AIR (A)

SCIENTIFIC ASSESSMENTS Part III

Commissioner *for* Environmental Sustainability Victoria

Traditional Owners

The Commissioner for Environmental Sustainability proudly acknowledges Victoria's Aboriginal community and their rich culture and pays respect to their Elders past and present.

We acknowledge Aboriginal people as Australia's first peoples and as the Traditional Owners and custodians of the land and water on which we rely. We recognise and value the ongoing contribution of Aboriginal people and communities to Victorian life, and how this enriches us.

We embrace the spirit of reconciliation, working towards the equality of outcomes and ensuring an equal voice.

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Air

This chapter includes assessments of Victoria's ambient air quality and the associated health impacts of air pollution, emissions of major air pollutants, indoor air quality, stratospheric ozone, light pollution and odour pollution. It also includes an assessment of noise pollution and its associated health impacts.

Background

Good air quality is essential for human health. The links between air quality, population exposure and health are an increasing focus for research and policy development. The greatest adverse health effects from air pollution are usually experienced in densely populated areas that are exposed to emissions from motor vehicles, industrial facilities and domestic activities (such as using wood heaters), while significant smoke impacts from bushfires and planned burns (for example, fuel reduction, coupe and ecological burns) can cause poor air quality in urban and rural areas.

Victoria's air quality is considered good relative to international standards, although poor air quality is still measured near major industrial facilities, during major incidents (such as bushfires, industrial fires and dust storms) and during periods of planned burns.

Recently, poor air quality in populated areas has been recorded for multiple consecutive days near major fires – notably the Hazelwood mine fire in 2014,[1] the industrial fire at a recycling facility near Coolaroo in 2017[2] and the peat fires near Cobden in 2018.[3]

Between 1996 and 2013, the length of the fire season in eastern Australia has increased, in association with climate change.[4] This has necessitated more intensive fuel reduction burns over shorter periods. As fuel reduction burns must be undertaken during calm weather conditions that facilitate the buildup of air pollution, more intense burn programs increase the risk of widespread particle pollution.

As Victoria's population increases, and the average age of the population increases, the health impacts of poor air quality are likely to increase, unless there is a decrease in air pollution. Climate change will compound existing threats: higher temperatures and longer periods of reduced rainfall are likely to increase the risk of frequent and severe fires and dust storms and exacerbate conditions for summer smog formation.[5]

Environment Protection Authority Victoria (EPA Victoria) has increased the number of air-monitoring stations since the publication of SoE 2013. EPA Victoria now monitors air quality at 19 sites across Victoria – 12 in Melbourne (Figure A.1), 5 in the Latrobe Valley (Figure A.2) and 1 each in Geelong and Wangaratta. Since the 2014 Hazelwood mine fire, EPA Victoria has worked with the Latrobe Valley community to design a more extensive air-monitoring network in the region.[6]

1 EPA 2015, 'Summarising the air monitoring and conditions during the Hazelwood mine fire, 9 February to 31 March 2014', Carlton, Victoria http://www.epa.vic.gov.au/~/media/Publications/1598.pdf Accessed 3 December 2018.

2 EPA, 'EPA completes air monitoring campaign in Coolaroo', Carlton, Victoria http://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2017/july/21/epa-completes-air-monitoring-campaign-in-coolaroo. Accessed 3 December 2018.

3 EPA, 'Last EPA air monitoring station leaving as Cobden gets the all clear', Carlton, Victoria http://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2018/may/08/last-epa-air-monitoring-station-leaving-as-cobden-gets-the-all-clear Accessed 3 December 2018.

4 Jolly M, Cochrane M, Freeborn P, Holden Z, Brown T, Williamson G, Bowman D 2015, 'Climate-induced variations in global wildfire danger from 1979 to 2013', *Nature Communications*, 6(7537), pp. 1-11.

5 EPA 2013, 'Future Air Quality in Victoria: Final Report, 2013', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1535.pdf Accessed 3 December 2018.

6 EPA, 'Latrobe Valley air monitoring co-design', Carlton, Victoria http://www.epa.vic.gov.au/our-work/programs/latrobe-valley-air-monitoring/latrobe-valley-air-monitoring-codesign Accessed 3 December 2018.

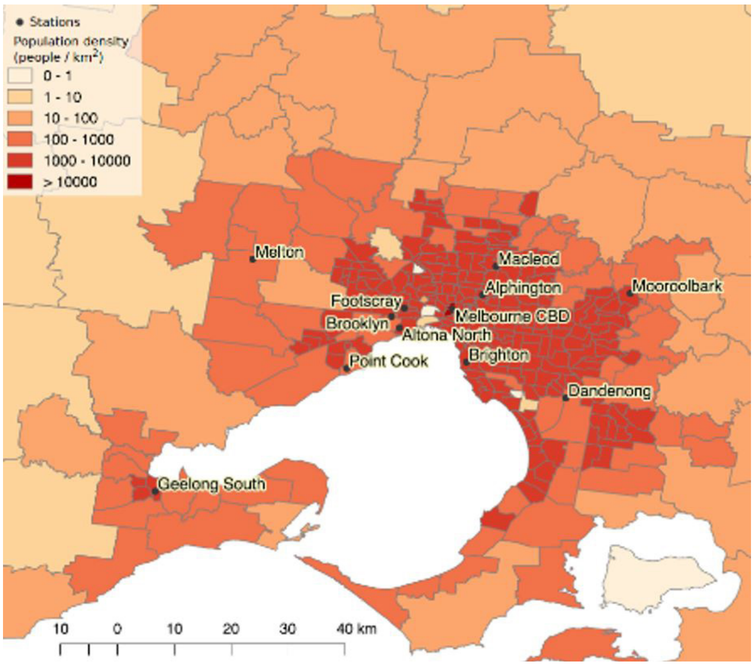

Figure A.1 EPA Victoria air-monitoring stations in Melbourne and Geelong

(Image source: EPA Victoria, 2018)

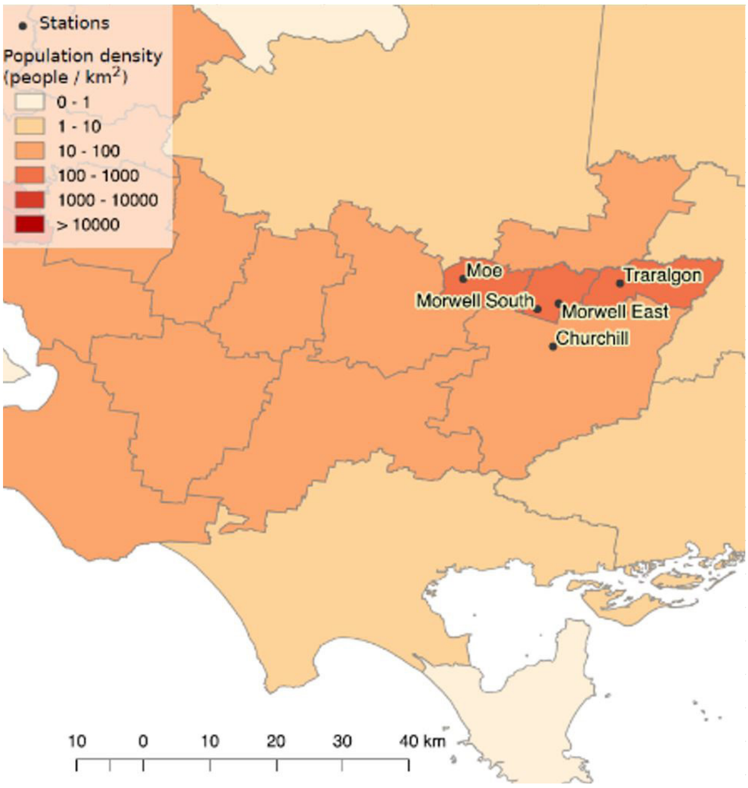

Figure A.2 EPA Victoria air-monitoring stations in the Latrobe Valley

(Image source: EPA Victoria, 2018)

Despite EPA Victoria expanding its air-monitoring network, a 2018 Victorian Auditor-General's Office (VAGO) report found EPA Victoria cannot demonstrate that its current monitoring provides a representative measure of ambient air quality across the state. The VAGO report recommended an expanded air-monitoring network for Victoria that better aligns coverage with pollution risks.[7]

Studies investigating the long-term health effects of air pollution have been conducted in Australia,[8,9] but there is no comprehensive understanding of the impacts on human health. Few long-term studies that document the association between mortality and air pollution exposure have been carried out in Australia. Given the delay between the publication of long-term studies and policy development, it is important to complement longer studies with epidemiological studies that generate useful associations between air pollution and health impacts from just a few years of data. There is a increasing body of evidence demonstrating that air pollution, even at concentrations below the current air-quality standards, is associated with adverse health effects.[10] The strongest evidence relates to premature mortality and effects on the respiratory and cardiovascular system.[11]

Odour and noise can also impact wellbeing, while excessive exposure to noise can impact human health. Odour is the most frequent type of pollution report received by EPA Victoria, prompting about 4,000 reports per year.[12] Common sources of odour pollution are landfills and composting facilities, animal processing and intensive agriculture.

The critical challenges facing Victoria's air-quality management now and in the future include:

- reducing air-pollution emissions and population exposure to air pollution emissions
- reducing human health impacts associated with an increasing and ageing population, particularly during pollution events and in areas with greater air-pollution emissions
- expanding Victoria's air-monitoring network to include a greater coverage across regional Victoria and some areas of Melbourne, as well as including targeted roadside air-monitoring sites
- improving understanding of the sources and extent of air pollution through better monitoring and reporting and a more comprehensive pollution inventory
- improving knowledge of the link between air quality and health, particularly during short-to-medium pollution events (for example, the effects of being exposed to significant amounts of smoke from bushfires, industrial fires or planned burns)
- ensuring suitable buffer protection measures are in place between odorous industries and residential communities
- identifying opportunities to include air quality in urban planning decisions, particularly in relation to urban green space, and opportunities to reduce reliance on causes of pollution (for example, motor vehicles)[13]
- identifying and managing the effects of climate change on the impact of pollution from bushfires, planned burns, summer smog formation and dust storms.

7 VAGO 2018, 'Improving Victoria's Air Quality', Melbourne, Victoria, https://www.audit.vic.gov.au/sites/default/files/2018-03/20180308-Improving-Air-Quality.pdf Accessed 3 December 2018.
8 Lazarevic N, Dobson AJ, Barnett AG, Knibbs LD 2015, 'Long-term ambient air pollution exposure and self-reported morbidity in the Australian Longitudinal Study on Women's Health: a cross-sectional study', British Medical Journal 5(10), pp. 1-10.
9 Knibbs LD, Cortés de Waterman AM, Toelle BG, Guo Y, Denison L, Jalaludin B, Marks GB, Williams GM 2018, 'The Australian Child Health and Air Pollution Study (ACHAPS): A national population-based cross-sectional study of long-term exposure to outdoor air pollution, asthma, and lung function', Environment International, 120, pp. 394-403.
10 EPA 2018, 'Air pollution in Victoria – a summary of the state of knowledge', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1709.pdf Accessed 3 December 2018.
11 Ibid.
12 EPA 2017, '2016-17 Annual Report', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1665.pdf Accessed 3 December 2018.

13 World Health Organization Regional Office for Europe 2016, 'Urban green spaces and health', Copenhagen, Denmark http://www.euro.who.int/__data/assets/pdf_file/0005/321971/Urban-green-spaces-and-health-review-evidence.pdf Accesed 3 December 2018.

Current Victorian Government Settings: Legislation, Policy, Programs

In May 2018, the Victorian Government released *Clean Air for All Victorians – Victoria's Air Quality Statement*. The statement contains ideas on what could be done to protect Victoria's air quality through to 2030. Public comments on the statement, and a subsequent Clean Air Summit and workshops, are informing the development of a Victorian Clean Air Strategy for release in 2019. The Victorian Government has allocated $1.2 million to develop this strategy, which will articulate policy and programs to underpin air-quality management to 2030.

In 2016, a Ministerial Advisory Committee (MAC) completed its inquiry into EPA Victoria. One of the MAC's recommendations was for EPA Victoria to 'assess the adequacy of its air and water monitoring networks, particularly in relation to air quality and consider options to improve data sharing and accessibility, and community communication' (recommendation 6.3).[14] Another recommendation was to 'create a consolidated and enhanced environmental health capability for Victoria within the EPA, with appropriate governance arrangements recognising its critical relationship with the Department of Health and Human Services' (recommendation 6.2), which was completed in December 2016.[15,16]

The Victorian Government is investing $182.4 million to reform EPA Victoria into a modern environmental regulator focused on preventing pollution, and to give the agency stronger powers and tools to prevent and manage instances of air pollution. The *Environment Protection Act 1970* has been reformed through two pieces of legislation: the *Environment Protection Act 2017*, which establishes EPA Victoria as a statutory authority and legislates the role of its board, chief executive officer and chief environmental scientist, and the *Environment Protection Amendment Act 2018*, which provides the foundation for transforming Victoria's environment protection laws. The Victorian Government intends for this new legislation to take effect from 1 July 2020.

The updated legislation provides the foundation for the following changes:

- a preventative approach through a general environmental duty
- a tiered system of EPA Victoria permissions to support risk-based and proportionate regulatory oversight
- significant reforms to contaminated land and waste management
- increased maximum penalties
- requirements for more environmental information to be publicly available
- modernising and strengthening EPA Victoria's compliance and enforcement powers.

The 2018 VAGO report, *Improving Victoria's Air Quality*, recommended EPA Victoria:

- expand its air-monitoring network
- improve its reporting on air quality
- expand and update its knowledge of Victoria's air quality
- work with all relevant councils to address air-quality issues at the Brooklyn Industrial Precinct
- work with the Department of Environment, Land, Water and Planning (DELWP) to clarify the roles and responsibilities of relevant Victorian Government agencies with respect to air-quality management.

DELWP and EPA Victoria have accepted all recommendations of the VAGO report and are commencing actions to address them.

14 MAC 2016, 'Independent inquiry into the Environment Protection Authority', http://www.epa-inquiry.vic.gov.au/__data/assets/file/0008/336698/Inquiry-report-EPA_June.pdf Accessed 3 December 2018.
15 Ibid.
16 EPA, 'Environmental public health', Carlton, Victoria https://www.epa.vic.gov.au/our-work/environmental-public-health Accessed 3 December 2018.

National and state ambient air quality legislation was amended in 2016 to reflect the adoption of annual and daily $PM_{2.5}$ standards and an annual PM_{10} standard.[17] The Victorian annual PM_{10} standard was set to a much more stringent level than the national standard. The amendment also included a future tightening of the particle standards in 2025.

Some regulations relevant to this chapter have been revised, or are in the process of being revised, including the:

- Environment Protection (Vehicle Emissions) Regulations
- *State Environment Protection Policy (Control of Noise from Commerce, Industry and Trade) No. N-1*
- *State Environment Protection Policy (Control of Music Noise from Public Premises) No. N-2*
- Environment Protection (Residential Noise) Regulations 2008.[18,19,20]

Other noise policies related to the material presented in indicator A:06 (Odour and noise) include the standard for internal noise levels in apartment developments located near noise sources. This standard was introduced in the planning framework in 2017.[21]

VicRoads administers a traffic noise reduction policy that was developed in 2005 sets noise criteria for freeways and aims to limit noise impacts from new or upgraded roads.[22]

In the absence of a coordinated indoor air quality strategy or policy document, there are federal guidance documents relevant to indoor air quality published by the Department of the Environment and Energy, the Australian Building Codes Board, and the Department of Health.[23,24,25]

17 EPA, 'Review of national ambient air quality standards', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/review-of-national-ambient-air-quality-standards Accessed 3 December 2018.
18 EPA, 'Air legislation', Carlton, Victoria https://www.epa.vic.gov.au/about-us/legislation/air-legislation Accessed 3 December 2018.
19 EPA, 'Review of the noise SEPPs', Carlton, Victoria https://www.epa.vic.gov.au/our-work/setting-standards/environmental-standards-reform/noise Accessed 3 December 2018.
20 EPA, 'Review of Residential Noise Regulations', Carlton, Victoria https://www.epa.vic.gov.au/our-work/setting-standards/review-of-residential-noise-regulations Accessed 3 December 2018.
21 DELWP, 'Better Apartments', East Melbourne, Victoria https://www.planning.vic.gov.au/policy-and-strategy/planning-reform/better-apartments Accessed 3 December 2018.
22 VicRoads 2005, 'Traffic Noise Reduction Policy', Melbourne, Victoria https://www.vicroads.vic.gov.au/-/media/files/documents/planning-and-projects/environment/noise/trafficnoisereductionpolicy.ashx?la=en&hash=6C28650833D6FD178B03FC47E5C7B60F Accessed 3 December 2018.

23 Australian Department of the Environment and Energy, 'Indoor air', Canberra, Australia http://www.environment.gov.au/protection/air-quality/indoor-air Accessed 3 December 2018.
24 Australian Building Codes Board 2018, 'Indoor Air Quality Handbook 2018', Canberra, Australia http://www.abcb.gov.au/-/media/Files/Resources/Education-Training/11HandbookIndoorAirQuality2018.pdf Accessed 3 December 2018.
25 Australian Department of Health 2002, 'Healthy Homes - A guide to indoor air quality in the home for buyers, builders and renovators', Canberra, Australia.

Ambient Air Pollutants

Note that:

1. The data for these indicators (A:01 to A:04) has been sourced from EPA Victoria's air-monitoring database (MONSYS).
2. The data included in these indicators does not contain all of EPA Victoria's air-monitoring stations. However, stations have been selected for inclusion in this report based on their length of operation (so as to provide a trend), proximity to populated areas and frequency of peak results.
3. Data for Geelong comes from two sites (Geelong #1 from 1991 to 1996, and Geelong South from 1998 to 2017).
4. Data for Melbourne City comes from four sites (Science Museum from 1981 to 1986, Parliament from 1992 to 1995, RMIT from 1996 to 2006, and Richmond from 2007 to 2014).
5. The data included in these indicators is only taken from monitoring equipment that meets current or historical reference criteria for assessment against the legislated air-quality standards in Australia and Victoria (For example, $PM_{2.5}$ data includes only data measured by a Partisol or Beta Attenuation Monitor.)
6. Air-quality standards used in the assessment of these indicators come from the *State Environment Protection Policy (Ambient Air Quality)*.[26]

26 EPA, 'State Environment Protection Policy (Ambient Air Quality)', Carlton, Victoria https://www.epa.vic.gov.au/about-us/legislation/~/media/Files/About%20us/Legislation/Air/160726consolidatedvariedSEPPAAQ.pdf Accessed 3 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:01 Ambient ozone levels (summer smog)						DATA QUALITY Good
Data custodian EPA Victoria						

Ozone is the primary pollutant in summer smog, which forms around large cities on sunny days with light winds.[27,28] Ozone is formed when reactions between hydrocarbons and oxides of nitrogen take place during intense sunlight. Ozone can increase respiratory problems and most strongly affects the elderly and those with lung disease.[29]

The frequency and magnitude of peak ambient ozone concentrations have reduced in Victoria since the early 1980s (Figure A.3 and Figure A.4). The rate of air-quality improvement has slowed considerably since the turn of the century, although very few summer smog days have been recorded in Melbourne this century, with all Victorian stations recording 10 or fewer days exceeding the four-hour average ozone standard this century. The few days exceeding ozone standards in recent years have generally been due to smoke from bushfires, as occurred during the 2002 to 2003 and 2006 to 2007 summer bushfire seasons.[30]

There are two air-quality standards for ozone in Victoria, and the data selected for this indicator is based on the four-hour average standard, which is the standard exceeded most frequently in Victoria.[31]

The main sources of pollutants leading to the formation of ozone are motor vehicle and industrial emissions, as well as domestic activities such as solvent use or the operation of gardening equipment with small engines.[32] Despite maintaining reduced ozone pollution during recent years, if emissions are not kept in check, climate change is predicted to cause significant increases in summer smog, particularly beyond 2030.[33] These increases would occur because the formation of ozone would be enhanced by more frequent periods of warm, sunny conditions in summer. An increase in inner-city ozone is also expected in Melbourne.[34] A projected increase in the frequency and severity of bushfires is also likely to increase peak ozone levels.

Monitoring in major towns such as Ballarat,[35] Bendigo,[36] Geelong,[37] Mildura,[38] Shepparton,[39] Traralgon[40] and Warrnambool[41] has shown that, apart from smoke impacts during intense bushfires, ozone concentrations do not exceed air-quality standards. This situation is likely to continue.

27 EPA, 'Ozone in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/ozone-in-air Accessed 3 December 2018.
28 EPA 2007, 'Summer Smog in Victoria', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1188.pdf Accessed 3 December 2018.
29 EPA, 'Ozone in air', Carlton, Victoria, https://www.epa.vic.gov.au/your-environment/air/air-pollution/ozone-in-air Accessed 3 December 2018.
30 EPA 2018, 'Air monitoring report 2017 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton Victoria, https://www.epa.vic.gov.au/~/media/Publications/1703.pdf Accessed 3 December 2018.
31 Ibid.
32 EPA, 'Ozone in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/ozone-in-air Accessed 3 December 2018.
33 EPA 2013, 'Future Air Quality in Victoria: Final Report, 2013', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1535.pdf Accessed 3 December 2018.
34 Ibid
35 Environment Protection Authority Victoria 2007, 'Air monitoring at Ballarat August 2005 to August 2006', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1111.pdf.
36 Environment Protection Authority Victoria 2006, 'Air monitoring at Bendigo, May 2004 to July 2005', Carlton, Victoria
37 EPA 2018, 'Air monitoring report 2017 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton Victoria, https://www.epa.vic.gov.au/~/media/Publications/1703.pdf Accessed 3 December 2018.
38 Environment Protection Authority Victoria 2008, 'Airborne particle monitoring at Mildura, December 2004 to June 2006', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1201.pdf Accessed 3 December 2018.
39 Environment Protection Authority Victoria 2005, 'Airborne particle monitoring at Shepparton, December 2003 to December 2004', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/992.pdf Accessed 3 December 2018.
40 Environment Protection Authority Victoria 2017, 'Air monitoring report 2016 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1663.pdf Accessed 3 December 2018.
41 Environment Protection Authority Victoria 2008, 'Air monitoring at Warrnambool, October 2006 to October 2007', Carlton, Victoria.

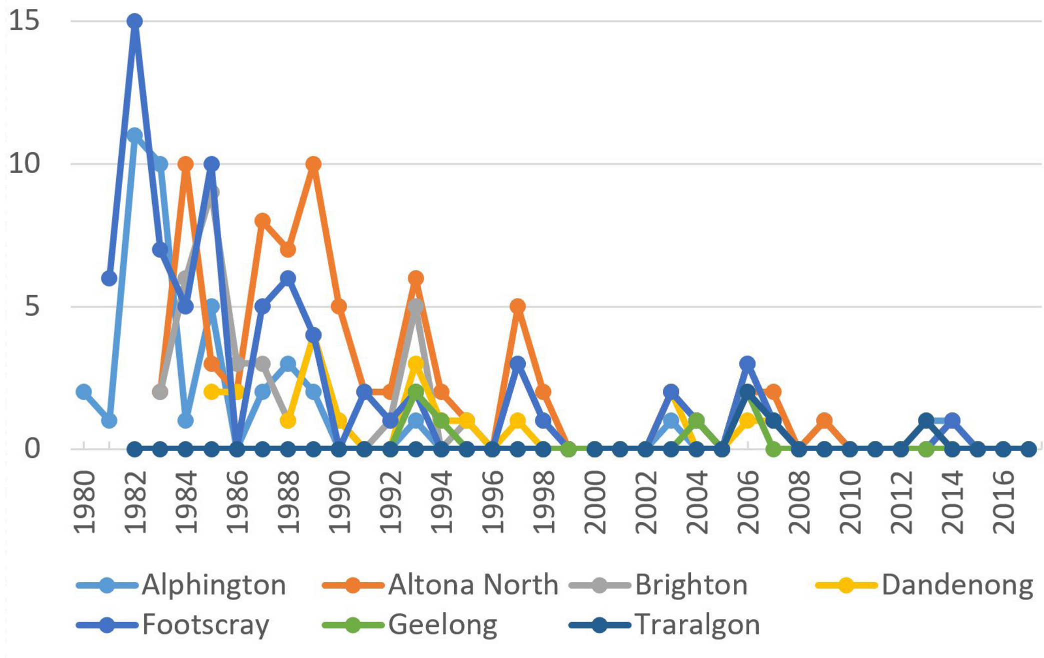

Figure A.3 Number of days exceeding the ozone (4-hour average) standard at monitored sites in Victoria, 1980–2017

(Data source: EPA Victoria, 2018)

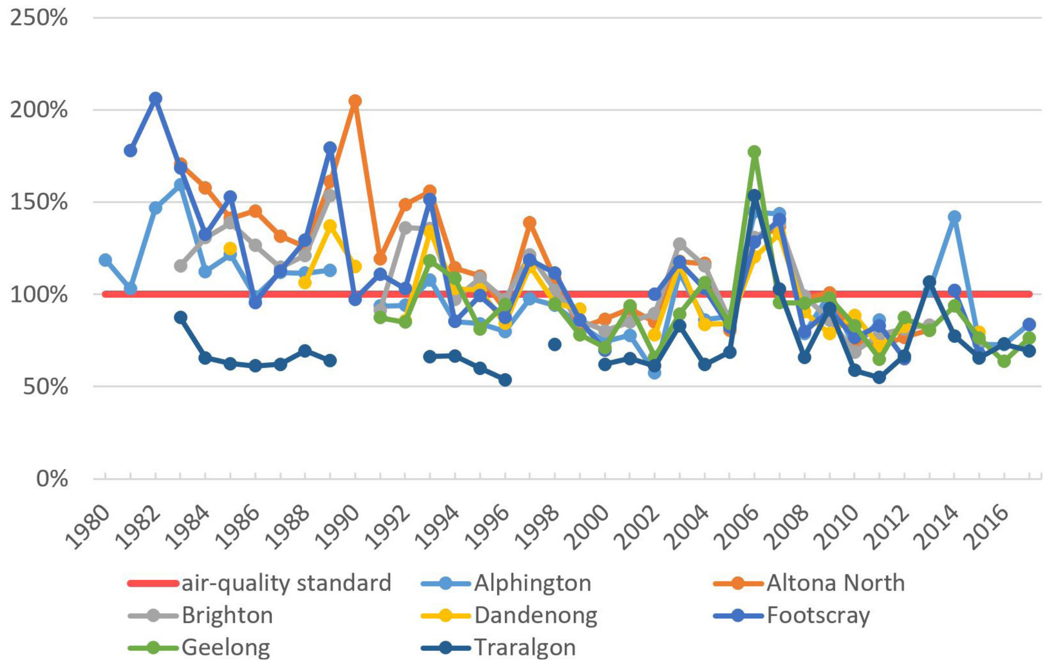

Figure A.4 Annual maximum ozone (4-hour average) concentrations at monitored sites in Victoria, 1980–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
A:02 Carbon monoxide and nitrogen dioxide Data custodian EPA Victoria	GOOD	↗	DATA QUALITY Good

Exposure to elevated concentrations of carbon monoxide in the air can cause tissue damage in humans and animals. People with cardiovascular disease are particularly at risk.[42]

Increased concentrations of nitrogen dioxide can affect the throat and lungs. Those most at risk from nitrogen dioxide pollution are people with respiratory problems, particularly infants, children and the elderly.[43]

Carbon monoxide and nitrogen dioxide concentrations are closely linked to motor vehicle emissions. Large industrial facilities also emit these pollutants, but industrial emissions are often treated before release from tall stacks, so rarely impact significantly on ground-level concentrations in populated areas.

Both carbon monoxide and nitrogen dioxide concentrations are expected to gradually reduce in-line with forecast improvements in vehicle and fuel technology, and with the potential significant increase in the proportion of motor vehicles that are electric.

Carbon Monoxide

Carbon monoxide concentrations have dramatically reduced in Victoria since the early 1980s, with a steady reduction in peak levels still recorded to the end of 2017 (Figure A.5). A notable exception to this was the spike in carbon monoxide recorded in the southern area of Morwell during the Hazelwood mine fire in February 2014. Measurements showed the carbon monoxide standard was exceeded for three days during the fire, but it is likely that the standards were also exceeded at the start of the fire, before air monitoring commenced. The last time EPA Victoria recorded similiar levels of carbon monoxide in populated areas was more than 25 years ago, when motor vehicle carbon monoxide emissions were much higher.

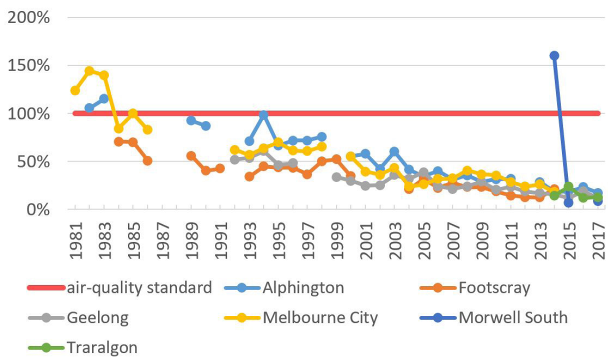

Figure A.5 Annual maximum carbon monoxide (8-hour average) concentrations in Victoria, 1981–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

42 Environment Protection Authority Victoria 'Carbon monoxide in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/carbon-monoxide-in-air Accessed 3 December 2018.
43 Environment Protection Authority Victoria 'Nitrogen dioxide in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/nitrogen-dioxide-in-air Accessed 3 December 2018.

Nitrogen Dioxide

There are two air-quality standards for nitrogen dioxide in Victoria. One standard is based on hourly average data, the other for annual average data. The hourly average standard has not been exceeded in Victoria since autumn 1991, when it was exceeded at Footscray on a day when an accumulation of motor vehicle emissions during calm weather was the likely cause of pollution (Figure A.6). The annual standard has never been exceeded (Figure A.7). Peak nitrogen dioxide (based on hourly average data) decreased significantly in Melbourne during the late 1980s and early 1990s: despite more vehicles, changing technology has meant fewer emissions per vehicle. The trend has continued this century, albeit at a much slower rate.[44] After a slight reduction in annual average concentrations for nitrogen dioxide during the first 10 years since monitoring began, there has been no noticeable trend during the past decade.

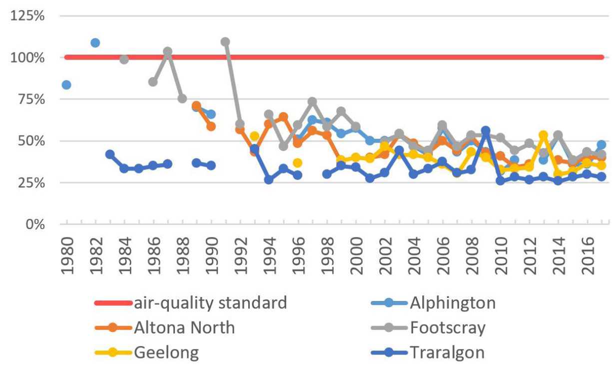

Figure A.6 Annual maximum nitrogen dioxide (1-hour average) concentrations in Victoria, 1980–2017

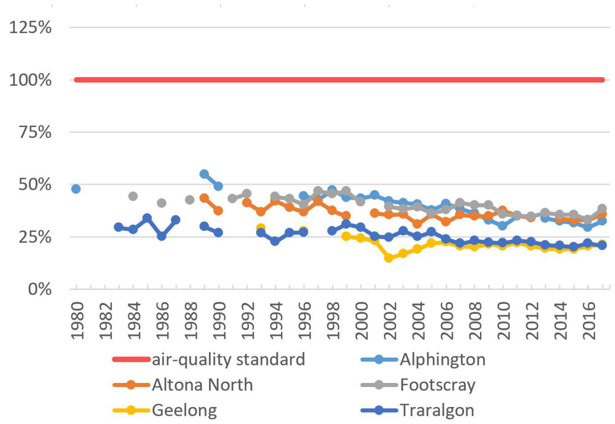

Figure A.7 Annual average nitrogen dioxide concentrations in Victoria, 1980–2017

Note: A.6 and A.7 Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

44 Commissioner for Environmental Sustainability 2013, 'State of the Environment report 2013', Melbourne, Victoria https://www.ces.vic.gov.au/sites/default/files/publication-documents/2013%20SoE%20report%20full.pdf Accessed 3 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:03 Particle pollution (PM_{10} and $PM_{2.5}$)	Elsewhere in Victoria	Brooklyn	Geelong, the Latrobe Valley and most of Melbourne		→	DATA QUALITY Fair
Data custodian EPA Victoria						

Two main particle pollutants are measured in Victoria: $PM_{2.5}$ (particles less than 2.5 micrometres in diameter) and PM_{10} (particles less than 10 micrometres in diameter). Monitoring technology to measure $PM_{2.5}$ has not been available for as long as the instruments that measure PM_{10}, so the $PM_{2.5}$ dataset is shorter and, until recently, quite limited in spatial coverage.

Greater concentrations of $PM_{2.5}$ and PM_{10} particles in the air can cause wheezing, chest tightness and difficulty breathing for people with existing heart or lung conditions (including asthma).[45,46] $PM_{2.5}$ particles are smaller than PM_{10} and can be breathed deeper into the lungs. Children and people over 65, and those with existing heart or lung conditions (including asthma), are more sensitive to the effects of breathing in smaller particles.[47]

The air-quality standards for particle pollution are exceeded more frequently than for other pollutants. Despite this, Victoria's particle pollution is reasonably low by global standards.[48] Particle pollution sources in Victoria include:

- smoke from bushfires, planned burns, industrial fires and domestic wood-heating
- windblown dust during dry and windy conditions
- exhaust emissions from motor vehicles
- road dust from vehicles travelling on unsealed roads
- industrial facilities
- small particles formed in the air by chemical reactions between other pollutants.

45 EPA, 'PM10 particles in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/pm10-particles-in-air Accessed 3 December 2018.
46 EPA, 'PM2.5 particles in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/pm25-particles-in-air Accessed 3 December 2018.
47 Ibid.
48 World Health Organization, 'WHO Global Urban Ambient Air Pollution Database (update 2016)', Geneva, Switzerland http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/ Accessed 3 December 2018.

Smoke from large bushfires has resulted in the most widespread particle pollution impacts across Victoria, with smoke from large fires capable of travelling across vast parts of Victoria. This happened in February 2014, when smoke from a large bushfire in the far east of the state blew over Bass Strait and resulted in poor air quality in Melbourne for four consecutive days. The smoke plume from this fire is visible in Figure A.8.

Other events, such as the 2014 Hazelwood mine fire, have caused more severe impacts for nearby populations, while PM_{10} pollution remains an issue in Brooklyn in Melbourne's inner west, and is associated with dust emissions generated by industry and vehicles.

Smoke from domestic wood heaters also contributes to particle pollution in the cooler months. It is estimated that Victoria has nearly 150,000 wood heaters.[49]

As recommended by VAGO, a more comprehensive air-monitoring network for Victoria that better aligns coverage with pollution risks is required. This would enable a better understanding of the magnitude of particle pollution affected by wood smoke and dust (especially in regional areas), as well as improving knowledge of the impacts associated with motor vehicle exhaust emissions near major urban roads.

49 EPA 2017, 'Variation to the Waste Management Policy (Solid Fuel Heating) policy impact assessment', Carlton, Victoria.

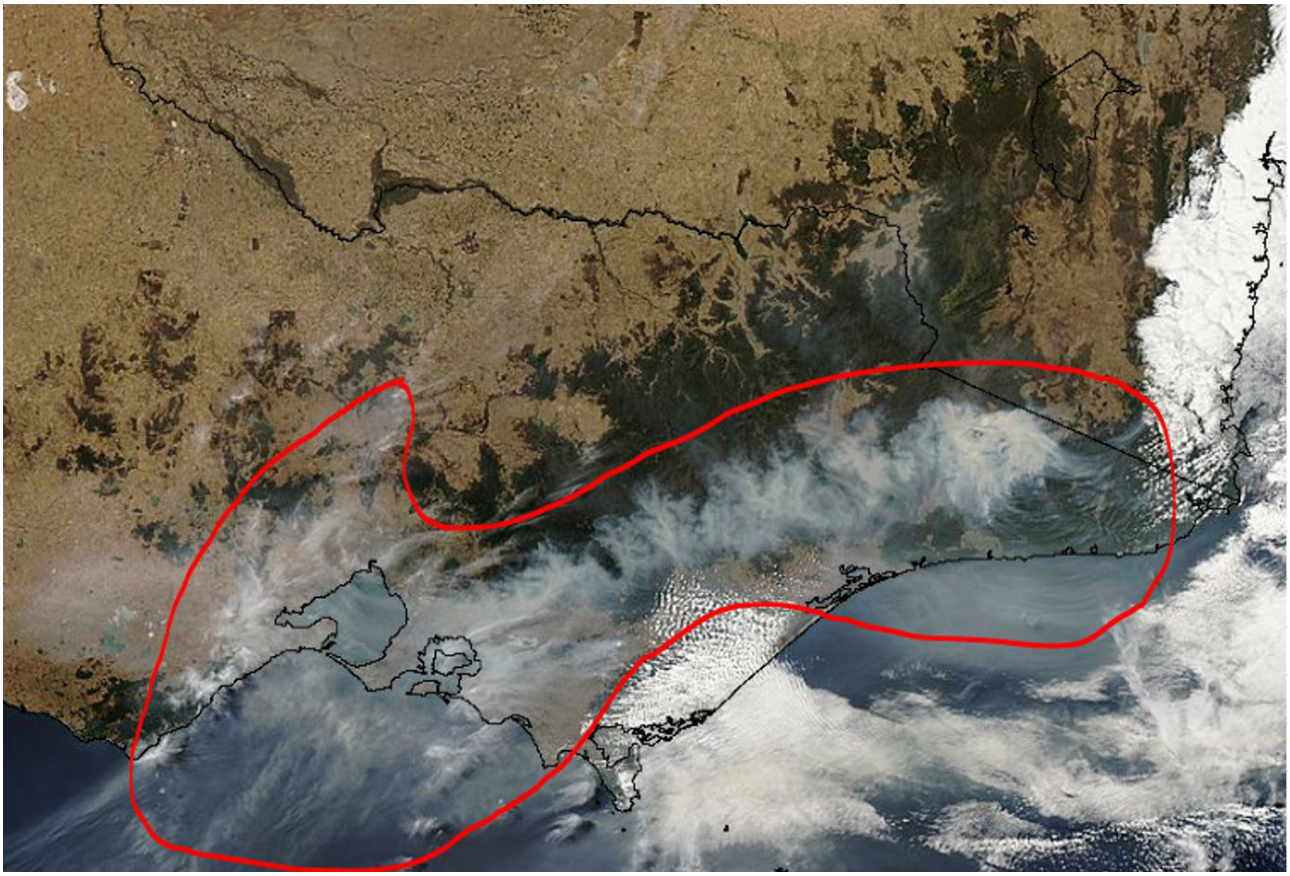

Figure A.8 NASA satellite image, 11 February 2014[50]

Note: Red shows the extent of smoke plume from a fire that started in the far east.

Ultrafine particles (particles less than 1 micrometre in diameter) are smaller than $PM_{2.5}$ and PM_{10}, and can therefore penetrate further into the lungs.[51] Ultrafine particles are difficult to measure and are not included in national or state ambient air quality standards. Therefore, no ultrafine particle data is available for this report. A small number of studies have investigated the health effects of ultrafine particles and found some evidence of an association between ultrafine particles and cardiovascular health effects, although more research is needed to determine the nature of this association.[52]

50 United States National Aeronautics and Space Administration, 'Australia6 Subset – Aqua 1km True Color 2014/042', https://lance-modis.eosdis.nasa.gov/imagery/subsets/?subset=Australia6.2014042.aqua.1km Accessed 3 December 2018.

51 EPA 2018, 'Air pollution in Victoria – a summary of the state of knowledge', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1709.pdf Accessed 3 December 2018.

$PM_{2.5}$

$PM_{2.5}$ trend data in Victoria is only available from 2003, with data up to 2013 confined to Alphington and Footscray in Melbourne, other than for a few short-term monitoring projects. Alphington and Footscray were selected as initial monitoring locations as they are long-term trend stations in Melbourne for other pollutants and are in populated areas near $PM_{2.5}$ pollution sources (industrial and wood-heating). $PM_{2.5}$ monitoring has increased, particularly in Melbourne and the Latrobe Valley since the 2014 Hazelwood mine fire.

The frequency of days exceeding the $PM_{2.5}$ air-quality standard has been relatively stable since 2003: fewer than four days typically exceed the standard each year (Figure A.9). Years with major fires are exceptions – for example, the summer of 2006 to 2007 (Alpine fires) and 2014 (the Hazelwood mine fire and a large East Gippsland fire).[53,54,55]

Poor air quality has also been recorded during cool, calm and stable atmospheric conditions when particles from a wide variety of sources (including smoke from planned burns and wood heaters) accumulate over populated areas. Notably, in 2017, a record number of days exceeded the $PM_{2.5}$ air-quality standard at Alphington.[56] The magnitude of the peak $PM_{2.5}$ concentrations recorded at Morwell South air-monitoring station during the 2014 Hazelwood mine fire were unprecedented in Victoria, with peak levels recorded at nearly 17 times the air-quality standard (Figure A.10).

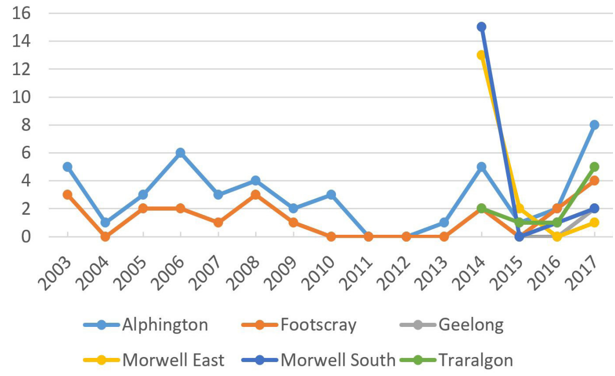

Figure A.9 Number of days exceeding the $PM_{2.5}$ (daily average) standard in Victoria, 2003–2017

(Data source: EPA Victoria, 2018)

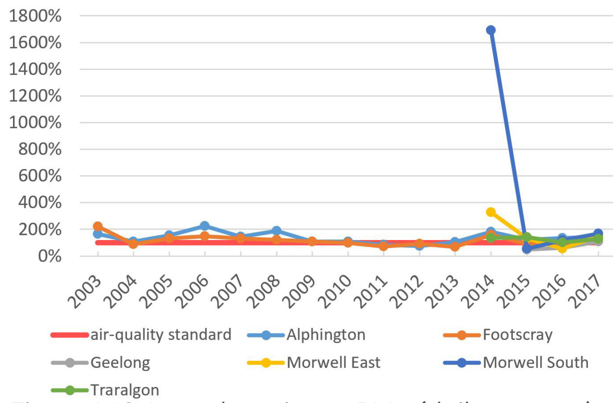

Figure A.10 Annual maximum $PM_{2.5}$ (daily average) concentrations in Victoria, 2003–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

The annual average $PM_{2.5}$ air-quality standard is currently 8 µg/m³(micrograms per cubic metre), although this will tighten in Victoria to 7 µg/m³ by 2025.[57] The current annual average $PM_{2.5}$ standard has been met for every year of monitoring in Footscray, but has been exceeded nearly half the time at Alphington (Figure A.11). It is likely that Alphington records slightly greater levels of $PM_{2.5}$ pollution than Footscray due to greater urban emissions (including from wood heaters) in Alphington and surrounding suburbs. The annual standard has been achieved in each

52 Ibid.
53 EPA 2007, 'Air monitoring report 2006 – Compliance with the National Environment Protection (Ambient Air) Measure', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1137.pdf Accessed 3 December 2018.
54 EPA 2008, 'Air monitoring report 2007 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1231.pdf Accessed 3 December 2018.
55 EPA 2015, 'Air monitoring report 2014 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1604.pdf Accessed 3 December 2018.
56 EPA 2018, 'Air monitoring report 2017 – Compliance with the National Environment Protection (Ambient Air Quality) Measure', Carlton Victoria https://www.epa.vic.gov.au/~/media/Publications/1703.pdf Accessed 3 December 2018.

57 EPA, 'State Environment Protection Policy (Ambient Air Quality)', Carlton, Victoria https://www.epa.vic.gov.au/about-us/legislation/~/media/Files/About%20us/Legislation/Air/160726consolidatedvariedSEPPAAQ.pdf Accessed 3 December 2018.

year of monitoring in the Latrobe Valley since 2014, except for Morwell South and Morwell East in 2014 (associated with smoke impacts from the Hazelwood mine fire) and Traralgon in 2017. It is likely that areas of regional Victoria that most frequently use wood heaters and are impacted by smoke from planned burns will have greater $PM_{2.5}$ concentrations. However, due to the limitations associated with the extent of the current monitoring network, these assumptions cannot be verified.

The closure of the Hazelwood mine and power station in March 2017 does not appear to have significantly changed $PM_{2.5}$ levels in the region, with the annual $PM_{2.5}$ average at the Morwell South air-monitoring station, adjacent to the former mine and power station site, dropping by just 3% from 2016 to 2017. A full, detailed analysis - accounting for variations in bushfire, planned burns and wood smoke - is required to determine the exact impact of the mine and power station closure on $PM_{2.5}$ levels. The results presented here suggest the closure has not significantly improved $PM_{2.5}$ levels.

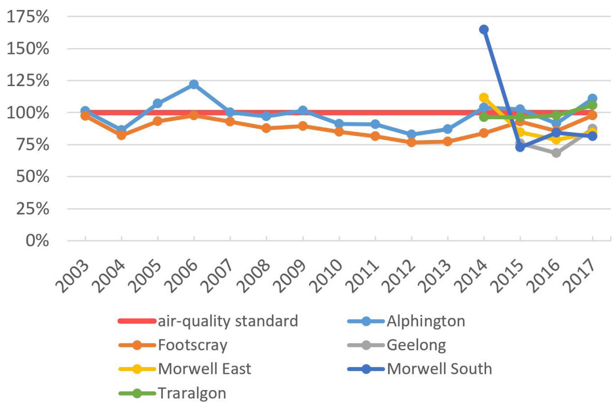

Figure A.11 Annual average $PM_{2.5}$ concentrations in Victoria, 2003–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

PM_{10}

The pattern of days exceeding the PM_{10} standard has traditionally aligned with that for $PM_{2.5}$, although more days generally exceed the PM_{10} standard. This pattern has changed over the past few years, particularly in 2017 when there were widespread $PM_{2.5}$ impacts and no days exceeding the PM_{10} standard, except at dust hotspots in Brooklyn and, to a lesser extent, Geelong (Figure A.12). Peak PM_{10} readings are associated with major fires (which occurred, for example, in 2003) or windblown dust events (which occurred, for example, in Geelong in 2015) (Figure A.13).

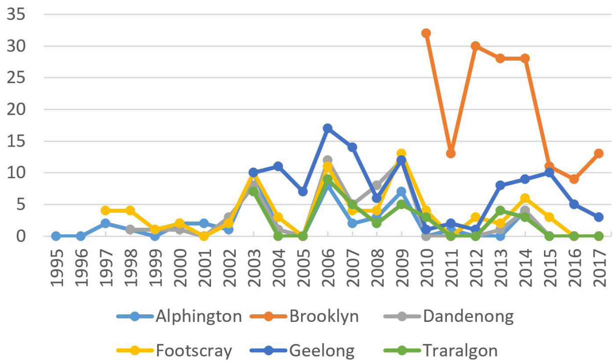

Figure A.12 Number of days exceeding the PM_{10} (daily average) standard in Victoria, 1995–2017

(Data source: EPA Victoria, 2018)

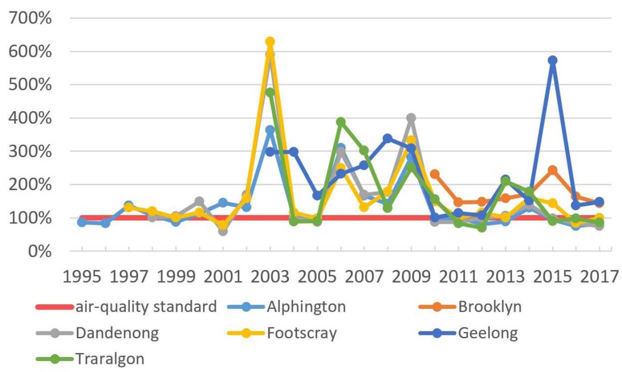

Figure A.13 Annual maximum PM_{10} (daily average) concentrations in Victoria, 1995–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

Due to PM_{10} impacts, Brooklyn is still Victoria's biggest air-pollution hotspot in terms of the number of days exceeding air-quality standards. The impacts in Brooklyn are linked to the large industrial precinct that sits immediately to the north of its residential area. Unsealed roads frequently used by heavy vehicles were sealed during 2015, resulting in a significant improvement in local air quality,[58] although more improvements are required to bring the suburb's air quality in-line with neighbouring suburbs such as Footscray.

An annual average PM_{10} standard was adopted in Victoria in 2016; previously, there had been no annual average PM_{10} standard at state or national level.[59] The Victorian annual PM_{10} standard of 20 µg/m³ is significantly more stringent than the national standard of 25 µg/m³. Annual average PM_{10} concentrations have been trending slightly down across Victorian this decade (Figure A.14), with 2014 the only year when monitoring sites exceeded the PM_{10} annual standard since 2009 (except for Brooklyn). The higher annual average PM_{10} readings from 2000 to 2009 may be due to drier conditions associated with the millennium drought. To demonstrate the recent improvement in annual PM_{10} concentrations, the current annual standard of 20 µg/m³ has only been exceeded at Footscray once from 2010 to 2017, compared with eight times in the period 1997 to 2009.

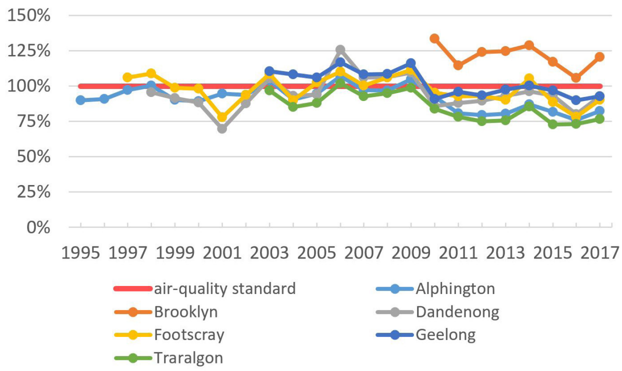

Figure A.14 Annual average PM_{10} concentrations in Victoria, 1995–2017

Note: Concentrations are shown as a percentage of the air-quality standard.

(Data source: EPA Victoria, 2018)

58 EPA 2016, 'Brooklyn air quality update: effectiveness of road sealing', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1627.pdf Accessed 3 December 2018.

59 EPA, 'Review of national ambient air quality standards', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/review-of-national-ambient-air-quality-standards Accessed 3 December 2018.

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
A:04 Sulfur dioxide Data custodian EPA Victoria	GOOD	→	DATA QUALITY Good

Prolonged exposure to sulfur dioxide can lead to increases in respiratory illnesses such as chronic bronchitis. The effect of sulfur dioxide on health is increased by the presence of airborne particles.[60] Acute effects can also occur, particularly irritation of the upper respiratory tract and the eyes, with asthmatics most sensitive to these effects.[61]

Power stations are the main driver of peak sulfur dioxide concentrations in Victoria. Ships that travel near the coast and dock at Victoria's ports are a secondary source. There have been no significant trends in sulfur dioxide concentrations in Victoria since the 1980s, with levels remaining well below the three air-quality standards legislated in this state (Figure A.15 to Figure A.17).[62] Victoria's peak sulfur dioxide levels are measured near major industrial facilities in Altona North and Traralgon.

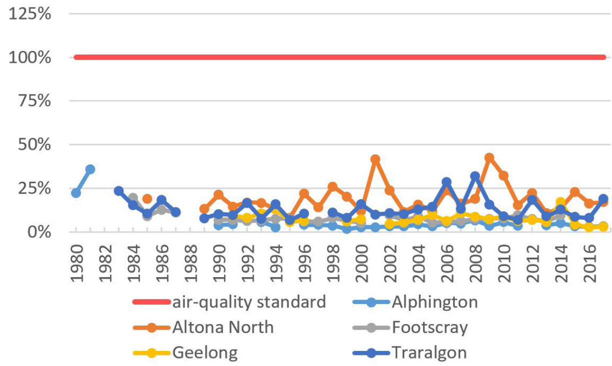

Figure A.16 Annual maximum sulfur dioxide (daily average) concentrations in Victoria, 1980–2017

(Data source: EPA Victoria, 2018)

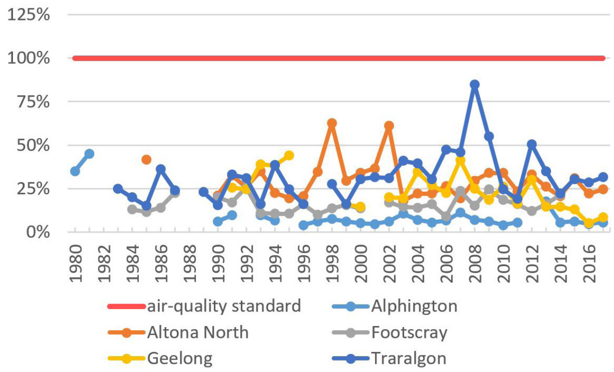

Figure A.15 Annual maximum sulfur dioxide (hourly average) concentrations in Victoria, 1980–2017

(Data source: EPA Victoria, 2018)

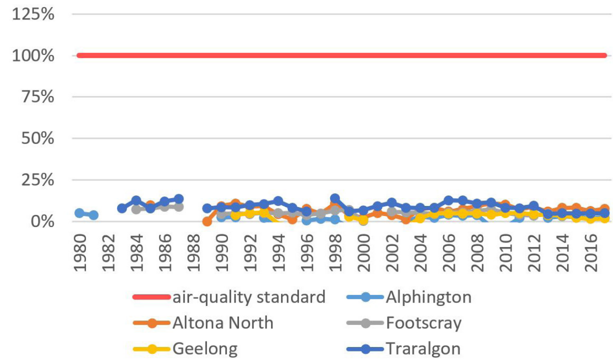

Figure A.17 Annual average sulfur dioxide concentrations in Victoria, 1980–2017

(Data source: EPA Victoria, 2018)

Note: Concentrations are shown as a percentage of the air-quality standard.

60 EPA Victoria, 'Sulfur dioxide in air', Carlton, Victoria https://www.epa.vic.gov.au/your-environment/air/air-pollution/sulfur-dioxide-in-air Accessed 3 December 2018.

61 United States National Research Council 2010, 'Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 8', National Academies Press (US), Washington, DC https://www.ncbi.nlm.nih.gov/books/NBK219999/ Accessed 3 December 2018.

62 EPA, 'State Environment Protection Policy (Ambient Air Quality)', Carlton, Victoria https://www.epa.vic.gov.au/about-us/legislation/~/media/Files/About%20us/Legislation/Air/160726consolidatedvariedSEPPAAQ.pdf Accessed 3 December 2018.

The closure of the Hazelwood mine and power station in March 2017 does not appear to have significantly changed sulfur dioxide levels in the region, however this assessment is only based on the nine months of data available since the closure and it would be ideal to do the comparison with at least 12 months of data to cover a full range of weather patterns. Annual average sulfur dioxide concentrations at Morwell South, adjacent to the former mine and power station site, were stable at 0.6 parts per billion (ppb) in 2015, 2016 and 2017, with similarly stable readings of between 0.9 and 1.0 ppb recorded at Traralgon. Morwell East's annual average sulfur dioxide concentrations decreased to 0.5 in 2017 relative to the two preceding years when the average was 0.7 ppb. Combining air quality results with modelling is required to determine the exact impact of the power station closure. However, this analysis suggests the power station closure has not significantly improved annual average sulfur dioxide levels in the region – although it may have contributed to a minor improvement in Morwell East.

Stratospheric Air Pollutants

Indicator	Status (UNKNOWN / POOR / FAIR / GOOD)	Trend	Data Quality
A:05 Stratospheric ozone Data custodian DEE, BoM	FAIR	→	DATA QUALITY Good

Stratospheric ozone impacts on ultraviolet radiation (UV). Less stratospheric ozone means more UV reaches the earth's surface. January is generally the month of greatest impact in Victoria: more people are on holidays and outside in the sun, and UV levels are greatest. Figure A.18 shows Melbourne's average UV levels in January since 1980. Measurement of the long-term trend includes satellite-based observations of UV levels without the impact of clouds. By contrast, recent ground-based measurements include the effect of clouds, which is why those UV levels are shown to be lower and more variable. Melbourne's UV levels have generally been stable since the 1980s, with a slight increase during the final two decades of the 20th century.

The long-term changes in stratospheric ozone due to ozone-depleting substances over a mid-latitude location such as Victoria are small compared to natural variations. Stratospheric ozone is currently measured as total column ozone (the total amount of ozone in a column from the surface to the edge of the atmosphere) and this is done by satellite and ground-based measurements. There is significant variability in ozone levels from year to year, largely due to changes in cloud cover. Overall, there was a clear decreasing trend in ozone during the 1980s and 1990s, followed by an increase this century (Figure A.19).

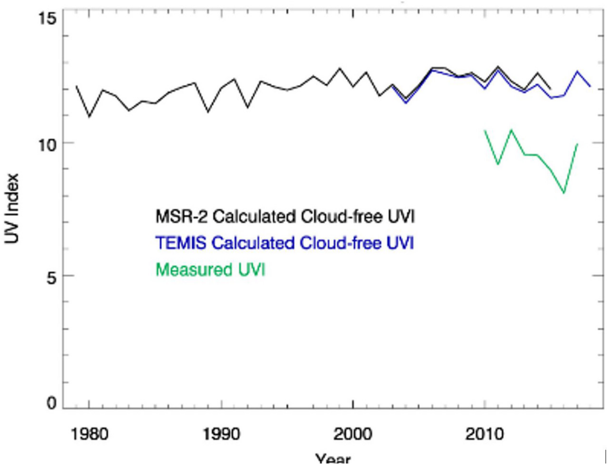

Figure A.18 Average UV index for Melbourne, 1979–2017

(Data source: BoM, 2018)

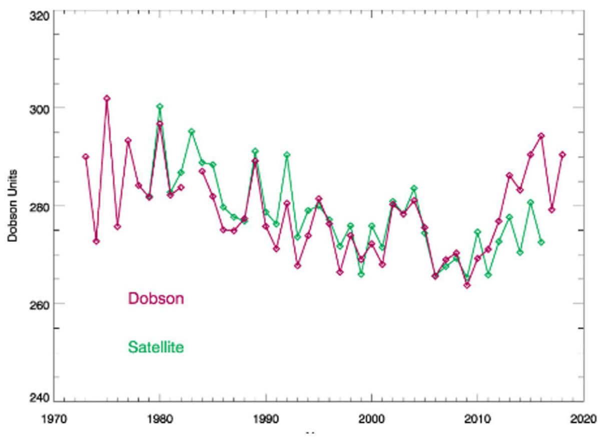

Figure A.19 Average total column ozone for Melbourne, 1973–2018

Note: A Dobson Unit is the number of molecules of ozone that would be required to create a layer of pure ozone 0.01 mm thick at 0°C and a pressure of 1 atmosphere.[63]

(Data source: BoM, 2018)

63 United States National Aeronautics and Space Administration, 'What is a Dobson Unit?', https://ozonewatch.gsfc.nasa.gov/facts/dobson_SH.html Accessed 3 December 2018.

Emission of chemicals such as chlorofluorocarbons (CFCs) into the air leads to the depletion of stratospheric ozone, exposing both marine and terrestrial life to additional harmful amounts of UV radiation. Under the Montreal Protocol, which started in 1989, signatory countries are formally required to control their emissions of ozone-depleting substances to protect the ozone layer. The protocol achieved global participation in 2009, and has been effective, particularly over Antarctica and polar regions. However, recent research has found the ozone layer recovery has not been as pronounced outside the polar regions (between 60°S and 60°N).[64]

Global emissions of ozone-depleting substances included in the Montreal Protocol peaked at 1.46M tonnes in the late 1980s, then declined at a rate of 10% per year to 314 tonnes in 2014. Australian emissions of ozone-depleting substances, weighted by ozone-depleting potential, also fell by about 13% per year from 1995 to 2005, then remained relatively constant through to 2013.[65]

Australia continues to achieve its committed targets as part of the Montreal Protocol, meeting or exceeding all of its phase-out obligations up until the end of 2016.

64 Ball et al 2018, 'Evidence for a continuous decline in lower stratospheric ozone offsetting ozone layer recovery', Atmospheric Chemistry and Physics, 18, pp. 1379–1394.

65 Fraser P, Dunse B, Krummel P, Steele P, Derek N 2014, 'Australian and Global Emissions of Ozone Depleting Substances', *Report prepared for Department of the Environment,* CSIRO Marine and Atmospheric Research, Centre for Australian Weather and Climate Research, Aspendale, Australia, pp. 29.

Amenity

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:06 Odour and noise Data Custodian EPA Victoria, local councils	●				↘	DATA QUALITY Fair

Impacts from odour and noise are a significant issue in Victoria, both in terms of amenity and complaints to regulators, while excessive exposure to noise can impact human health. Data for this indicator is limited to pollution reports received by EPA Victoria. Local councils and Victoria Police also receive a significant number of amenity reports. However, variation in recording of pollution report data by Victoria's 79 councils and the police dataset makes its use alongside the EPA Victoria data unfeasible.

Those who notify EPA Victoria of pollution may allege a source (such as a person or a business). Forty-six per cent of all odour and noise pollution reports in EPA Victoria's database have an alleged source.

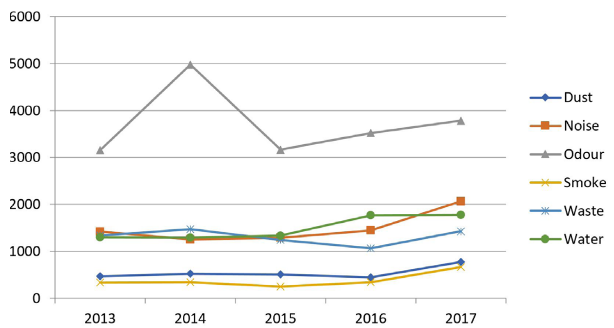

Figure A.20 Pollution reports received by EPA Victoria, 2013–17

(Data source: EPA Victoria, 2018)

Odour is the type of pollution most frequently reported to EPA Victoria. The regulator received more than twice as many complaints about odour from 2013 to 2017 (Figure A.20) than about noise, the next most-frequent source of complaints in that period. In EPA Victoria's pollution report database, a single pollution event can be duplicated if more than one reporter makes a report.

The location of pollution reports is heavily weighted towards populated areas: areas with more people are, on balance, more likely to have more pollution reports. Because of this, pollution reports are displayed as the total number of reports for each local government area (LGA) and the per capita reports for each LGA in Tables A.1 and A.2. Table A.1 shows the top five LGAs for pollution reports on a per capita basis, and Table A.2 shows the top five LGAs for pollution reports in total. There are some associations between per capita pollution reporting hotspots (from the 2013 to 2017 pollution report data) and socio-economic disadvantage. Victorians living in more affluent areas are generally reporting more impacts from noise, while Victorians in less affluent areas are reporting disproportionately more impacts from odour. This analysis of linking pollution report and socio-economic disadvantage data should be treated as indicative. Future reporting could expand on this analysis and formalise a methodology for evaluating environmental justice.

Table A.1 Top five LGAs for odour and noise pollution reports (ranked per capita) received by EPA Victoria, 2013–2017

LGA	Odour reports 2013–2017	Rank (per capita)
Hobsons Bay	1,791	1
Central Goldfields	247	2
Moyne	304	3
Kingston	2,550	4
Hepburn	256	5

LGA	Noise reports 2013–2017	Rank (per capita)
Hepburn	315	1
Glenelg	74	2
Banyule	459	3
Warrnambool	126	4
Corangamite	55	5

(Data source: EPA Victoria, 2018)

Table A.2 Top five LGAs for odour and noise pollution reports (ranked bytotal reports) received by EPA Victoria, 2013–17

(Data source: EPA Victoria, 2018)

LGA	Odour reports 2013–2017	Rank
Kingston	2,550	1
Melton	2,082	2
Hobsons Bay	1,791	3
Casey	1,397	4
Brimbank	1,337	5

LGA	Noise reports 2013–2017	Rank
Banyule	459	1
Moreland	424	2
Brimbank	418	3
Whitehorse	413	4
Hume	350	5

Odour

Odour continues to account for most pollution reports received by EPA Victoria. An average of almost 9,000 pollution reports were made to EPA Victoria each year from 2013 to 2017, with 42% of all those reports relating to odour pollution. Landfills and meat renderers dominate the list of the 10 most frequently alleged sources of odour pollution. The location of these facilities is represented by the red dots in the heat map in Figure A.21, which shows the distribution of odour pollution reporting hotspots in the Melbourne metropolitan area.

EPA served six notices to address odours in 2016–17.[66] This number represents only a fraction of odour inspections conducted. However, EPA Victoria has developed a capability to conduct proactive odour surveillance, and can now better understand trends in odour pollution reporting, allowing it to work with its licensed sites to better prevent pollution.[67]

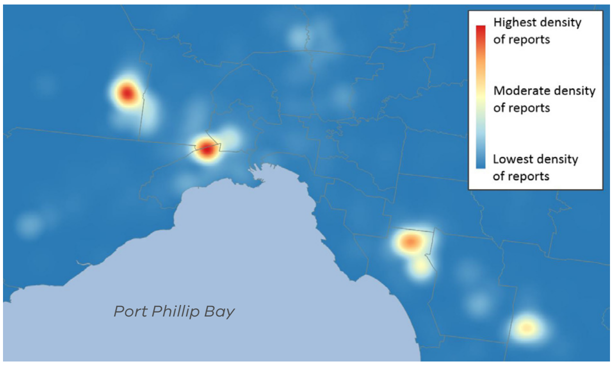

Figure A.21 Odour pollution reporting hotspots in Melbourne, 2013–17

(Data source: EPA Victoria, 2018)

66 EPA 2017, '2016-17 Annual Report', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1665.pdf Accessed 3 December 2018.

67 Marshall A, Bydder C 2017, 'Can you attend the site of a pollution incident before it occurs?', *Journal of the Australian Institute of Professional Intelligence Officers*,. 25(2), pp. 3-17.

Noise

The frequency of noise pollution reporting was fairly stable from 2013 to 2016, with between 1,255 and 1,446 reports received each year by EPA Victoria. Noise pollution reports recorded by EPA Victoria provide good intelligence on noise sources within the scope of regulations and policies for which EPA Victoria is custodian. However, EPA Victoria's noise pollution report data provides limited insight to major issues, such as residential and traffic noise. Future reporting needs to include assessments of noise monitoring and pollution reports from local councils and Victoria Police.

There was a significant spike in noise reports to EPA Victoria in 2017, with 2,066 reports made. Nearly half of this spike was driven by the emergence of localised noise issues near industrial facilities in Heidelberg West, Coolaroo and Blackburn South.

Figure A.22 shows locations of noise pollution reporting 'hotspots' in the Melbourne metropolitan area as red dots on a heat map. Note there are more noise hotspots than for odour (Figure A.21).

EPA conducted noise measurements at 66 locations in 2016–17 in response to noise pollution reports, and consequently issued 11 pollution abatement notices.[68] EPA Victoria's noise monitoring is generally reactive, and it is limited in scope to noise from industrial and commercial premises and music venues.

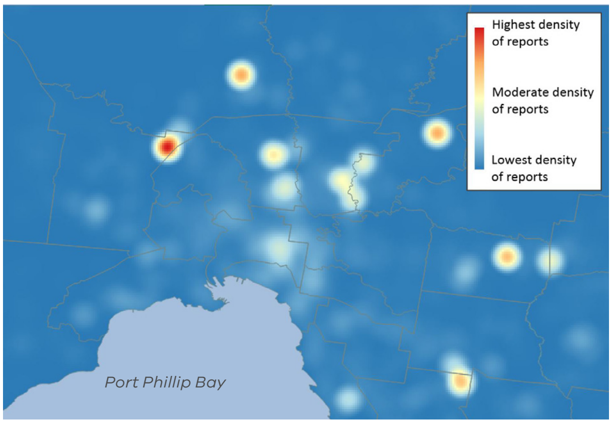

Figure A.22 Noise pollution reporting hotspots in the Melbourne metropolitan area, 2013–17

(Data source: EPA Victoria, 2018)

68 EPA 2017, '2016-17 Annual Report', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1665.pdf Accessed 3 December 2018.

Indicator	Status: UNKNOWN	POOR	FAIR	GOOD	Trend	Data Quality
A:07 Light pollution Data custodian None	●				?	DATA QUALITY Poor

Light pollution is excessive or obtrusive artificial light that has an adverse impact on biodiversity, and potentially human health.[69] It is a global issue, felt at both national and regional scales, and increasing in prevalence as the world becomes increasingly populated and industrialised. Light pollution due to poorly-aimed and unshielded outdoor lights is estimated to waste $US2 billion of energy in the United States each year.[70]

Australia is the sixth least polluted G20 country, according to the measure of population percentage exposed to extremely bright skies.[71] There are no systematic measurements of light pollution conducted in Victoria.

Light pollution also threatens reproduction and migratory habits of insects, amphibians, fish, birds, bats and other animals, while a distortion of the natural day/night cycle can affect plants.[73]

There is little published research about light pollution impacts in Victoria. A study published in 2017 analysed seabird survival patterns on Phillip Island in relation to artificial light. The study found many birds became grounded on roads after being attracted by artificial light. Short-tailed shearwater (*Ardenna tenuirostris*) fledglings captured at colonies just before departure were compared with fledglings washed up on beaches and with fledglings attracted by artificial light along roads.[74] Fledglings collected at the beach were much lighter in weight, and hence had a much lower chance of survival, than fledglings collected at the colony or on the roads. A conclusion of the study was that rescue programs should focus on rescuing birds from roads generally, as these weigh more, and have a higher probability of survival than beach-washed birds. Another piece of Victorian research, also published in 2017, found that artificial lighting reduced bat activity and species richness.[75]

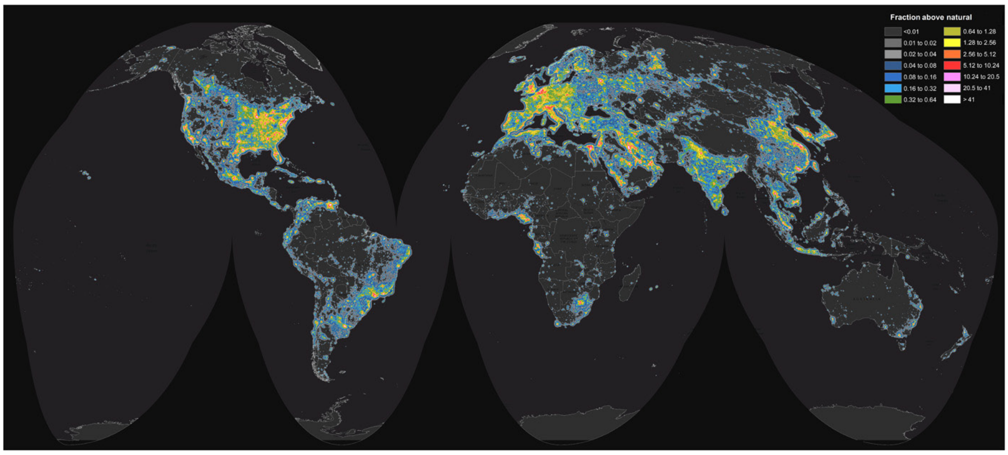

Figure A.23 World map of artificial sky brightness based on data collected in 2014[72]

69 Falchi F, Cinzano P, Duriscoe D, Kyba CCM, Elvidge CD, Baugh K, Portnov BA, Rybnikova NA, Furgoni R 2016, 'The new world atlas of artificial night sky brightness', *Science Advances*, 2(6).
70 United States National Optical Astronomy Observatory, 'Wasted lights and wasted nights: Globe at night tracks light pollution', https://www.noao.edu/news/2011/pr1101.php Accessed 3 December 2018.
71 Falchi F, Cinzano P, Duriscoe D, Kyba CCM, Elvidge CD, Baugh K, Portnov BA, Rybnikova NA, Furgoni R 2016, 'The new world atlas of artificial night sky brightness', *Science Advances*, 2(6).
72 Ibid
73 Hölker F, Wolter C, Perkin EK, Tockner K 2010, 'Light pollution as a biodiversity threat', *Trends in Ecology and Evolution*, 25, pp. 681–682.
74 Rodríguez A, Moffett J, Revoltós A, Wasiak P, McIntosh RR, Sutherland DR, Renwick L, Dann P, Chiaradia A 2017, 'Light pollution and seabird fledglings: Targeting efforts in rescue programs', *Journal of Wildlife Management*, 81, pp. 734–741.
75 Linley G 2017, 'The impact of artificial lighting on bats along native coastal vegetation', *Australian Mammalogy*, 39, pp. 178–184.

Elsewhere in Australia, a study found artificial light in Western Australia was causing some tammar wallabies to delay giving birth. This led to their misalignment with the resource cycle, meaning the wallabies could not sufficiently feed their young.[76] In another Western Australian study, researchers found increased artificial lighting at nesting beaches has the potential to disrupt turtle breeding success, with baby turtles becoming attracted to the artificial light and moving towards the light, rather than the ocean.[77] All species of marine turtles demonstrate similar sea-finding behaviour, so further damage to turtle nesting is likely as coastal development increases, unless lighting is addressed.

Mitigating the effects of light pollution can be achieved using the following measures:

- full shielding of lights
- using the minimum light for the task
- shutting off light or lowering levels substantially when areas are not in use
- decreasing the total installed flux (the amount of light produced)
- strongly limiting the 'blue' light that interferes with the approximate 24-hour cycle in the physiological processes of living beings (including plants and animals) and scotopic vision (the eyes' vision in poorly lit conditions).[78]

76 Robert KA, Lesku JA, Partecke J, Chambers B 2015, 'Artificial light at night desynchronizes strictly seasonal reproduction in a wild mammal', *Proceedings of the Royal Society B: Biological Sciences*, 282(1816).

77 Pendoley K, Kamrowski R 2015, 'Influence of horizon elevation on the sea-finding behaviour of hatchling flatback turtles exposed to artificial light glow', *Marine Ecology Progress Series*, 529, pp. 279-288.

78 Falchi F, Cinzano P, Duriscoe D, Kyba CCM, Elvidge CD, Baugh K, Portnov BA, Rybnikova NA, Furgoni R 2016, 'The new world atlas of artificial night sky brightness', *Science Advances*, 2(6).

Air Pollutants: Sources

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:08 Emissions of major air pollutants by sector Data custodian EPA Victoria			●		?	DATA QUALITY Fair

An understanding of air-pollution sources is a critical input for developing effective air-quality strategies. Determining the contribution of each major air-pollution source enables air-quality issues and initiatives to be prioritised, as well as enhancing the capability to model air-quality concentrations across Victoria.

EPA Victoria is compiling an air-pollution inventory for Victoria for emissions from the year 2016. As at 30 June 2018, EPA Victoria had completed the inventory update for most major emissions sources including motor vehicles, industry and wood heaters. The preliminary results are reported here (Note: these results are still to undergo peer review and may be revised by EPA Victoria at a later date). Key sources not available for inclusion in this report are natural sources such as biogenic emissions (emissions from natural sources such as plants and trees) and windblown dust. Upon completion, the inventory will contain estimations of all the air pollutants emitted in Victoria categorised by source (for example, motor vehicle, industrial, domestic), location (for example, council area, or '1 km by 1 km grid cell') and time. The completion of an air-pollution inventory at a state level requires significant resourcing and has not been completed by EPA Victoria since emissions were estimated for 2006.

The main findings from work completed so far on the 2016 inventory include:

- Motor vehicles contribute most of the carbon monoxide and oxides of nitrogen. As a proportion of total emissions across the state, motor vehicles are estimated to account for about 70% of carbon monoxide and 60% of nitrogen dioxide emissions in 2016.
- Large industry contributes 95% of the sulfur dioxide and significant amounts of oxides of nitrogen. More than 85% of the industrial sulfur dioxide emissions occur in the Latrobe LGA. However, in most cases, these industrial emissions are from tall stacks high above the ground, and therefore have minimal impact at ground level. Shipping also contributes a significant amount of sulfur dioxide emissions.
- Wood heaters and airports are significant $PM_{2.5}$ emission sources.

Bushfires, planned burns and structural fires are also expected to be large sources of $PM_{2.5}$ emissions, although these sources have not yet been quantified for the 2016 inventory.

EPA Victoria has also released an emissions trend report on air quality in Victoria, discussed in SoE 2013.[79] Key findings included:

- Total vehicle exhaust emissions are decreasing because of the introduction of better vehicle exhaust controls. The trend towards improved exhausts is outpacing 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 in 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.
- 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.

79 EPA 2013, 'Future Air Quality in Victoria: Final Report, 2013', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1535.pdf Accessed 3 December 2018.

Health

Indicator	Status	Trend	Data Quality
A:09 Health impacts of air pollution Data custodian None	FAIR (UNKNOWN / POOR / FAIR / GOOD)	?	DATA QUALITY Poor

This indicator looks at major air pollution and health impact studies published in the five years since SoE 2013. The indicator is focused on Victorian studies, but relevant research in other states has also been included.

Understanding of the health impacts associated with air quality continues to improve as researchers analyse the links between human health and air pollution. State and Commonwealth legislation currently define air-quality standards that are designed to adequately protect human health and wellbeing. However, adverse health effects also occur below the current air-quality standards, and any reduction in concentrations of pollutants – even if concentrations are already below the air-quality standards – will result in health benefits.[80,81,82,83]

Poor air quality can harm people's health and quality of life, and has been linked to respiratory and cardiovascular health effects, and premature mortality.[84] Because of this, the concept of continuous improvement is important for air-quality management. Gradual tightening of air-quality standards and reductions in pollutant concentrations and emissions are important markers for progress in reducing the health burden associated with air pollution.

Two major health studies analysing the health effects associated with smoke exposure during the 2006-07 summer were released in 2015 and 2016. The first study used ambulance records and found an association between exposure to forest fire smoke and an increase in the rate of cardiac arrests. This study, believed to be the first of its kind in the world linking ambulance data with bushfire smoke impacts, estimated that 24 to 29 extra out-of-hospital cardiac arrests occurred in Melbourne because the air quality was affected by smoke from the forest fires that summer.[85]

The second study also investigated health impacts associated with smoke exposure from the Victorian alpine bushfires of summer 2006-07, but with a particular focus on asthma. This study found a strong association between exposure to $PM_{2.5}$ from bushfire smoke and emergency department attendances for asthma during the bushfire season of 2006-07 in Victoria.[86]

A larger study is investigating the long-term health effects of the 2014 Hazelwood mine fire. The fire was one of the most significant air-pollution incidents in Victoria's history, due to the amount of smoke generated, the proximity of the fire to the township of Morwell, and its duration (45 days). Work on the 20-year study, funded by the Victorian Government, began in the Latrobe Valley in 2014.[87]

80 National Environment Protection Council, 'National Environment Protection (Ambient Air Quality) Measure', http://www.nepc.gov.au/nepms/ambient-air-quality Accessed 3 December 2018.

81 National Environment Protection Council, 'National Environment Protection (Air Toxics) Measure', http://www.nepc.gov.au/nepms/air-toxics Accessed 3 December 2018.

82 EPA, 'State Environment Protection Policy (Ambient Air Quality)', Carlton, Victoria https://www.epa.vic.gov.au/about-us/legislation/~/media/Files/About%20us/Legislation/Air/160726consolidatedvariedSEPPAAQ.pdf Accessed 3 December 2018.

83 EPA 2018, 'Air pollution in Victoria – a summary of the state of knowledge', Carlton, Victoria https://www.epa.vic.gov.au/~/media/Publications/1709.pdf Accessed 3 December 2018.

84 DELWP 2018, 'Clean Air for All Victorians – Victoria's Air Quality Statement', East Melbourne, Victoria, https://www.environment.vic.gov.au/__data/assets/pdf_file/0025/125719/Clean-Air-Statement.pdf Accessed 3 December 2018.

85 Dennekamp M, Straney LD, Erbas B, Abramson MJ, Keywood M, Smith K, Sim MR, Glass DC, Del Monaco A, Haikerwal A, Tonkin AM 2015, 'Forest fire smoke exposures and out-of-hospital cardiac arrests in Melbourne, Australia: a case-crossover study', *Environmental Health Perspectives*, 123, pp. 959–964.

86 Haikerwal A, Akram M, Sim MR, Meyer M, Abramson MJ, Dennekamp M 2016, 'Fine particulate matter (PM2.5) exposure during a prolonged wildfire period and emergency department visits for asthma', *Respirology*, 21, pp. 88–94.

87 Hazelwood Health Study, 'Hazelinks', https://hazelwoodhealthstudy.org.au/research-areas/hazelinks/ Accessed 3 December 2018.

Various studies are also being undertaken within the overall Latrobe Valley project study. Some initial findings have been published,[88,89,90,91] although these should be considered with caution, as some are based on small sample sizes.

Research elsewhere in Australia has also contributed to understanding the health impacts of air pollution. One study found that a 10% reduction in $PM_{2.5}$ exposure in Sydney would, over a 10 year period, result in approximately 650 fewer deaths – a gain of 3,500 life-years (calculated as the sum of the healthy years gained from avoiding a premature death linked to a pollution-related illness) and about 700 fewer respiratory and cardiovascular hospital visits.[92] These results suggest that small reductions in air pollution in major Australian cities could have substantial health benefits.

As climate change lengthens the fire season in southern Australia, the window for planned burns is likely to be shorter, meaning a more intensive planned-burning period. Planned burns reduce the risks associated with bushfires, but produce large amounts of smoke that can blanket nearby population centres and adversely affect health. Planned burns around Sydney reportedly caused smoky conditions during May 2016, with increased $PM_{2.5}$ concentrations on several days.[93] Poor air quality was recorded for multiple days across Victoria in autumn 2018 associated with smoke from planned burns.[94]

Victoria's responsible agencies now have increased capability and capacity to respond to smoke impacts from fires, with the introduction of a *State Smoke Framework* and improved incident air-monitoring capability, deployed to a variety of fires (bushfires, peat fires, planned burns and industrial fires) in 2016–17 and 2017–18.[95] The increased capability and capacity for incident air-monitoring in relation to significant smoke events is encouraging. However, the smoke impacts from autumn 2018 indicate that more needs to be done to manage planned-burning smoke impacts on Victorians.

88 Hazelwood Health Study 2017, 'Medicare Benefits Schedule and Pharmaceutical Benefits Scheme data: Time Series Analyses', http://hazelwoodhealthstudy.org.au/wp-content/uploads/2018/08/Hazelinks-MBS-PBS-Technical-Report-Version-1.4.pdf Accessed 3 December 2018.

89 Hazelwood Health Study 2018, 'The Latrobe Early Life Follow-up Cohort Study Vol 1', http://hazelwoodhealthstudy.org.au/wp-content/uploads/2017/01/20180201-_-HHS-_-ELF-Volume-1-Research-Summary.pdf Accessed 3 December 2018.

90 Hazelwood Health Study 2017, 'Adult Survey Comparison of Morwell to Sale'

91 Bond J, Dickinson HO, Matthews F, Jagger C, Brayne C 2006, 'Self-rated health status as a predictor of death, functional and cognitive impairment: a longitudinal cohort study', *European Journal of Ageing*, 3, pp. 193-206.

92 Broome RA, Fann N, Cristina TJ, Fulcher C, Duc H, Morgan GG 2015, 'The health benefits of reducing air pollution in Sydney, Australia', *Environmental Research*, 143, pp. 19–25.

93 Broome RA, Johnston FH, Horsley J, Morgan GG 2016, 'A rapid assessment of the impact of hazard reduction burning around Sydney, May 2016', *The Medical Journal of Australia*, 205, pp. 407-408.

94 EPA, 'EPA warns of smoky conditions' , https://www.epa.vic.gov.au/about-us/news-centre/news-and-updates/news/2018/april/30/epa-warns-of-smoky-conditions Accessed 3 December 2018.

95 Emergency Management Victoria, 'A new approach to smoke events', Melbourne, Victoria https://www.emv.vic.gov.au/news/a-new-approach-to-smoke-events Accessed 3 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:10 Health impacts of noise pollution					?	
Data custodian None	Fair for Melbourne and Unknown for the rest of Victoria					DATA QUALITY Poor

This indicator looks at the impacts of noise pollution on human health. As with air pollution, understanding of population exposure to noise pollution is increasing, which will enable a better understanding of the impacts of noise pollution on the community. An EPA Victoria investigation into population noise exposure tallied the number of people across metropolitan Melbourne exposed to various ranges of environmental noise using data from 2011 for road, rail and industrial zones.[96]

EPA Victoria compared the population exposure results with the European Union Environmental Noise Directive, which lists a night-time threshold of 50 dB, and with the World Health Organization recommended interim night-time target of 55 dB.[97,98,99] The thresholds and targets focus on night-time, when typically most people are at home.

Estimated population exposures from the investigation are provided below and presented as a range to account for a 95% confidence interval in the noise exposure model. The study showed:

- 19 to 35% of Melburnians were exposed to night-time noise levels of 50 dB or more
- 9 to 21% of Melburnians were exposed to night-time noise levels of levels of 55 dB or more.

The main source of noise exposure was road traffic, mostly from arterial roads. When considering traffic noise only:

- 11 to 22% of Melburnians were exposed to night-time traffic noise levels of 50 dB or more
- 4 to 12% of Melburnians were exposed to night-time traffic noise levels of 55 dB or more.

Figure A.24 shows that the proportion of the population exposed to high levels of road traffic noise in Melbourne for the base year 2011 was similar to that in the quieter European capital cities.[100]

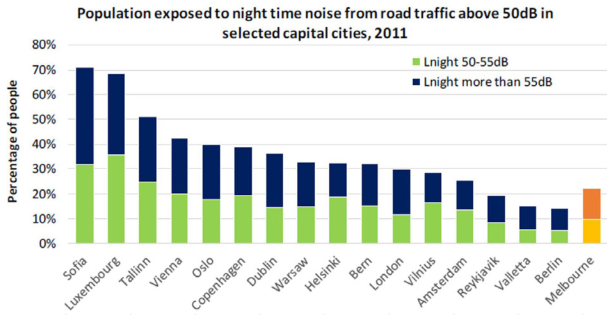

Figure A.24 Indicative comparison of the night-time exposure to road traffic noise for metropolitan Melbourne (2011) compared with selected capital cities of the European Union [101,102]

As a lower proportion of people are exposed to excessive night-time noise in Melbourne than in many of Europe's capital cities (where similar data is available to enable a comparison), the status for this indicator has been assessed as fair for Melbourne. No data is available for the rest of Victoria, and there is no trend data, so the status of the health impacts of noise pollution in regional Victoria is unknown, and the trends across Victoria are unclear. It is important that future work quantifies the health burden associated with population exposure to noise pollution.

96 EPA, communication dated 26/09/2018 ("Additional noise submission for SOE report").

97 Note: Night time noise levels, as mentioned here, are defined as the $L_{Aeq,8h}$ for the period of 10pm-6am (i.e. the average sound between 10pm-6am).

98 European Union Environmental Noise Directive 2002, 'Document 32002L0049', https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32002L0049 Accessed 3 December 2018.

99 World Health Organization Europe 2009, 'Night Noise Guidelines for Europe', http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf?ua=1 Accessed 3 December 2018.

100 Note: The methodology to estimate noise exposure may vary from country to country and these comparisons should be treated as indicative.

101 Note: Based on data reported by countries by 28 August 2013. Noise mapping and assessment methods differ by country, which means information reported for cities is not always comparable. 55dB L_{night} is the World Health Organization (WHO) Interim Target.

102 European Environment Agency, 'The NOISE Observation & Information Service for Europe', http://noise.eea.europa.eu/ Accessed 3 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:11 Indoor air quality	●				?	DATA QUALITY Poor

Data custodian None

People typically spend most of their time indoors, which means good indoor air quality is critical for health and wellbeing. A study found that Americans spend 93% of their time indoors – 87% in buildings and 6% in vehicles.[103] An Australian study showed that Australians aged 15 to 20, and over 60, spend 2 to 4 hours outdoors per day, approximately 1 hour in transport and generally more than 20 hours indoors.[104] Despite this, relatively little research has been done on the quality of air in homes, schools, recreational buildings, restaurants, public buildings and offices, or in cars.[105]

Only a handful of Victoria-specific indoor air quality studies have been published, and the concentrations of indoor air pollutants in Victoria are not well understood. One indoor air quality study conducted in Melbourne in 2008 and 2009 found older residential properties generally had better indoor air quality, most likely due to newer homes having less ventilation to meet energy efficiency regulations, to the detriment of indoor air quality.[106] The study also noted that combustion and cooking activities affect multiple indoor air quality pollutants. Some pollutants, including formaldehyde and total volatile organic compounds, had indoor concentrations that were higher than outdoor concentrations.[107]

Another recent study investigated volatile organic compounds from building materials and fragranced consumer products, also finding the pollutant concentrations were higher in all indoor environments than outdoor.[108]

Most other Victorian studies are more than 15 years old. Research conducted in the Latrobe Valley and published in 1998 found gas stove exposure was a significant risk factor for respiratory symptoms in children aged 7 to 14.[109] In another study, focused on Melbourne in 2002, total volatile organic compounds (that is, vapours of gases associated with painted surfaces, fabrics, carpets, household cleaners and cosmetics) were found to be low, but still four times greater than in outdoor air.[110] The presence of attached garages, site contamination and wool carpet were associated with higher indoor pollution.[111]

Biological contaminants such as moulds and fungi are known air contaminants that can degrade indoor air quality.[112] Moulds and fungi can produce toxins and irritants that are suspected to damage respiratory health.[113] Mould germination is more likely to occur overnight when heating is turned off and the indoor temperature drops below 14°C. Inadequate ventilation and building design (for example, cooler surfaces such as concrete walls) can have adverse effects on indoor air quality.

103 Klepeis NE, Nelson WC, Ott WR, Robinson JP, Tsang AM, Switzer P, Behar JV, Hern SC, Engelmann WH 2001, 'The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants', *Journal of Exposure Analysis and Environmental Epidemiology*, 11, pp. 231–252.
104 Environment Protection and Heritage Council 2004, 'Time Activity Study – Summary of Finding' http://www.nepc.gov.au/system/files/resources/220add0d-0265-9004-1d22-0c312998402c/files/aq-tas-time-activity-study-summary-findings-final-200405.pdf Accessed 3 December 2018.
105 Australian Department of the Environment and Energy, 'Indoor air', Canberra, Australia http://www.environment.gov.au/protection/air-quality/indoor-air Accessed 3 December 2018.
106 Molloy SB, Cheng M, Galbally IE, Keywood MD, Lawson SJ, Powell JC, Gillett R, Selleck PW 2012, 'Indoor air quality in typical temperate zone Australian dwellings', *Atmospheric Environment*, 54, pp. 400-407.
107 Ibid.
108 Goodman NB, Wheeler AJ, Paevere PJ, Selleck PW, Cheng M, Steinemann A 2018, 'Indoor volatile organic compounds at an Australian university', *Building and Environment*, 135, pp. 344-351.
109 Garrett MH, Hooper MA, Hooper MB, Abramson MJ 1998, 'Respiratory symptoms in children and indoor exposure to nitrogen dioxide and gas stoves', *American Journal of Respiratory and Critical Care Medicine*, 158, pp. 891–895.
110 National Pollutant Inventory, 'Total Volatile Organic Compounds', Canberra, Australia http://www.npi.gov.au/resource/total-volatile-organic-compounds Accessed 3 December 2018.
111 Brown SK 2002, 'Volatile organic pollutants in new and established buildings in Melbourne, Australia', *Indoor Air*, 2002, 12, pp. 55–63.
112 Australian Building Codes Board 2018, 'Indoor Air Quality Handbook 2018', Canberra, Australia http://www.abcb.gov.au/-/media/Files/Resources/Education-Training/11HandbookIndoorAirQuality2018.pdf Accessed 3 December 2018.
113 Australian Building Codes Board 2014, 'Condensation in Buildings Handbook 2014', Canberra, Australia http://www.abcb.gov.au/-/media/Files/Resources/Education-Training/Handbook-Condensation-in-Buildings-2014.pdf Accessed 3 December 2018.

Future Focus

Improve air-quality assessment capability

EPA Victoria currently compiles an air-pollution inventory to quantify the sources of air pollution spatially and temporally across Victoria. However, the immediacy of data access is an issue, with data generally unavailable until at least two years after the base year of the pollution inventory. Future versions of the inventory need to be more dynamic, and coupled with meteorology and ambient air-quality modelling. Blending air-quality monitoring and modelling will enable more robust and real-time assessments of the Victorian population's exposure to air pollution.

As determined by VAGO,[114] Victoria's current air-monitoring network is inadequate and needs to be expanded, to cover more of regional Victoria and the growth areas of Melbourne, and have the flexibility to target hotspots such as major roadsides and industrial areas. This is an opportunity to ensure adequate air-monitoring in disadvantaged communities and, by working with the Victorian community, to design a comprehensive and targeted monitoring network. Monitoring must be expanded to include ultrafine particles and would include consultation with the National Environment Protection Council to determine whether an ambient air-quality standard is required for ultrafine particles.

In 2016, a ministerial advisory committee completed an inquiry into EPA Victoria. The committee's recommendations included for EPA Victoria to 'assess the adequacy of its air and water-monitoring networks, particularly in relation to air quality, and consider options to improve data-sharing and accessibility, and community communication' (recommendation 6.3). It also recommended implementation, through DELWP, of statewide environmental monitoring, a spatial data system and reporting on outcomes (recommendation 7.2).[115]

It is critical that the implementation of these two recommendations be prioritised and expedited to enable comprehensive, real-time (or near real-time) estimates of air pollution across Victoria, including in areas currently without local air-monitoring stations. The results would be published online and clearly explained, so any member of the community could understand their local air quality. Health researchers would be able to use the data to develop population exposure metrics.

The Air chapter identifies the significant knowledge gap for indoor air quality in Victoria. This is significant, considering that Victorians are likely to spend up to 90% of their time indoors.[116]

It is also critical to couple improved data on population exposure with modern health studies that improve understanding of the health effects associated with air pollution in Victoria, particularly those incorporating indoor air quality. There needs to be an ongoing commitment to epidemiology in Victoria, and to pushing the boundaries of this science to shift the focus to developing accurate exposure metrics. Being able to quantify and understand the population's exposure to air pollution will be an essential component of air-quality management, enabling the future development of air-quality policies and timely assessments on the effectiveness of policy interventions.

Recommendation 3: That EPA Victoria prioritise the implementation of the EPA Inquiry Recommendations 6.3 and 7.2 to develop a publicly accessible, real-time assessment of air quality across Victoria that incorporates air-quality monitoring data, citizen science observations, air-quality modelling and an up-to-date air-pollution inventory. Future monitoring and assessments would also be expanded to include ultrafine particles and data on indoor air quality.

114 Victorian Auditor-General's Office 2018, 'Improving Victoria's Air Quality', Melbourne, Victoria, https://www.audit.vic.gov.au/sites/default/files/2018-03/20180308-Improving-Air-Quality.pdf. Accessed 3 December 2018

115 Ministerial Advisory Committee 2016, 'Independent inquiry into the Environment Protection Authority', http://www.epa-inquiry.vic.gov.au/__data/assets/file/0008/336698/Inquiry-report-EPA_June.pdf. Accessed 3 December 2018

116 Australian Department of the Environment and Energy, 'Indoor air', Canberra, Australia http://www.environment.gov.au/protection/air-quality/indoor-air Accessed 3 December 2018

Improve community access to timely information on pollen levels in air

Up to 50% of the population has the potential to suffer from the allergy conditions of hay fever and seasonal asthma, with 25% of the population suffering regularly.[117]

Pollen is monitored at eight locations across Victoria, with a single measurement recorded and reported every 24 hours at each location through a process reliant on significant manual work.[118] Recent investment in this field has focused on enhancing pollen forecasting – and a six-day outlook of daily pollen forecasts is now provided for the eight locations with pollen monitors.[119] Additional three-day epidemic thunderstorm asthma forecasts are provided by region across the state.[120] This information is available to the public online and via the mobile phone app Melbourne Pollen Count. App users can help researchers by answering a hay fever symptom survey.[121]

As many Victorians are affected by pollen levels, and pollen is a factor in the formation of epidemic thunderstorm asthma events, future SoE reports will include an indicator that reports on the status and trends for pollen levels. Advances in forecasting need to be complemented by a contemporary pollen-monitoring network that operates with statewide coverage, increased automation and real-time observations. The ability to measure pollen on an hourly, or at minimum three-hourly, basis would enable the development of a pollen profile. This would enhance the ability of allergy sufferers to reduce their exposure risk, and allow forecasters to produce forecasts at a finer time resolution than a daily forecast.

Developments in technology are leading to increasing automation of pollen monitoring in other parts of the world, with eight automatic pollen monitors installed in Bavaria, Germany during 2018.[122, 123]

Recommendation 4: That Victoria's Chief Environmental Scientist, supported by relevant government agencies and research partners, lead the establishment of a contemporary pollen-monitoring network to enable community access to information on pollen levels in the air in a timely manner, through actions including increasing the number of locations monitored, the frequency of the monitoring, and automating the monitoring process.

117 The University of Melbourne, *'Melbourne Pollen Count and Forecast'*, Parkville, Victoria https://www.melbournepollen.com.au/who-are-we/about-us/. Accessed 3 December 2018
118 The University of Melbourne, *'Melbourne Pollen Count and Forecast'*, Parkville, Victoria https://www.melbournepollen.com.au/. Accessed 3 December 2018
119 The Premier of Victoria, *'New Thunderstorm Asthma Forecasting System'*, Melbourne, Victoria https://www.premier.vic.gov.au/new-thunderstorm-asthma-forecasting-system/. Accessed 3 December 2018
120 Department of Health and Human Services, *'Epidemic thunderstorm asthma forecast'*, Melbourne, Victoria https://www2.health.vic.gov.au/public-health/environmental-health/climate-weather-and-public-health/thunderstorm-asthma/forecasting?sc_camp=63FD78C0EDAA4C3B87FA92A400469DEE&%20utm_source=web&utm_medium=melbournepollen&utm_campaign=thunderstorm_asthma_awareness&utm_term=thunderstorm-asthma. Accessed 3 December 2018
121 The University of Melbourne, *'Melbourne Pollen Count and Forecast'*, Parkville, Victoria https://www.melbournepollen.com.au/mobile-app/. Accessed 3 December 2018
122 Buters J, Schmidt-Weber C, Oteros J 2018, 'Next-generation pollen monitoring and dissemination', Allergy, 73(10), pp. 1944-1945. https://doi.org/10.1111/all.13585.
123 Buters JTM, Antunes C, Galveias A, Bergmann KC, Thibaudon M, Galan C, Schmidt-Weber C 2018, 'Pollen and spore monitoring in the world', Clinical and Translational Allergy, 2018;8:9. https://doi.org/10.1186/s13601-018-0197-8.

Accounting for the Environment

Under the System of Environmental-Economic Accounting (SEEA), air pollution is categorised as a residual flow from the economy to the environment. An air emissions account records the connection between economic activity and flows of waste to the atmosphere by reporting the generation of air emissions by economic units (such as industry sectors, government and households) and by type of pollutant. Tracking this connection over time, along with economic activity, can help highlight trends in the relative contributions of different sectors, including levels expected with growth in economic activity. This type of account can also be used to assess efforts by government, industry and households to reduce emissions.

Air pollution can reduce amenity, and exposure to air pollution can cause a number of adverse health effects and even death. Cardiovascular and respiratory impacts are most common and contribute to increased general practice and hospital presentations, hospital admissions and general health-system use.

The impact of air pollution on people and the environment already appears to some extent in Victoria's traditional economic accounts (the System of National Accounts). For example, impacts would be captured as expenditure in the health system from doctor visits and hospital admissions, medication costs, productivity losses from absenteeism and costs related to premature death. However, the amounts attributable to air pollution are not identified in the traditional accounts.

A 2014 study suggested the annual costs of air pollution in Australia may be more than $24 billion.[124] Expenditure to prevent and manage health impacts from air pollution currently count towards Victoria's gross state product, rather than being recorded as a cost to the Victorian community.

The SEEA framework also recognises the benefit that environmental assets provide through the ecosystem service of air-quality regulation, for example with vegetation improving air quality as it absorbs or traps particles, air toxics, sulfur dioxide and nitrogen dioxide.

However, ecosystems can also be a source of air emissions that flow from the environment to the economy. Australian native vegetation can increase the level of ozone and secondary particle pollution through emission of natural volatile organic compounds, with a consequent impact on human health. Forest and grass fires are a key source of emissions from the environment to the economy.

An ecosystem asset account linked to ecosystem services and benefits would record these connections between the environment and the economy, showing both the quantity of pollutants removed and produced by environmental assets, and the impact of this on air quality and the corresponding benefit (or cost) to the Victorian community in terms of reduced exposure to air pollution and avoided health impacts.

As outlined above, air-quality regulation is complex and the amount and value of air-quality regulation provided in any location in Victoria would vary depending on topographic and air shed (atmospheric) characteristics; the amount, type and location of vegetation in relation to pollution sources and populations; and the population density, with greater benefits in higher-density areas, as more people would benefit from improvements in air quality.

An example from the United Kingdom of quantifying the service of air-quality regulation following the environmental-economic accounting logic is shown in Table A.3. This demonstrates how accounts can help provide information on the trade-offs between investing in more health services or investing in urban vegetation to reduce the demand for health services.

124 National Environment Protection Council 2014, 'Draft variation to the National Environment Protection (Ambient Air Quality) Measure: impact statement', Canberra, Australia http://www.environment.gov.au/system/files/pages/dfe7ed5d-1eaf-4ff2-bfe7-dbb7ebaf21a9/files/aaq-nepm-draft-variation-impact-statement.pdf Accessed 3 December 2018.

Table A.3 Air quality regulation in an environmental-economic accounting framework[125]

Asset	Condition	Services	Benefits
Urban vegetation	Vegetation characteristics	Absorption of pollutants	Avoided health impacts
Example from scoping study of UK natural capital accounts			
Urban vegetation including woodland (99,400 ha), grassland (420,400 ha), and freshwater/saltwater habitat (22,700 ha)	Vegetation age, height, width, size, species diversity	Absorption of 2.78 kilotonnes of fine particles; reducing the concentration of fine particles in the atmosphere by 0.056 μg/m^3 in 2015	Avoided impacts in 2015: respiratory hospital admissions (123) cardiovascular hospital admissions (108) loss of life-years (5,538) Economic value of £195 million per annum

In addition to air-quality regulation, ecosystems also provide important noise regulation services. Noise pollution can directly affect people, harming health and reducing amenity. Ecosystems play an important role in reducing noise as vegetation forms natural noise reduction infrastructure. For example, vegetated areas near busy roads can help reduce the impact of noise pollution from traffic.

125 Jones L, Vieno M, Morton D, Cryle P, Holland M, Carnell E, Nemitz E, Hall J, Beck R, Reis S, Pritchard N, Hayes F, Mills G, Koshy A, Dickie I 2017, 'Developing Estimates for the Valuation of Air Pollution Removal in Ecosystem Accounts', *Final report for Office of National Statistics*