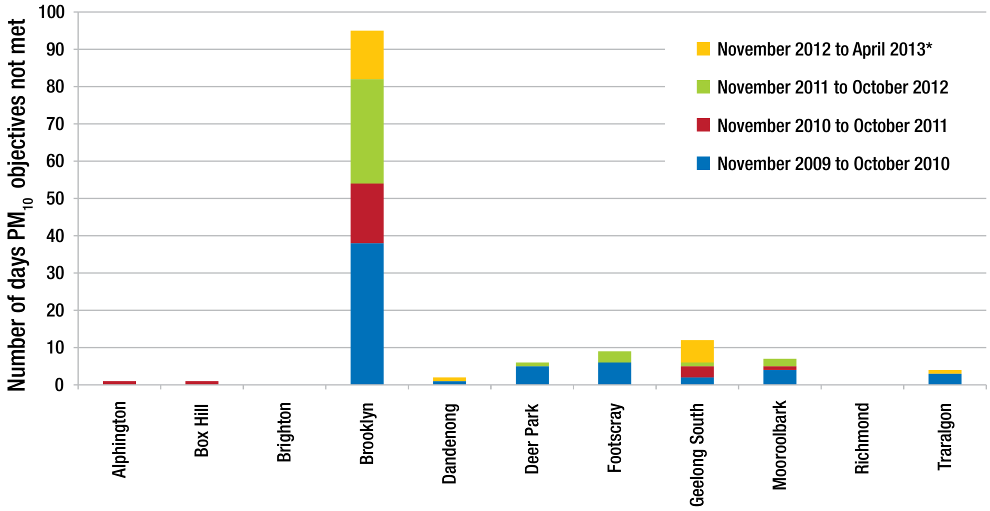


Figure A.1.23: Number of days PM_{10} objectives not met, Victorian air-quality monitoring stations

Source: EPA Victoria.

*Note: *Only six months of monitoring data available for 2012–13, from November to April.*

Poor air quality in Brooklyn generally occurred on weekdays, particularly mornings, during dry periods with strong and persistent northerly winds.

In addition, the $PM_{2.5}$ reporting standard was not exceeded, showing that larger particles are causing the poor air quality. The major source of larger particles was windblown dust, derived from clay, soil, silt, sand, crushed building material, unpaved roads and other similar material. No other harmful particles were found.

These findings confirm that activities within the Brooklyn Industrial Precinct are the source of the ongoing air pollution, including from large trucks travelling along unsealed roads in the industrial estate. About 30% of the PM_{10} measured during days with high particle levels is attributable to dust from roads in the estate.

The Victorian EPA is continuing to monitor air quality in Brooklyn. The monitoring enables the EPA to respond to community concerns and work with local industries and government to improve dust management practices in the area.

Regional Victoria

Knowledge of regional air quality is limited to short-term measurements (typically 12 months) taken in a limited number of Victorian towns (including Bairnsdale, Ballarat, Bendigo, Bright, Mildura, Morwell East, Shepparton, Wangaratta and Warrnambool), and evidence from targeted emission studies. While regional air quality is generally better than in Melbourne, problems do occur, including:[24, 27]

- poor air quality during dust storms, bushfires and planned burning activities, including agricultural burning
- odour and dust, which can be serious problems, especially near local industries such as agriculture, mining and intensive animal production
- smoke from the use of wood heaters in winter
- elevated sulfur dioxide levels in areas around power stations, refineries and smelters.

Future issues

The EPA has identified the following issues for future air quality in Victoria.[27]

- The key pollutants of concern in the future are expected to be particles ($PM_{2.5}$ and PM_{10}) and ozone (O_3). These pollutants are likely to continue to breach current air quality standards.
- Emissions from many unregulated sources are expected to increase or, at best, remain unchanged. These sources include wood heaters, small petrol engines (used for garden maintenance, generators, etc.), and small to medium industries.
- Bushfires, dust storms and planned burns are likely to cause major air-quality impacts. These will vary from year to year depending on weather conditions.

Indicator AQ1: Status and Trends in Levels of Air Pollutants

Particle pollution (PM_{10} and $PM_{2.5}$)

Particle pollution is the most significant air-quality issue in Victoria, with high levels associated with respiratory and cardiovascular illness. 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.

The most common measures of particles are PM_{10} (particles smaller than 0.010 mm) and $PM_{2.5}$ (particles smaller than 0.0025 mm). Particles smaller than 2.5 micrometres are considered to have more significant health impacts due to their deeper penetration into the lungs.

Particle pollution is usually the community's main indicator of air quality, often evident as a haze that reduces visibility. Particle pollution can result from both anthropogenic sources (industry, motor vehicles – particularly diesel, wood heaters) and natural sources (dust storms, bushfires, sea salt).

Climate change is likely to increase the occurrence of particle pollution with conditions leading to dust storms and more prevalent fires.

PM_{10}

PM_{10} has been measured on a daily basis since 1995 in Melbourne and since late 2002 in Geelong and the Latrobe Valley. Annual average PM_{10} levels (Figure A.1.24) have remained relatively unchanged over the monitoring period and show no clear trend. Although the data suggest a higher particle load in Geelong, results have been influenced by a local dust source and may not accurately represent the Geelong region. Average PM_{10} results are generally a little higher in Melbourne than in the Latrobe Valley.

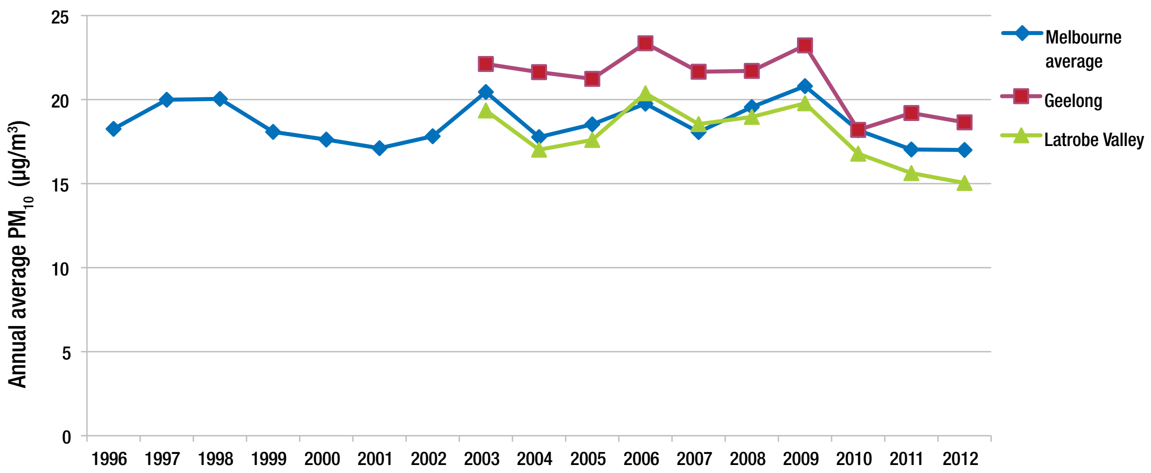


Figure A.1.24: Annual average PM_{10} 1996–2012

Source: EPA Victoria.

In most years of monitoring, the National Environment Protection Measure (NEPM) 24-hour average standard (50 µg/m³) was exceeded because of dust storms caused by prolonged below-average rainfall and, to a lesser extent, fire events (Figure A.1.25).

These events strongly influence the concentration of airborne particles. In severe events, winds can transport soil particles and smoke many hundreds of kilometres, affecting air quality across large areas of the state.

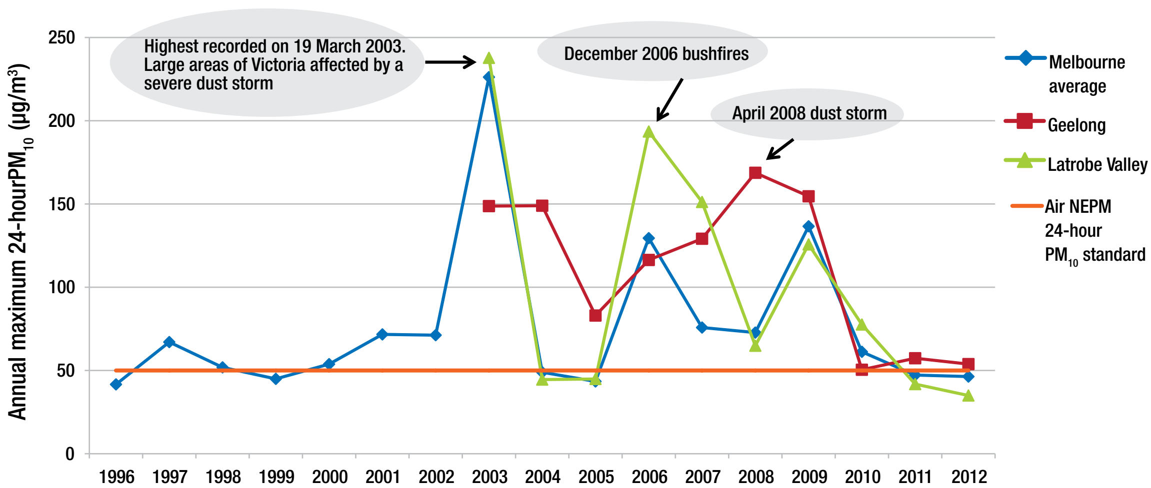


Figure A.1.25: Annual maximum 24-hour average PM_{10} 1996–2012

Source: EPA Victoria.

$PM_{2.5}$

There is currently no national standard for $PM_{2.5}$ particles. However, the NEPM specifies advisory reporting standards for $PM_{2.5}$ levels not to exceed a concentration of 25 µg/m³ per day, or an average of 8 µg/m³ per year. EPA Victoria assesses $PM_{2.5}$ at two suburban locations in Melbourne (Alphington and Footscray).

The annual data from 1996 to 2012 suggest no long-term trend in $PM_{2.5}$ (Figure A.1.26). The Melbourne average $PM_{2.5}$ level (derived from the two monitoring locations) only exceeded the annual advisory reporting standard in years with major bushfires.

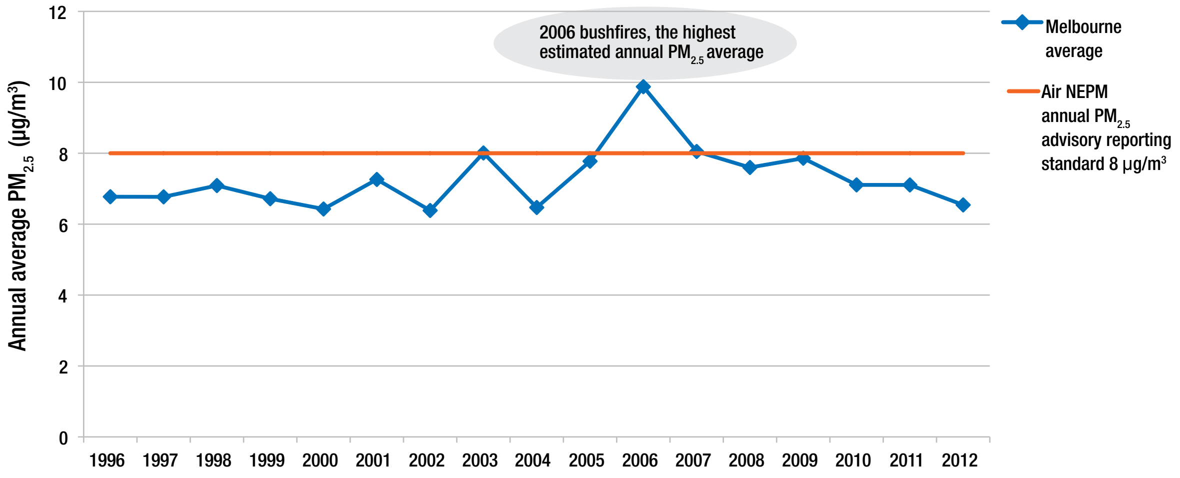


Figure A.1.26: Annual average $PM_{2.5}$ 1996–2012

Source: EPA Victoria.

Note: $PM_{2.5}$ levels are assessed at two suburban locations in Melbourne (Alphington and Footscray). These datasets have been combined to provide an estimate of the Melbourne average.

The daily advisory standard was exceeded for most years of monitoring (Figure A.1.27). In recent times, bushfires have been the main cause of high $PM_{2.5}$ levels in Melbourne, with some planned burning activities also resulting in $PM_{2.5}$ levels above the advisory standards. Other causes of high $PM_{2.5}$ include wood heaters and the accumulation of urban pollution on calm autumn and winter days. The highest Melbourne 24-hour average $PM_{2.5}$ level was 141 µg/m³, recorded on 20 December 2006, a day of severe bushfire smoke.

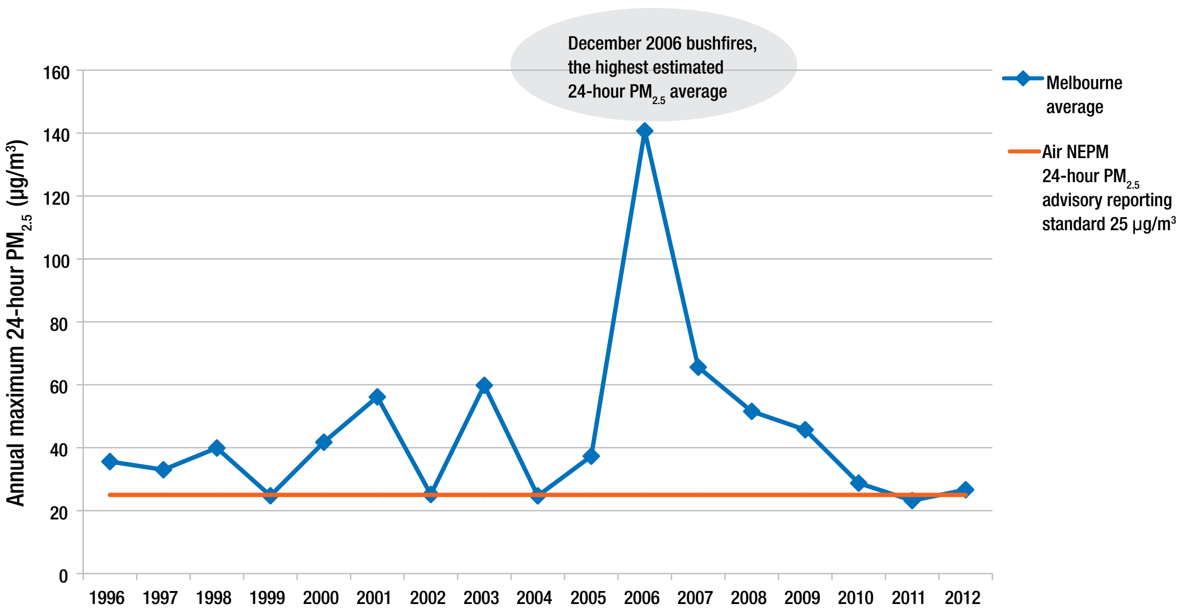


Figure A.1.27: Annual maximum 24-hour average $PM_{2.5}$ 1996–2012

Source: EPA Victoria.

Note: $PM_{2.5}$ levels are assessed at two suburban locations in Melbourne (Alphington and Footscray). These datasets have been combined to provide an estimate of the Melbourne average.

Visibility

Fine particles reduce how far we can see through the air. The Victorian State Environment Protection Policy (SEPP) for ambient air quality includes a visibility objective of 20 km in dry air – that means it should be possible on a fine day to see a contrasting object against a background at a distance of 20 km. This Victorian air-quality objective is more stringent than any of the national standards for airborne particles.

Visibility is expressed using an Airborne Particle Index (API), the lower the visibility, the higher the API. No significant trends over time were found in the annual average API levels (Figure A.1.28). However, the data does suggest that the Latrobe Valley experiences more fine particles than Melbourne. This is likely to be caused by air pollutants from wood heaters and planned burns, which can easily accumulate in the Latrobe Valley under light wind conditions.

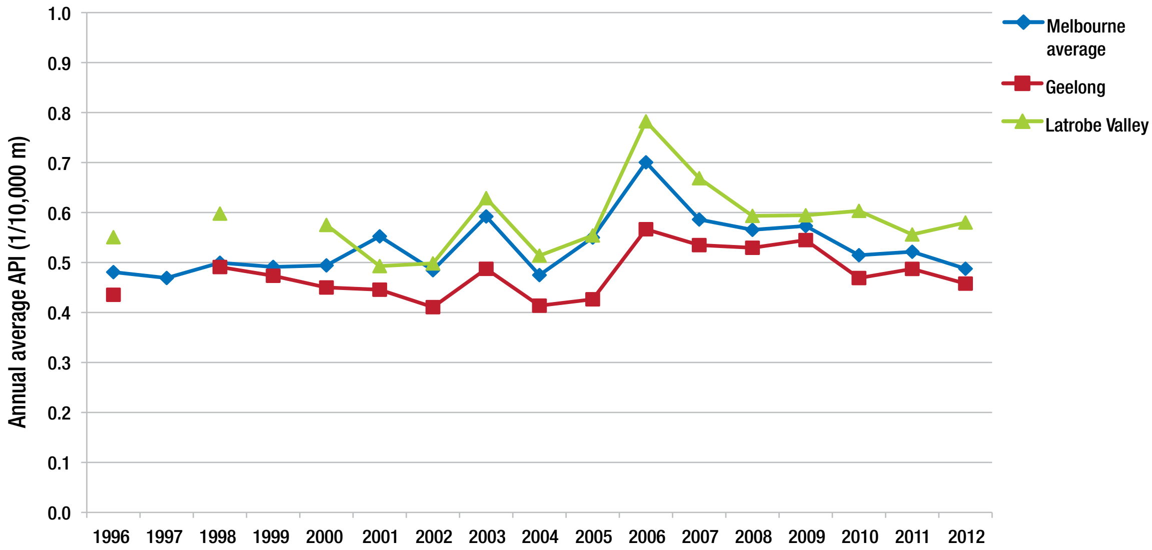


Figure A.1.28: Annual average Airborne Particle Index (API) 1996–2012 (1/10,000 m)

Source: EPA Victoria.

The annual maximum 1-hour API shows that the visibility objective is breached almost every year (Figure A.1.29). Bushfires are the main cause of poor visibility, with planned burns, winter smog and dust storms also impacting on visibility.

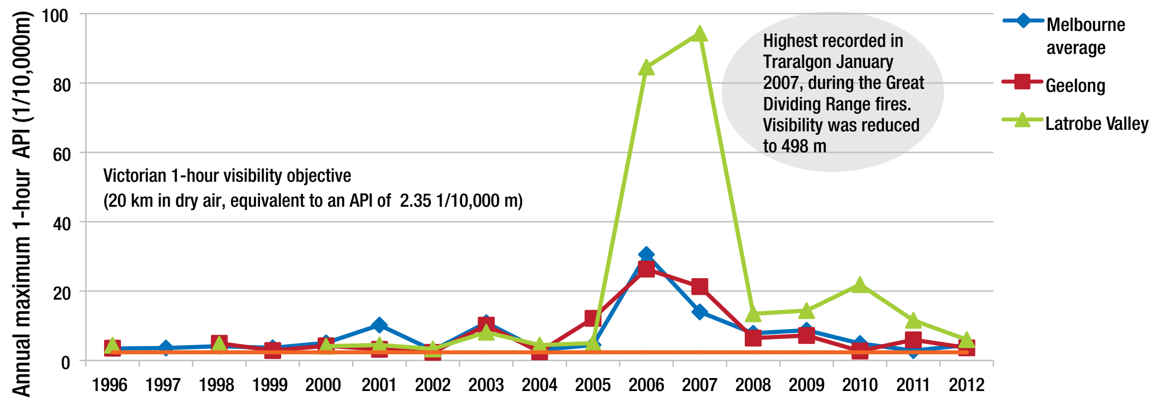


Figure A.1.29: Annual maximum 1-hour Airborne Particle Index (API) 1996–2012 (1/10,000 m)

Source: EPA Victoria.

Ambient ozone levels (summer smog)

Summer smog may appear on hot afternoons between November and March, mostly around Melbourne and Geelong. It is usually seen on the horizon as a white or grey haze. Summer smog is caused by reactions between various air pollutants. Ozone is the most significant component of the resulting mixture and provides an indication of summer smog levels.

Ozone is not directly emitted into the air. It is formed when volatile organic compounds (from industry, vehicles and vegetation) and oxides of nitrogen (from industry, vehicles and natural gas use) react in sunlight. These reactions only produce significant amounts of ozone on warm, sunny days with light or recirculating winds. Ozone can also form downwind of bushfires when the chemicals in smoke react in the presence of sunlight.

Human exposure to high concentrations of ozone can result in decreased lung function, increases in asthma attacks, and increases in hospital admissions for people with heart and lung conditions.

Although ozone levels occasionally breach the air-quality standards in Victoria, levels have remained fairly stable with no discernible trend since 1996 (Figure A.1.30). The highest levels of ozone in Victoria have been linked to bushfires, such as those occurring in 2006–07.

In the future, the higher temperatures predicted as a result of climate change are likely to lead to a greater potential for ozone formation.

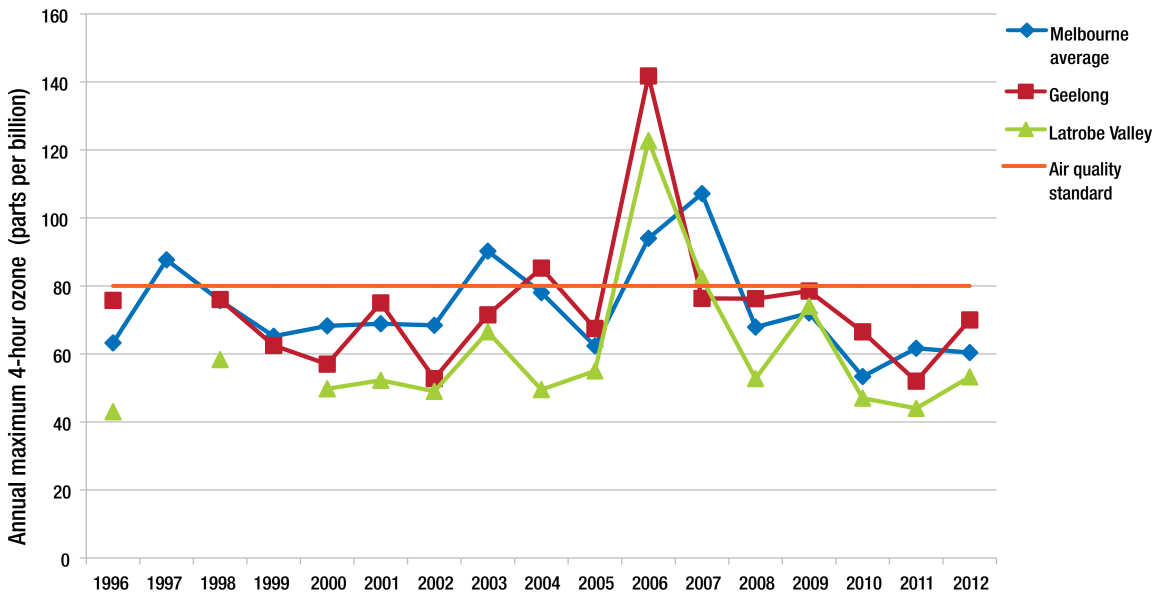


Figure A.1.30: Annual maximum 4-hour ozone (O_3) 1996–2012 (parts per billion)

Source: EPA Victoria.

Carbon monoxide and nitrogen dioxide

Carbon monoxide (CO) and nitrogen dioxide (NO_2) are produced from petrol engine exhaust. NO_2 is also produced by the burning of fuels such as natural gas and diesel. Both are harmful to human health, especially for children, the elderly and those with asthma.

Carbon monoxide and nitrogen dioxide levels have been decreasing in Melbourne since 1996 – remaining below air-quality standards. This is mainly because of progressive improvements in motor vehicle emissions. Controls on tailpipe emissions from cars and trucks have outweighed the growth in traffic over this time.

Since 2002, average carbon monoxide levels in Geelong have increased, and are now similar to those in Melbourne. This increase may be caused by factors other than motor vehicles, or may simply reflect an increase in urban density.

Average levels of nitrogen dioxide are higher in Melbourne than in Geelong and the Latrobe Valley, mainly due to the greater population and traffic density. There are no clear trends in nitrogen dioxide levels in Victoria, with increased levels usually occurring as a result of bushfires.

Average levels of nitrogen dioxide in Geelong and Latrobe Valley are lower than in Melbourne, and show no clear trend. Slightly higher levels can occur during major bushfires.

Sulfur dioxide

Most sulfur dioxide (SO_2) emissions are from coal-fired power stations and metal smelting industries. This gas can irritate the lungs, and is particularly harmful for people with asthma.

Levels of sulfur dioxide are extremely low in most areas of Melbourne and Geelong, remaining well below air-quality standards. This can be attributed to the very low sulfur content of the fuels used in Melbourne and Geelong for both heating and transport. Much higher levels of sulfur dioxide are measured near industrial sites, although results are still below air-quality standards.

Lead

Due to the removal of lead from petrol, lead levels have decreased to such an extent that ongoing monitoring is no longer undertaken in Victoria.

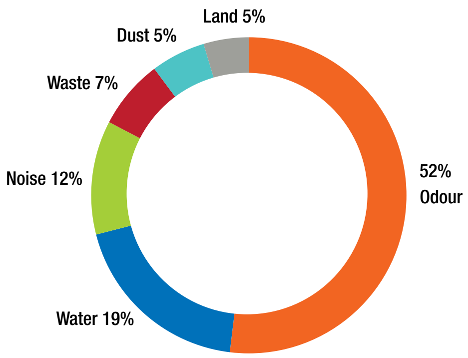
Amenity: dust, noise and odour

Odour, dust and noise can impact on the wellbeing of Victorians. Between 2000 and 2010, nearly 86,500 complaints were made to EPA Victoria regarding environmental conditions (Figure A.1.31). Odour was responsible for 52% of complaints made, with noise and dust responsible for 12% and 5% respectively.

Odour is clearly a significant issue in Victoria, with around 4,000 complaints made each year. Odour issues are not limited to high population areas, with some regional towns also affected by wastewater treatment plants and intensive animal industries. Anecdotal evidence suggests that residential encroachment on industry (including landfills, farms, composting operations and manufacturing) has made the problem worse in some locations.

Figure A.1.31: Complaints to EPA Victoria, 2000 to 2010

Source: EPA Victoria.



Indicator AQ2: Emissions of Major Air Pollutants by Sector

The sources and amounts of pollutants emitted into the atmosphere are influenced by many factors, including population, economic activity, prosperity, mobility and personal behaviour.

The Victorian Environment Protection Authority is currently producing a 2011 air pollutant inventory. The main findings from the previous inventory in 2006 were reported in the 2008 State of the Environment report. Main findings included the following.

- Motor vehicles contribute most of the carbon monoxide and oxides of nitrogen, except in the Latrobe Valley, where most oxides of nitrogen come from industry.
- Large industry contributes most of the sulfur dioxide and significant amounts of oxides of nitrogen.
- Windblown dust contributes most of the particle emissions, bushfires are also important sources in some areas.
- Bushfires also contribute large amounts of particles, as well as carbon monoxide.
- Biological sources contribute most of the volatile organic compounds.

For sources of greenhouse gases see Indicator CC.1: Trends in Greenhouse Gas Emissions in Victoria.

The Victorian Environment Protection Authority has also released projections for future air quality in Victoria.[27] Key findings include the following.

- Total vehicle exhaust emissions are decreasing because of the introduction of better vehicle exhaust controls. The trend towards improved exhausts is happening faster than the growth in vehicle traffic, resulting in a net reduction in total exhaust emissions from cars and trucks over time. In contrast, road dust, caused by the movement of vehicles on roads during dry weather, is expected to increase in line with traffic growth.
- Industrial emissions are relatively stable over time. Some growth in industrial emissions can be expected due to general economic growth. However, in most cases, these emissions take place high above the ground (from tall stacks), and therefore have minimal impact at ground level.
- Emissions linked to domestic and business activity are expected to grow in line with population growth. In most cases these emissions are not well regulated (see Part B Goal 4.5).

Indicator AQ3: Health Impacts of Air Pollution

No long-term studies that document the association between mortality and air pollution exposure have been carried out in Australia. However, short-term studies suggest that there are similar relationships between health and air pollution in Australia to those observed in Europe and North America.[28] These studies have observed significant associations between high concentrations of PM_{10}, NO_2 and CO and daily cardiorespiratory mortality.

Studies in Melbourne (carried out in the 1990s) indicated that air pollution contributed to approximately 300 deaths and 1,000 hospital admissions per year.[29, 30] The impacts of air pollution on human health is dependent on a range of factors, including exposure level and the age and background health status of individuals.

For example, across all Australian cities, air pollution has been significantly associated with cardiovascular disease hospital admissions in people over the age of 65.[31]

In recognition of this, national standards are moving towards the position that there is no safe concentration for sensitive people, especially for particles (PM_{10} and $PM_{2.5}$).[32]

Data gaps

While air-quality monitoring is generally good across Melbourne, statewide data is lacking. Only two sites are currently monitored in regional Victoria, one in Geelong and one in Traralgon in the Latrobe Valley.

For a comprehensive assessment of air quality in Victoria, wider monitoring coverage is required. Information is also lacking on the impacts of air pollution on human health in Victoria.

Koala