



VICTORIAN STATE OF THE ENVIRONMENT 2018 REPORT

SCIENTIFIC ASSESSMENTS



Commissioner
for Environmental
Sustainability
Victoria

ISBN: 978-0-6485069-1-1



CULTURAL LANDSCAPE HEALTH AND MANAGEMENT (CL)

SCIENTIFIC ASSESSMENTS Part III



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Cultural Landscape Health and Management

Background

Aboriginal existence and identity is underpinned by healthy cultural landscapes. Along with water and other natural resources, the land that is now the State of Victoria was managed for thousands of years according to traditional laws, customs and practices. Shaped by a sustainable-use regime and managed with a deep understanding of natural systems and an embedded lore and culture, Country (land, water, animals, plants, people, spirits and customs) has provided for the material, cultural and spiritual needs of thousands of generations of Aboriginal people.¹

Victoria's cultural landscapes are unique. They are host to one of the oldest continuing cultures in the world, and home to a vast array of plants, animals and places that have both symbolic and practical value to Aboriginal Victorians and all other Victorians. Today's cultural landscapes are a reflection of how Aboriginal people engage with their world and experience their surroundings. They are the product of generations of economic activity, material culture and settlement patterns. While colonisation resulted in the landscape being broken up into different land tenures and established different management regimes, Aboriginal people remain connected to Country and cultural landscapes continue across these artificial boundaries.²

Aboriginal cultural heritage in Victoria is protected under the *Aboriginal Heritage Act 2006* (the Act). The Act establishes a framework of mechanisms for the management and protection of Aboriginal cultural heritage, including cultural heritage management plans, cultural heritage permits, Protection Declarations and Aboriginal cultural heritage land management agreements.

Registered Aboriginal Parties is a status provided under the Act to Traditional Owner organisations that hold decision-making powers under the Act for the protection and management of Aboriginal cultural heritage within a specified geographic area. Registered Aboriginal Parties are appointed by the Victorian Aboriginal Heritage Council. The Council consists of up to 11 Traditional Owners who are appointed by the Minister for Aboriginal Affairs. All members are Victorian Traditional Owners who have relevant experience or knowledge of Aboriginal cultural heritage in Victoria. There are currently 11 Registered Aboriginal Parties covering over 60% of Victoria.

A number of Victorian Traditional Owner organisations, including Registered Aboriginal Parties, are working in partnership with government and non-government organisations in developing Country Plans, strategies and assessment frameworks that articulates a Traditional Owner group's aspirations by integrating cultural heritage and spiritual values, self-determination and governance, health and wellbeing, and economic capacity to improve, care and manage the cultural landscape health of Country. Traditional Owners are formally recognised in three ways by the Victorian Government: through the *Native Title Act 1993* (Cwlth), by way of a determination of a co-operative management agreement through a Recognition and Settlement Agreement under the *Traditional Owner Settlement Act 2010* (Vic.), and through appointment as a Registered Aboriginal Party under the *Aboriginal Heritage Act 2006* (Vic.). These areas of recognition, establishes a partnership between the State Government and Traditional Owner groups to jointly manage and share in decision making over determined areas of Crown Land.

This State of the Environment (SoE) 2018 report provides a transition from the singular focus on Aboriginal cultural heritage reporting in the SoE 2013 report to cultural landscape health and management assessment. This new reporting approach includes indicators aligning to four themes that aim to incorporate the social, economic, spiritual, cultural, environmental, and health and wellbeing values of Victorian

1. Parks Victoria. 2018. 'Managing Country Together', Melbourne, Victoria https://parkweb.vic.gov.au/_data/assets/pdf_file/0006/724695/Managing-Country-Together.pdf Accessed 3 December 2018.

2. Ibid

Traditional Owners, Registered Aboriginal Parties and Aboriginal Victorians (Table CL.1). This SoE report understands that the condition of cultural landscapes is difficult to distil into a single metric. The approach provided below assumes that increased connection, participation and self-determination in managing and looking after Country can lead to improvement in the condition of cultural landscapes and therefore serve as proxy indicators that may be formed from quantitative and/or qualitative data and information (Table CL.1). These themes and indicators were adapted from the *Health and Wellbeing Outcomes of the Aboriginal and Torres Strait Islander Gathering Place Model in Victoria: A Place for Inclusion, Connection and Empowerment* report^{3,4} and the Aboriginal Waterways Assessment Program.⁵ This approach for future SoE assessments allows indicators to be adapted and modified to suit Traditional Owner and Registered Aboriginal Party reporting needs. Sharing of indicator data and stories to inform reporting on cultural landscape health and management is at the discretion of Traditional Owner groups.

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3. Thorpe A, Munro-Harrison E, Kingsley J 2016, 'Health and Wellbeing outcomes of the Aboriginal and Torres Strait Islander gathering place model in Victoria: A place for inclusion, connection and empowerment.' Indigenous Health Equity Unit, The University of Melbourne and Gathering Place Reference Group, Melbourne, Victoria.
 4. Kingsley J, Munro-Harrison E, Jenkins A, Thorpe A, 2018. "'Here we are part of a living culture': Understanding the cultural determinants of health in Aboriginal gathering places in Victoria, Australia.' *Health & Place*, 54, pp. 210-220.
 5. Murray-Darling Basin Authority 2015, 'Aboriginal Waterways Assessment Program', Victoria, Australia.

Future Themes and Indicators

Table CL.1 Future themes and indicators

Theme	Future indicator
Connection to Country: Cultural Knowledge, Protocols and Practices	Community storylines and intergenerational learning
	Traditional ecological knowledge projects on Country
	Restoration/Protection of cultural heritage sites on Country; this includes tangible and intangible cultural heritage
	Repatriation of artefacts and ancestral remains to Country
	Cultural harvesting practices
Capacity Building: Programs, Resources, Education and Training Provided by Organisations	Number and types of training programs relating to managing Country
	Number of hours spent in training programs relating to managing Country
	Number of Traditional Owners enrolled in the Certificate IV in Aboriginal Cultural Heritage Management, delivered by Aboriginal Victoria
	Number of Traditional Owners who have been involved in knowledge transfer from training programs to manage Country
Land Justice, Self-determination, Governance and Mechanisms for Sustainability	Number of long-term plans, strategies and partnership agreements developed by Traditional Owners for managing Country, for example, Country Plans. (An example of existing data is provided in Table CL.2)
	Area (ha) of Country under formal recognition (Native Title, Registered Aboriginal Party). (An example of existing data is provided in Table CL.3)
	Area (ha) of Country under Aboriginal ownership. (An example of existing data is provided in Table CL.3)
	Number of Traditional Owner groups working on and managing Country
	Number of Traditional Owner group representation in government decision-making for managing Country
	Number of Traditional Owner enterprises associated with managing Country and/or cultural tourism
	Number of opportunities for Traditional Owner participation in emerging markets for managing Country
	Number of Traditional Owner, Registered Aboriginal Party, Native Title and Treaty partnership agreements with other organisations
Funding and Pathways to other Organisations	Number of Traditional Owner secondments and learning opportunities with other organisations
	Number of cultural awareness training programs provided to other organisations
	Traditional Owner participation in emergency management
	Funding opportunities for Traditional Owners to manage Country

Table CL.2 Formal agreements between the Victorian Government and Traditional Owner groups for joint management of their traditional lands under the *Traditional Owner Settlement Act 2010 (Vic.)*, *Native Title Act 1993 (Cwlth)* and *Conservation, Forests and Lands Act 1987 (Vic.)*

Agreement Name	Traditional Owner
Yorta Yorta Co-operative Management Agreement (2004)	Yorta Yorta Nation Aboriginal Corporation
Wotjobuluk Co-operative Management Agreement (2005)	Barengi Gadjin Land Council Aboriginal Corporation
Gunditjmara Settlement Agreement (2007)	Gunditj Mirring Traditional Owners Aboriginal Corporation
Gunditjmara Co-operative Management Agreement (2007)	
Yorta Yorta Traditional Owner Land Management Agreement (2010)	Yorta Yorta Traditional Owner Land Management Board
Gunaikurnai Recognition and Settlement Agreement (2010)	Gunaikurnai Traditional Owner Land Management Board
Dja Dja Wurrung Recognition and Settlement Agreement (2012)	
Dja Dja Wurrung Joint Management Plan (2018)	Dhelkunya Dja Land Management Board
Taungurung Recognition and Settlement Agreement (2018)	Taungurung Clans Aboriginal Corporation

Table CL.3 Formal and informal management agreements for Victorian Traditional Owner groups to have access and rights that protect their cultural heritage

Agreement	Area (ha)
<ul style="list-style-type: none"> Gunditj Mirring Traditional Owners Aboriginal Corporation Barengi Gadjin Land Council Aboriginal Corporation Taungurung Clans Aboriginal Corporation Yorta Yorta Nation Aboriginal Corporation Wurundjeri Land and Compensation Cultural Heritage Council Aboriginal Corporation Martang Pty Ltd Dja Dja Wurrung Clans Aboriginal Corporation Wathaurung Aboriginal Corporation Eastern Maar Aboriginal Corporation Gunaikurnai Land and Waters Aboriginal Corporation Bunurong Land Council Aboriginal Corporation 	<p>14,862,100</p> <p>(a)</p>

(a) At the time of writing this report, the Taungurung Recognition and Settlement Agreement 2018 had just been formally recognised and therefore this figure does not reflect this additional land area

Agreement	Area (ha)
Indigenous Protected Areas	
<ul style="list-style-type: none"> Deen Marr Indigenous Protected Area is located in the South East Coastal Plain bioregion and was declared in 1999. The land was purchased by the Framlingham Aboriginal Trust in 1993. 	453
<ul style="list-style-type: none"> Kurtonitj Indigenous Protected Area is located in the centre of the Budj Bim National Heritage Landscape between Mount Eccles volcanic plain and the sea. Declared in 2009, Kurtonitj is owned by the Gunditj Mirring Traditional Owners Aboriginal Corporation and managed by the Winda-Mara Aboriginal Corporation on behalf of the Gunditjmara people. 	353
<ul style="list-style-type: none"> Tyrendarra Indigenous Protected Area on Darlot Creek, a tributary of Land Condah near Portland, was declared in 2003. Tyrendarra is owned and managed by the Winda-Mara Aboriginal Corporation on behalf of the Gunditjmara people. 	248
<ul style="list-style-type: none"> Lake Condah Indigenous Protected Area is part of the Budj Bim National Heritage Landscape listed in 2004 due to its outstanding cultural heritage value in Victoria. The Kerrup Gunditj clan traditionally had an extensive and complex aquaculture system at Lake Condah including eel and fish harvesting. Today, it is managed by the Gunditj Mirring Traditional Owners Aboriginal Corporation. 	1,700
Private forest	
<ul style="list-style-type: none"> Framlingham Forest 	1,130
<ul style="list-style-type: none"> Lake Condah Indigenous protected area (includes the four properties of Lake Condah, Allambie, Muldoons and Vaughans) 	1,700
<ul style="list-style-type: none"> Freehold land owned by the Gunditjmara community (Gunditj Mirring Traditional Owners Aboriginal Corporation and Winda Mara Aboriginal Corporation) and declared or intended as Indigenous Protected Areas by the Gunditjmara community owners and recognised by the Australian Government. 	4,430
<ul style="list-style-type: none"> Lake Tyres Forest 	1,600
Other Crown land/Aboriginal co-managed areas	
<i>Dja Dja Wurrung Clans Aboriginal Corporation</i>	
The Dja Dja Wurrung People have been granted title to six parks and reserves within their native title settlement area including:	
<ul style="list-style-type: none"> Greater Bendigo National Park Hepburn Regional Park Kara Kara National Park (that falls within the agreement area) Kooyoorra State Park Paddys Ranges State Park Wehla Nature Conservation Reserve. 	47,502
These parks will be jointly managed and overseen by the Dhelkunya Dja Land Management Board.	

Agreement	Area (ha)
<p>Grampians National Park</p> <p>This includes the very small strip of Crown land (Crown allotment 2A, Parish of William) that is reserved under section 4 of the Crown Land Reserves Act 1978 (Vic.)</p>	167,219
<p>Gunaikurnai Joint Management Plan</p> <p>Partnership between the Gunaikurnai Land and Waters Aboriginal Corporation on behalf of the Gunaikurnai people, and the Victorian Government to jointly manage 10 parks and reserves in Gippsland.</p> <ul style="list-style-type: none"> • Buchan Caves Reserve • Corringale Foreshore Reserve • Gippsland Lakes Coastal Park • Lakes National Park • Lake Tyers State Park • Mitchell River National Park • New Guinea Cave • Raymond Island Gippsland Lakes Reserve • Tarra-Bulga National Park • The Knobs Reserve 	47,070

Gunaikurnai Joint Management Plan

The Gunaikurnai Joint Management Plan with the Victorian Government, formally established in July 2018, is the first Joint Management Plan to be approved in Victoria. This plan establishes a partnership between the Gunaikurnai peoples, Parks Victoria and the Department of Environment, Land, Water and Planning (DELWP) in co-managing the following parks and reserves under Aboriginal title in the Gippsland region:

- Buchan Caves Reserve
- The Knobs Reserve
- Corringlie Foreshore Reserve
- Gippsland Lakes Reserve on Raymond Island
- Mitchell River National Park
- New Guinea Cave (in Snowy River National Park)
- Tarra-Bulga National Park
- The Lakes National Park

The Joint Management Plan builds on the Gunaikurnai Whole-of-Country Plan (2015), by enabling the knowledge and culture of the Gunaikurnai people to influence, and be recognised in, the management of the parks and reserves.⁶ This plan also furthers the Gunaikurnai's Recognition and Settlement Agreement of 2010 through reconciliation, self-determination and social justice objectives. The Gunaikurnai Traditional Owner Land Management Board will monitor and evaluate the plan, with the Gunaikurnai Land and Water Aboriginal Corporation being responsible for plan implementation via partnerships while monitoring compliance and performance. The management plan provides the joint management strategies and actions that are specific to each of the parks and reserves and have a 10-year planning horizon. They describe how the aspirations and strategic direction, outlined in the Strategic Plan, will be translated at an operational level within each jointly managed park and reserve.

6. Gunaikurnai Traditional Owner Land Management Board and State of Victoria 2018, 'Gunaikurnai and Victorian Government Joint Management Plan', Victoria <https://www.gunaikurnai.com.au/joint-management/the-plan>. Accessed 18 October 2018.

Victorian Aboriginal Cultural Heritage

The Victorian Aboriginal Heritage Council (the Council) was established under the *Aboriginal Heritage Act 2006* (Act) to ensure that Traditional Owners throughout Victoria play a central role in the protection and management of their heritage. It is the only Victorian statutory authority embodying Aboriginal self-determination, comprising up to 11 Traditional Owners who are appointed by the Minister for Aboriginal Affairs.⁷ Aboriginal cultural heritage can include tangible and intangible archaeological, historical and anthropological Aboriginal heritage places, including landforms and land categories. The Victorian Aboriginal Heritage Register (VAHR) is maintained by the Secretary, Department of Premier and Cabinet through their delegate, the Registrar, Aboriginal Victoria. The VAHR is not an open-access register. Access is limited to persons listed in the Act and information that is listed as sensitive has further access restrictions. Sensitive information includes information about Aboriginal ancestral remains and burials. Registered Aboriginal Parties, and the Council in non-Registered Aboriginal Party areas, have the right to determine if and how information on the VAHR can be accessed.

Aboriginal people are the primary guardians, keepers and knowledge-holders of their heritage. The Act empowers Traditional Owners as protectors of their cultural heritage on behalf of Aboriginal and all other people. Registered Aboriginal Parties are Traditional Owner groups appointed by the Council who have statutory responsibility for the protection and management of Aboriginal cultural heritage in their appointed area. Registered Aboriginal Parties are appointed by the Council according to criteria set out in the Act and the Council's own decision-making principles for Registered Aboriginal Party applications.

7. VAHC 2017, 'Annual Report 2016 -2017', Victorian Aboriginal Heritage Council, Melbourne, Victoria.

As part of the Council's work in the protection and management of cultural heritage, it has provided input into Victoria's Climate Change Adaptation Plan 2017–2020 (the Plan; produced by DELWP) through representation on the Climate Change Advisory Panel. The Plan recommends a specific cultural focus and link to Victorian legislation and/or policy. Although further consultation with Traditional Owners is required regarding the Plan, it provides a foundation for the upcoming State of Cultural Heritage Report that will be led by Council as part of their reporting requirements. This report can then inform future SoE reporting.

Managing Cultural Landscapes in Victoria's Parks and Reserves

Parks Victoria is building on its existing reporting frameworks, which largely focus on ecology and natural systems, by adding three key elements that are special to determining the health of cultural landscapes. These three elements are:

1. social, spiritual and emotional wellbeing of Traditional Owners
2. extent and condition of culturally significant species
3. tangible and intangible Aboriginal cultural heritage

Recognising that changes in landscape condition can take a long time to become apparent, long-term monitoring is required. At the time of developing this report, Parks Victoria in partnership with Victorian Traditional Owners was in a process of realigning reporting frameworks, including State of the Parks reporting, to better incorporate cultural landscape management and condition.

The above three key elements for improving cultural landscapes are underpinned by the following values:

- **Land Justice and Reconciliation** – This includes the right to use, manage and direct what happens on Country. The Victorian Government is committed to self-determination for Aboriginal people through the *Aboriginal Heritage Act 2006*, *Traditional Owner Settlement Act 2010* and the *Aboriginal Victorians Bill 2018*.
- **Gather, record, share and use traditional and contemporary knowledge** – As the first inhabitants of Victoria, Aboriginal people have a deep knowledge of Country. Supporting Traditional Owner land management, cultural values and knowledge of Country can provide a strong basis for improving management of Country. At the same time, there are opportunities to support non-Aboriginal people to better understand Traditional Owner values and perspectives.

- **Connection to Country** – Maintaining a physical connection to Country is well-recognised as a fundamental pillar of the wellbeing of Aboriginal people and the broader cultural landscape. It can provide a means of cultural and spiritual renewal, employment, improved land management outcomes and economic independence. Importantly, it can provide Traditional Owners with the opportunity to meet their cultural obligations to care for Country.
- **Management** – The cultural landscapes of Victoria are mostly highly modified environments that have been adapted to suit the needs of their inhabitants, while still maintaining the core attributes that have shaped them over thousands of years. The decisions that managers and users of cultural landscapes make can have a significant impact on the natural and cultural values of those places. In many places, modern land management techniques have focused on meeting the needs of growing populations without recognising the underlying needs and capacity of Country. By integrating traditional and modern management approaches, actively protecting and improving cultural heritage values and returning ancestors to rest in their rightful Country, we can take steps to reverse some of this impact.
- **Sustainable natural resources** – According to traditional laws and customs, it is imperative that natural resources are managed sustainably, to ensure they continue to provide for current and future generations. Embedding this principle into the range of ways that cultural landscapes are used – including harvesting, tourism and enterprise development – will help to bring them back to cultural and ecological health.

Joint Management Plan for the Dja Dja Wurrung Parks

The Dja Dja Wurrung Joint Management Plan was officially launched in October 2018.⁸ This plan establishes a partnership between the Dja Dja Wurrung people Parks Victoria and DELWP in managing the following Dja Dja Wurrung Parks under Aboriginal title in Loddon Mallee:

- Greater Bendigo National Park
- Hepburn Regional Park
- Kara Kara National Park
- Kooyoorra State Park
- Paddys Ranges State Park
- Wehla Nature Conservation Reserve.

The above parks fall within the Country of the Dja Dja Wurrung Traditional Owners and are considered living landscapes that hold sites of Ceremony, lore and healing, stories of ancestral beings, memories and spirits of Djaara ancestors, totemic animals, birds, plants, elements and entities that create a relationship with Country. The Dhelkunya Dja Land Management Board will oversee the Plan's implementation through partnerships while monitoring compliance and performance. This Plan provides opportunities and benefits for all Dja Dja Wurrung People through long-term economic development.⁹ The main goal of this Plan is to enable Traditional Owner knowledge and connection to Country to be expressed in the planning and management of the lands. The Dhelkunya Dja Land Management Board will work closely with the Dja Dja Wurrung Clans Aboriginal Corporation to ensure the Plan aligns with the goals and aspirations of the Dja Dja Wurrung People as expressed in their Dja Dja Wurrung Country Plan, *Dhelkunya Dja*.

8. Dhelkunya Dja Land Management Board and State of Victoria 2018, 'Joint Management Plan for the Dja Dja Wurrung Parks: Strategy', Victoria <http://www.dhelkunydja.org.au/the-plan/joint-management-plan> Accessed on 18 October 2018.

9. Ibid

Current Victorian Government Settings: Legislation, Policy, Programs

The Victorian Aboriginal Heritage Council aims to appoint Registered Aboriginal Parties across all of Victoria to ensure Traditional Owner-led management and protection of Aboriginal cultural heritage. Aboriginal Ancestral Remains are particularly vulnerable to the detrimental effects of climate change and Registered Aboriginal Parties (and other Traditional Owners) are best placed to care for this Country.

Aboriginal cultural heritage land management agreements (ACHLMAs) are voluntary agreements made between a Registered Aboriginal Party and a public land manager under the Act. ACHLMAs are designed to facilitate a proactive, holistic approach to managing and protecting Aboriginal cultural heritage and cultural landscapes during land management activities within a specific area, for an agreed duration.

Aboriginal intangible heritage¹⁰ refers to the practices, expressions, knowledge and skills that communities recognise as part of their cultural heritage. It is communicated from generation to generation and is constantly recreated by communities in response to their environment and their history. It provides communities and individuals with a sense of identity and continuity.

In Victoria, Aboriginal intangible heritage includes:

- Ceremony
- Creation Stories
- skills involved in the creation of cultural items
- knowledge and skills associated with medicinal plant use
- language
- dance
- song

- a great variety of other cultural expressions and cultural knowledge systems.

Aboriginal intangible heritage often has a strong relationship with Country. The Act allows for the registration of Aboriginal intangible heritage on the VAHR. Whereas, for the purposes of the Act, Aboriginal cultural heritage denotes Aboriginal places, objects and Ancestral Remains, Aboriginal intangible heritage denotes elements of living culture – traditional knowledge and cultural expressions, held collectively by Aboriginal people or a particular group of Aboriginal people, and passed down across generations with or without adaptations and evolutions.

By providing a mechanism for registering Aboriginal intangible heritage under the Act, it:

- recognises the central role that intangible heritage plays in keeping Victorian Aboriginal cultures strong
- recognises Traditional Owners' rights as cultural custodians, and the shortcomings of existing laws in adequately protecting these rights
- gives Traditional Owners more control over the protection, management and potential use of their intangible heritage
- encourages a focus broader than physical places and objects within the Victorian Aboriginal cultural heritage management system.

Once Aboriginal intangible heritage is registered on the VAHR, anyone who wants to use that intangible heritage for commercial purposes has a legal responsibility to seek the permission of the representative group of the Traditional Owners, and may enter into an Aboriginal intangible heritage agreement. Agreements allow Traditional Owners to identify and/or negotiate the terms under which the Aboriginal intangible heritage may be used by others.

10. Office of the Chief Parliamentary Counsel 2016, 'Aboriginal Heritage Amendment Act 2016', Melbourne, Victoria [http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/edfb620cf7503d1aca256da4001b08af/1D1B929B4736B758CA257F8C0018EF03/\\$FILE/16-011aa%20authorised.pdf](http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/edfb620cf7503d1aca256da4001b08af/1D1B929B4736B758CA257F8C0018EF03/$FILE/16-011aa%20authorised.pdf) Accessed on 18 October 2018.

With responsibility for managing more than 4 million hectares of Victoria's most intact landscapes, Parks Victoria recognises the value of working in partnership with Traditional Owners to sustainably manage cultural landscapes. Parks Victoria's Managing Country Together program is an ambitious reform agenda that aims to embed Traditional Owner partnerships into all aspects of park management and build the shared capacity of government and Traditional Owners to jointly manage the parks estate into the future.

The Managing Country Together program aims to improve the natural and cultural values of the parks estate within broader cultural landscapes. It is doing this by working with Traditional Owners to:

- provide for effective management and appropriate development of the parks estate
- provide practical and symbolic recognition of Traditional Owner rights
- foster positive relationships between government and Traditional Owners
- facilitate economic development opportunities for Traditional Owners
- ensure cultural heritage values are understood, conserved and enhanced
- develop agency and sector capacity in joint protected area and cultural heritage management.

The program includes a range of commitments that will support effective management of cultural landscapes, including:

- overarching principles that align with the Victorian charter of human rights and responsibilities and apply obligations under the United Nations Declaration on the Rights of Indigenous Peoples in the Victorian context
- policies, tools and resources to effectively conserve, protect and enhance Aboriginal cultural heritage values across the parks estate
- an Aboriginal employment and wellbeing program to support Aboriginal people working in park management.

DELWP identifies Traditional Owner participation in natural resource management (NRM) is increasing. Traditional Owners have strategies for their participation in NRM detailed within a Natural Resource Agreement (this agreement articulates the rights of Traditional Owners as part of their Recognition and Settlement Agreements).

These strategies determine the scope of Traditional Owner participation in NRM, under their agreements, that involves broad and multiple relationships between Traditional Owner groups with settlement determination and NRM agencies, such as DELWP, Parks Victoria, Catchment Management Authorities and other agencies with a role in NRM. These strategies also have a strong linkage to Joint Management and Strategic Planning being delivered by established Traditional Owner Land Management Boards.

Future Focus

Develop cultural indicators for future SoE reporting

There are opportunities to enhance the role of Victoria's Traditional Owners in cultural landscape health and management based on the objectives outlined in the *Aboriginal Heritage Act 2006*. Importantly, Aboriginal cultural heritage needs to be recognised as a fundamental part of Aboriginal community life and cultural identity, and celebrated as a significant part of the heritage of all Australians. There are many sources of information that can provide insights to progress towards medium and long-term outcomes for cultural landscapes.

Recommendation 1: That the Victorian Government, in consultation with Traditional Owners and relevant agencies, develop contemporary cultural indicators to inform future environmental reporting. These indicators must reflect the priorities of Traditional Owners, have practical and cost-effective data-collection methods, and be meaningful and demonstrate change within a five-year reporting period.



CLIMATE CHANGE IMPACTS (CC) SCIENTIFIC ASSESSMENTS Part III



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Climate Change Impacts

This chapter includes assessments of how Victoria's climate is changing and the associated impacts of those changes. Three key themes are covered: climate, impacts of climate change and management.

The climate theme incorporates a synthesis of the latest data and science on observed and projected surface temperature, rainfall, sea level, snow cover, and observed sea-surface temperature, while also including an update of Victoria's greenhouse gas (GHG) emissions with respect to the targets in the *Climate Change Act 2017*.

The impacts of climate change theme looks at the occurrence and impacts of extreme weather, the extent and condition of climate-sensitive ecosystems, and community awareness of climate risks and associated responsibilities.

The management theme assesses how councils are developing urban forestry plans and considering climate change risks in land-use planning, and also looks at the way agri-businesses are using long-term weather and climate projections. There are direct links to climate change adaptation, which are listed in Appendix A.

Themes in this chapter are covered in greater detail in other chapters. In particular, the Fire chapter includes commentary on the increased bushfire risk associated with climate change, and the Energy and Transport chapters cover GHG emissions from those sectors in greater detail.

Background

Climate research continues to show that temperatures, sea levels and sea-surface temperatures are rising in Australia.¹ Further changes will drive ongoing and significant ecosystem and biodiversity impacts, and will expose Victorians to more frequent and intense droughts, fires, heatwaves, extreme rainfall events and coastal inundation.² SoE 2018 reports on the effect climate change is having in these areas, as well as the potential future implications.

Victoria's climate is influenced by a range of factors, including the effect of major ocean-atmosphere phenomena such as the El Niño–Southern Oscillation, which produces El Niño and La Niña events, and the Indian Ocean Dipole. These drivers of climate contribute to large natural year-to-year variations in temperature and rainfall. However, long-term climate change caused by increasing GHG concentrations is occurring at global scales.³

The link between increasing GHG concentrations and climate change has been a growing area of focus for environmental policy-makers since countries adopted the *United Nations Framework Convention on Climate Change* in 1992,⁴ which was a precursor to the adoption of the Kyoto Protocol in 1997⁵ and the Paris Agreement in 2015.⁶

1. BoM and CSIRO 2016, 'State of the Climate 2016', Melbourne, Victoria <http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf> Accessed 4 December 2018.
2. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
3. Intergovernmental Panel on Climate Change 2013, 'Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.' Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
4. United Nations 1992, 'United Nations Framework Convention on Climate Change', <https://unfccc.int/resource/docs/convkp/conveng.pdf> Accessed 4 December 2018.
5. United Nations 1998, 'Kyoto Protocol to the United Nations Framework Convention on Climate Change', <https://unfccc.int/sites/default/files/kpeng.pdf> Accessed 4 December 2018.
6. United Nations 2015, 'Paris Agreement', https://unfccc.int/sites/default/files/english_paris_agreement.pdf Accessed 4 December 2018.

The challenges associated with mitigating and adapting to climate change impacts are significant. Rising to these challenges will be increasingly important in the coming decades, when the magnitude of climate change is expected to increase. Scientists have produced detailed climate change projections: it is imperative that planning and policy development leverage them to enable decision-making that fully prepares Victoria to manage climate change impacts.

Critical challenges facing Victoria's management of climate change and its associated impacts, now and in the future, include:

- reducing GHG emissions to mitigate the speed and severity of climate change as part of the national and global effort
- developing understanding of the impacts of climate change through better real-time monitoring, trend analysis and predictive capabilities to enable strategic and timely responses to protect the environment and communities
- reducing the health burden associated with heatwaves and other natural disasters
- maintaining/designing vital infrastructure, such as power generation and rail transport, for reliability in the face of changes to the average climate and more frequent and intense weather events
- maintaining secure water supplies across the state as population grows, average rainfall reduces and evaporation increases, leading to less available water
- maintaining the viability of the agricultural sector
- protecting biodiversity from the impacts of climate change
- mitigating the effects of sea-level rise and associated adverse coastal impacts, including more frequent and severe flooding in low-lying coastal areas, dune erosion, loss of coastal ecosystems and reduced public access to coastal environments.

Current Victorian Government Settings: Legislation, Policy, Programs

The *Climate Change Act 2017* took effect on 1 November 2017. It establishes a long-term emissions reduction target of net zero by 2050, with interim emissions reduction targets set for five-year periods from 2021. The Act also requires the government to develop a Climate Change Strategy and Adaptation Action Plans every five years from 2021 for key systems vulnerable to the impacts of climate change. The Act mandates periodic reporting of the following measures:

- standalone reports on the science and data relevant to climate change in Victoria
- annual GHG emissions reports at the end of each interim target period.⁷

To develop the five-yearly emissions reduction targets, the Victorian Government is required to seek expert independent advice. In March 2018, an independent panel of experts released an issues paper that explored the issues relevant to setting interim emissions reduction targets for Victoria for 2021 to 2025 and 2026 to 2030, and trajectories to net zero emissions by 2050.⁸

Climate change responses are being integrated into federal, state and local government policies and strategies across many sectors. Recent notable publications include *Protecting Victoria's Environment – Biodiversity 2037*, which outlines a vision for Victoria's biodiversity in a time of climate change; *Water for Victoria*, the 2016 water plan, which links climate science and adaptation to water management; and the Agriculture Victoria Strategy, which identifies research and capacity-building programs that help farmers adapt to climate change as priorities.^{9,10,11}

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7. Office of the Chief Parliamentary Counsel Victoria 2017, 'Climate Change Act 2017', Melbourne, Victoria [http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/\\$FILE/17-005aa%20authorised.pdf](http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/$FILE/17-005aa%20authorised.pdf) Accessed 4 December 2018.
 8. DELWP 2017, 'Independent Expert Panel: Interim Emissions Reduction Targets for Victoria (2021-2030)', East Melbourne, Victoria https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0019/121924/Issues-Paper_28-03-2018.pdf Accessed 4 December 2018.
 9. DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', East Melbourne, Victoria https://www.environment.vic.gov.au/_data/assets/pdf_file/0022/51259/Protecting-Victorias-Environment-Biodiversity-2037.pdf Accessed 4 December 2018.

Sustainability Victoria is delivering the TAKE2 program, designed to support individuals, government, business and other organisations to help Victoria achieve net zero emissions by 2050.¹² The program requires government agencies to make pledges to act on climate change, while businesses and the community are invited to make their own public commitments to reduce emissions in Victoria. The program is designed to build momentum towards a lower GHG emissions future as well as recognising organisations that are leading the way.

State and Commonwealth agriculture ministers have initiated a work program on climate change. The program covers climate change impacts, managing emissions across the sector and identifying the risks and opportunities of adaptation in agriculture. A national approach to climate change in the agriculture sector will be delivered to the Agriculture Ministers' Forum by May 2019.

In April 2016, the Victorian and Commonwealth governments jointly funded the construction of a Doppler weather radar in the Wimmera, to extend the Bureau of Meteorology (BoM) to provide farmers in the region with more accurate rainfall data.¹³





Note that the government response to climate change includes additional initiatives, which are covered in other chapters, including the Energy, Land, Biodiversity and Water Resources chapters.

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10. DELWP 2016, 'Water for Victoria Water Plan', East Melbourne, Victoria https://www.water.vic.gov.au/_data/assets/pdf_file/0030/58827/Water-Plan-strategy2.pdf Accessed 4 December 2018.
 11. DEDJTR 2017, 'Agriculture Victoria Strategy', Melbourne, Victoria http://agriculture.vic.gov.au/_data/assets/pdf_file/0011/385949/Agriculture-Victoria-Strategy_FINAL.pdf Accessed 4 December 2018
 12. Sustainability Victoria, 'TAKE2', Melbourne, Victoria <https://www.sustainability.vic.gov.au/About-Us/What-we-do/Campaigns/TAKE2> Accessed 4 December 2018
 13. Victorian State Government 2016, 'Media Release: Andrews Labour Government puts Wimmera on the radar', Melbourne, Victoria, <https://www.premier.vic.gov.au/wp-content/uploads/2016/04/160406-Andrews-Labor-Government-Puts-Wimmera-On-The-Radar.pdf> Accessed 4 December 2018

Indicator Assessment

Legend




Status

N/A Not Applicable The indicator assessment is based on future projections or the change in environmental condition and providing a status assessment is not applicable. Only a trend assessment is provided.	 Unknown Data is insufficient to make an assessment of status and trends.	 Poor Environmental condition is under significant stress, OR pressure is likely to have significant impact on environmental condition/human health, OR inadequate protection of natural ecosystems and biodiversity is evident.	 Fair Environmental condition is neither positive or negative and may be variable across Victoria, OR pressure is likely to have limited impact on environmental condition/human health, OR moderate protection of natural ecosystems and biodiversity is evident.	 Good Environmental condition is healthy across Victoria, OR pressure is likely to have negligible impact on environmental condition/human health, OR comprehensive protection of natural ecosystems and biodiversity is evident.
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Trend



















N/A Not applicable This indicator assessment is based on current environmental condition only and it is not applicable to provide a trend assessment. Only a status assessment is provided.	 Unclear	 Deteriorating	 Stable	 Improving
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Data quality













 Poor Evidence and consensus too low to make an assessment	 Fair Limited evidence or limited consensus	 Good Adequate high-quality evidence and high level of consensus
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Summary		Status	Trend		
		UNKNOWN	POOR	FAIR	GOOD
Indicator CC:01 Observed average rainfall	Victoria has received below-average to record-low cool season rainfall for the most recent 30 years from 1985–2015. This has been influenced by declining cool season rainfall.				
Region Victoria					
Measures (i) Victorian annual rainfall anomaly (ii) Victorian rainfall deciles for the warm and cool seasons					
Data custodian BoM		DATA QUALITY			Good
Indicator CC:02 Snow cover	A decline in snow accumulation has been observed at several locations across the Victorian alps. Snow cover and volume will decline to the extent that eventually only the highest peaks will experience any snow by 2070–99.				
Region Victoria's alpine region					
Measures Snow cover					
Data custodian None		DATA QUALITY			Good
Indicator CC:03 Observed surface temperature	The five years from 2013–17 were all in the top-ten warmest years on record for Victoria. There has been an observed warming in both maximum (daytime) and minimum (overnight) temperatures.				
Region Victoria					
Measures (i) Victorian annual mean temperature anomaly (ii) Victorian annual maximum temperature anomaly (iii) Victorian annual minimum temperature anomaly					
Data custodian BoM		DATA QUALITY			Good

Summary		Status				Trend
		UNKNOWN	POOR	FAIR	GOOD	
Indicator	Physical evidence, past trends and various models all suggest Victoria will continue warming this century, so an ongoing warming is projected with high confidence.					
CC:04 Projected changes in temperature						
Region	Victoria	DATA QUALITY				
Measures	Annually averaged warming in 2030 and 2090 for various emission scenarios relative to the climate of 1986-2005	Good				
Data custodian	BoM, CSIRO					
Indicator	The observed reduction in cool season (April-October) rainfall during the past twenty years is projected to continue in the future.					
CC:05 Projected changes to average rainfall						
Region	Victoria	DATA QUALITY				
Measures	Percentage change in annual rainfall in 2030 and 2090 for various emission scenarios relative to the climate of 1986-2005	Fair (some uncertainty in long-term rainfall projections)				
Data custodian	BoM, CSIRO					

Summary		Status				Trend
		UNKNOWN	POOR	FAIR	GOOD	
Indicator CC:06 Regional climate projections Region Victoria Measures Projected number of hot and frost days for various emission scenarios in 2030 and 2070 Data custodian BoM, CSIRO	Further warming and declines in cool season rainfall are projected. The number of hot days is expected to increase by approximately 50% by 2030 and double by 2070 at most of Victoria's major cities and towns, while the number of frost days is likely to halve.					
					DATA QUALITY Good	
Indicator CC:07 Observed sea level Region Victoria's coastline Measures (i) Annual mean sea level (ii) Annual maximum sea levels Data custodian BoM	There have been rises of mean and maximum sea levels, as well as an increasing frequency of very high sea levels.					
					DATA QUALITY Fair (at Victorian sites until 1993 because data until 1993 has not been formally standardised). Good (at Victorian sites since 1993)	
Indicator CC:08 Projected sea level Region Victoria Measures Projected mean sea level in 2030, 2050, 2070 and 2090 for all emission scenarios Data custodian BoM, CSIRO	Further mean sea-level rises and an increase in the frequency of extreme inundation events are projected.					
					DATA QUALITY Good	

Summary		Status	Trend			
		UNKNOWN	POOR	FAIR	GOOD	
Indicator CC:09 Sea-surface temperature	Sea surface temperatures in the Australian region have been observed at record-warm levels in recent years.					
Region Victoria						
Measures (i) Australian region sea surface temperatures (ii) Australian sea surface temperature anomaly – southern region		DATA QUALITY Good				
Data custodian BoM, CSIRO						
Indicator CC:10 Annual greenhouse gas emissions	Victoria's per capita GHG emissions are relatively large compared to other OECD countries, however per capita and total GHG emissions have been reducing in Victoria since 2005.					
Region Victoria						
Measures (i) Per capita greenhouse gas emissions (ii) net greenhouse gas emissions (iii) greenhouse gas emissions by sector		DATA QUALITY Good				
Data custodian DELWP						

Summary		Status	Trend		
		UNKNOWN	POOR	FAIR	GOOD
Indicator CC:11 Victorian ecosystem carbon stocks Region Victoria Measures (i) land sector carbon stocks (ii) blue carbon stocks Data custodian DELWP	There has been a 1% growth in carbon stocks from 2007-16.				 
					Stable for land sector and Unknown for marine and coastal ecosystems
					
		DATA QUALITY Fair (no comprehensive statewide and trend data for marine and coastal ecosystems)			
Indicator CC:12 Occurrence and impacts of extreme weather Region Victoria Measures (i) Frequency of extreme heat days (ii) number of excess deaths associated with extreme heat days (iii) Forest Fire Danger Index (iv) Financial cost associated with natural disasters Data custodian BoM, CSIRO, DHHS, EMV	Extreme weather events (e.g. bushfires, extreme heat events and floods) are already causing significant impacts, with an increased frequency of these events being observed (particularly extreme heat days and more dangerous weather conditions for bushfires).				 
					
		DATA QUALITY Good			

Summary		Status	Trend			
		UNKNOWN	POOR	FAIR	GOOD	
Indicator	Examples of ecosystems and species under threat include bird species in floodplain forests, alpine Sphagnum bogs and seagrass in Corner Inlet.					?
CC:13 Extent and condition of key climate-sensitive ecosystems						
Region	Victoria	DATA QUALITY				
Measures	Case study examples	Fair (good issue-specific research but no comprehensive statewide data)				
Data custodian	DELWP					
Indicator	Nearly 80% of Victorians surveyed in 2016 and 2017 were concerned about climate change, with the main area of concern focused on water shortage and drought.					?
CC:14 Community awareness of climate risks and associated responsibilities						
Region	Victoria	DATA QUALITY				
Measures	(i) Percentage of Victorians are concerned by climate change (categorised by area of concern) (ii) Percentage of Victorians support current GHG targets	Good (for awareness of climate risks and mitigation) and Unknown (for adaptation to climate change)				
Data custodian	SV	Fair (recent data collected is good but no long-term data is available for trend analysis)				

Summary		Status	Trend			
		UNKNOWN	POOR	FAIR	GOOD	
Indicator CC:15 Councils (or other organisations) with urban forestry plans or urban greening or cooling-related strategies Region Victoria Measures Percentage of councils with, or developing, urban forestry plans Data custodian Resilient Melbourne, The Nature Conservancy	Urban forestry planning is a developing area of research in Victoria. Thirteen of the 32 councils within metropolitan Melbourne and some regional councils such as Geelong and Ballarat have developed or are developing urban forestry strategies.					
		DATA QUALITY Fair (no monitoring and evaluation provided)				
Indicator CC:16 Considering climate change risks in land use planning (including in the coastal zone) Region Victoria Measures Percentage of councils rated high or advanced for consideration of climate change in land use planning Data custodian DELWP	There is good agreement across local councils, particularly coastal councils, that land-use planning should be informed by up-to-date climate science.					
		DATA QUALITY Fair (no trend analysis)				

Summary		Status	Trend			
		UNKNOWN	POOR	FAIR	GOOD	
Indicator	Survey results show an increasing climate literacy and decisiveness of management actions in the agricultural sector in relation to climate change.					
CC:17 Percentage of agri-businesses using long-term weather and climate change projections						
Region	Victoria	DATA QUALITY				
Measures	(i) Number of agricultural businesses subscribing to information about climate conditions (ii) Percentage of businesses strongly agreeing or somewhat agreeing that the information improved their ability to make decisions to manage seasonal risk and improved their knowledge and understanding of seasonal climate variability	Fair (limited sample)				
Data custodian	DEDJTR					

Climate

The climate of Victoria is highly variable and influenced by large-scale climate drivers that occur on interannual timescales in the oceans surrounding Australia, such as the El Niño–Southern Oscillation and the Indian Ocean Dipole.¹⁴ In addition to this natural climate variability, increasing concentrations of GHGs are causing rising surface and ocean temperature and decreasing cool-season rainfall.¹⁵

Some of the indicators in this chapter refer to different emissions scenarios. Current scenarios are referred to as Representative Concentration Pathways (RCPs). In this report, RCP8.5 is referred to as a 'high emissions scenario', RCP4.5 is referred to as an 'intermediate emissions scenario' and RCP2.6 is referred to as a 'low emissions scenario'. Note that RCP2.6 aligns most closely with the Paris Agreement target.¹⁶

14. Risbey JS, Pook MJ, McIntosh PC, Wheeler MC, Hendon HH 2009, 'On the remote drivers of rainfall variability in Australia', *Monthly Weather Review*, 137(10), pp. 3233–3253.

15. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.

16. CSIRO and BoM 2016, 'Australia's changing climate', https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/176/AUSTRALIAS_CHANGING_CLIMATE_1.pdf Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:01 Observed average rainfall						
Data custodian BoM						Good

Rainfall over Victoria is highly variable from year to year, due to large-scale climate drivers such as the El Niño–Southern Oscillation. But beyond this variability, a drying trend is emerging. Below-average rainfall has been recorded most years since the late 1990s. The main exceptions are 2010 and 2011 (influenced by strong La Niña events) and 2016 (influenced by a strong negative Indian Ocean Dipole). Since the publication of SoE 2013, below-average rainfall conditions have dominated the climate and extended the overall drying pattern affecting the state.

The drying of Victoria's climate has become increasingly apparent since the mid-1990s, with only four of the past 20 years above the 1961 to 1990 average rainfall (Figure CC.1).

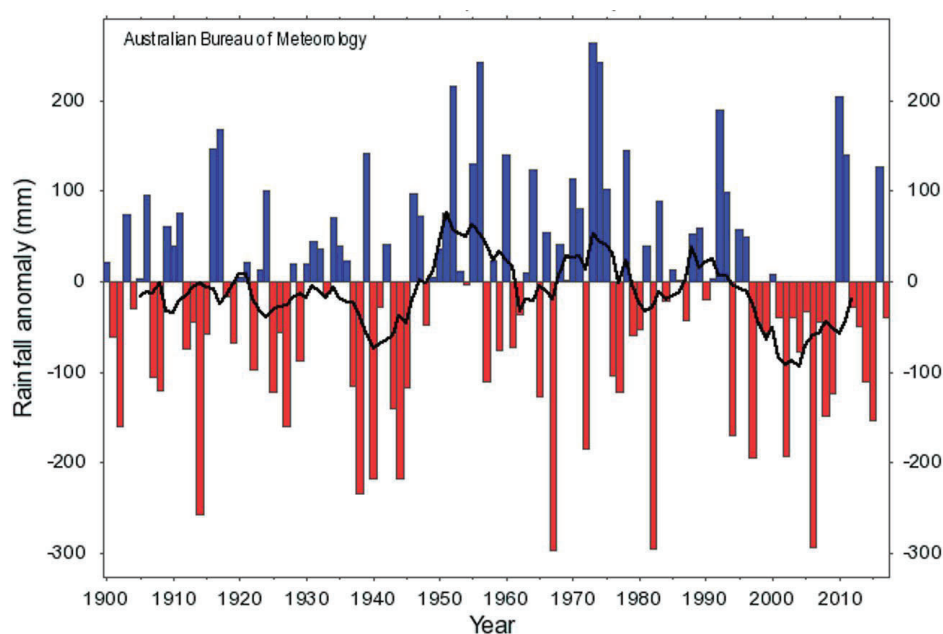


Figure CC.1 Victorian annual rainfall anomaly, 1900–2017

Note: 11-year running averages shown by black curve, Based on a 30-year climatology (1961–1990).

Anomalies calculated with respect to the 30-year climatology period 1961–1990 (average is 660.2 mm per year).

(Data source: BoM, 2018)

This drying mainly affects the cool season, from April to October. Figure CC.2 shows that nearly all of Victoria received below-average to record-low cool-season rainfall, for the most recent 30 years from 1985 to 2015. Therefore the trend for this indicator has been assessed as deteriorating. Dry conditions were in part due to increasing GHG concentrations, so they may be indicative of a longer-term change.¹⁷ The dry conditions are also linked to the millennium drought of 1996 to 2010. The decline in cool-season rainfall has particular consequences for agriculture, water resources and water quality.

Warm season (November to March) rainfall was generally above-average in northern Victoria and below-average in southern Victoria for the 30 years from 1985 to 2015 (Figure CC.2).

Rainfall in the coming decades will be determined by both anthropogenic climate change (likely to drive a general continuing decrease in rainfall) and ongoing natural variability. This means that in the short-to-medium term, Victoria may be wet or dry depending on the incidence of drought or wet events.

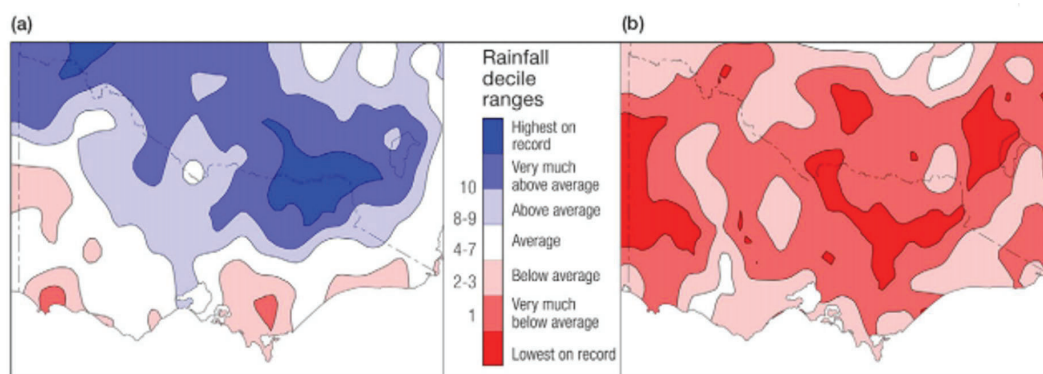


Figure CC.2 Victorian rainfall deciles, 1986–2015¹⁸

(a) the warm season (November–March)

(b) the cool season (April–October)

Note: Map shows where the rainfall is above-average, average or below-average for the recent period, compared with the rainfall record dating from 1900.

17. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.
18. Ibid

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:02 Snow cover						
Data custodian None						Good

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

A decline in snow accumulation has been observed at several locations across the Victorian Alps.^{19,20} Observations have also shown a decline in the frequency of smaller daily snowfall events (under 10 cm) across the Victorian Alps in the past 25 years.²¹ These changes are closely linked to increasing maximum temperatures in winter, indicating the role of anthropogenic climate change in reducing snow cover.²² Snow depth is also influenced by large-scale drivers such as the El Niño–Southern Oscillation and Indian Ocean Dipole.²³

In addition to ground-based observations, researchers have recently utilised technology such as satellite remote sensing to observe a reduction in snow cover in the Australian Alps from 2000 to 2014.²⁴ Remote sensing methods were automated as part of this study and can be consistently used to process remotely sensed imagery, enabling efficient monitoring of Australian snow cover changes.²⁵

Projections for snow in Australia are based on global climate models, and high-resolution climate modelling that uses global models as an input. There is very high confidence that as warming progresses, there will be a decrease in snowfall and an acceleration in snowmelt, reducing the snow season, particularly at lower elevations.^{26,27,28,29,30}

Snow cover and volume will decline to the extent that only the highest peaks will receive any snow by 2070 to 2099.³¹ This is likely to have a significant impact on the region's natural ecosystems, and on winter sport recreation. Figure CC.3 shows the change and projected change in snowfall at two elevations in an area where snow is currently observed. Figure CC.3 also demonstrates that the decreasing trend in snow cover that has been observed since 1950 is projected to continue to 2100.

19. Fiddes S, Pezza A, Barras V 2015, 'A new perspective on Australian snow', *Atmospheric Science Letters*, 16(3), pp. 246–252.
20. Timbal B, Ekstrom M, Fiddes S.L, Grose M, Kirono D.G.C, Lim E, Lucas C, and Wilson L, 2016, 'Climate change science and Victoria', Melbourne, Victoria (Bureau of Meteorology).
21. Fiddes S, Pezza A, Barras V 2015, 'A new perspective on Australian snow', *Atmospheric Science Letters*, 16(3), pp. 246–252.
22. Ibid
23. Pepler AS, Trewin B, Ganter C 2015, 'The influences of climate drivers on the Australian snow season', *Australian Meteorological and Oceanographic Journal*, 65(2), pp.195–205.
24. Thompson J 2016, 'A MODIS-derived snow climatology (2000–2014) for the Australian Alps', *Climate Research*, 68(1):25–38.
25. Ibid

26. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
27. Di Luca A, Evans JP, Ji F 2017, 'Australian snowpack in the NARCLIM ensemble: evaluation, bias correction and future projections' *Climate Dynamics*, 51(1–2) pp. 639–666.
28. Timbal B, Ekström B, Fiddes S, Grose M, Kirono D, Lim E-P, Lucas C and Wilson L 2016, 'Climate change science and Victoria: Bureau Research Report No. 14', *Report issued by the Bureau of Meteorology*.
29. Bhend J, Bathols JM, Hennessy KJ 2012, 'Climate change impacts on snow in Victoria. CAWCR Research Report', Centre for Australian Weather and Climate Research, Melbourne, Victoria.
30. Hennessy KJ, Whetton PH, Walsh KJE, Smith IN, Bathols JM, Hutchinson M, Sharples JJ 2008, 'Climate change effects on snow conditions in mainland Australia and adaptation at ski resorts through snowmaking', *Climate Research*, 35, pp. 255–270.
31. Antarctic Climate & Ecosystems Cooperative Research Centre 2016, 'The Potential Impacts of Climate Change on Victorian Alpine Resorts', Hobart, Tasmania http://www.arcc.vic.gov.au/uploads/publications-and-research/The%20Potential%20Impact%20of%20Climate%20Change%20on%20Victorian%20Alpine%20Resorts%20Study_FINAL.pdf Accessed 4 December 2018.

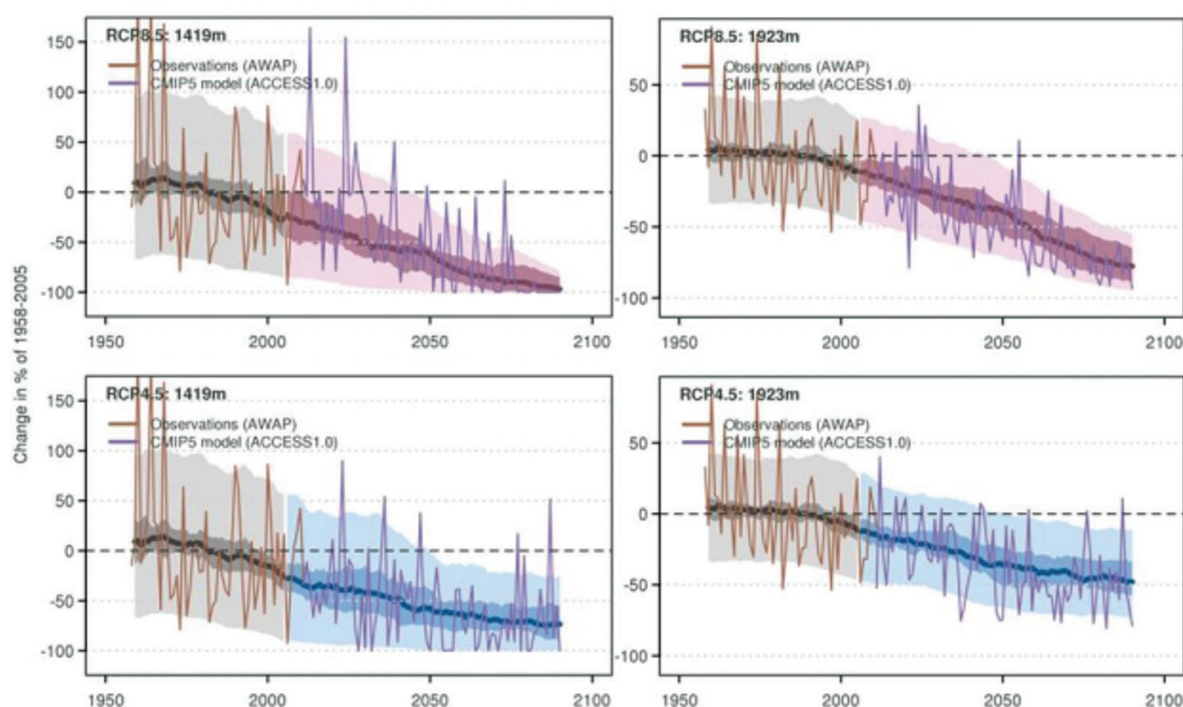


Figure CC.3 Change in snowfall for two grid boxes in the BoM operational 5 km gridded observations³²

Note: Change corresponds to a lower alpine elevation consistent with the current snowline (left panels) and for the highest elevation in the gridded observations (right panels). Future projections are provided from 2006 onward for high (top row) and intermediate (bottom row) emissions scenarios. Each panel shows the model ensemble median (thick line), the 10th and 90th percentile of annual snowfall (light shading) and the 10th and 90th percentile of the 20-year mean snowfall (dark shading), operational 5 km gridded observations (brown line) and an example of a possible future time series (light purple) from a single model (ACCESS-1.0).³³

There is a considerable interannual variability in various snow conditions and little research to date on the potential influence of climate change on extreme snowfall events. However, the research that has been conducted for Victoria consistently models a significant reduction in snow cover in the state's alpine locations.

Social research suggests that Australian skiers have a higher sensitivity to low snow cover than European skiers, which may heighten the impacts of reducing snow cover on the Victorian ski industry, with Victorian skiers potentially opting to ski in New Zealand or other international alpine regions.^{34,35,36}

Man-made snow could be used increasingly as a replacement for natural snow. However, the most prevalent snow-making techniques are expected to become less reliable as temperatures rise, and they will be limited by water availability. The most reliable way to produce snow in the future is likely to involve an expensive, energy-intensive technology known as a 'snow factory'.³⁷

32. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.

33. Ibid

34. Pickering CM, Buckley RC 2010, 'Climate Response by the Ski Industry: The Shortcomings of Snowmaking for Australian Resorts', *AMBIO*, 39, pp. 430-438.

35. Behringer J, Buerki R, Fuhrer J 2000, 'Participatory integrated assessment of adaptation to climate change in Alpine tourism and mountain agriculture', *Integrated Assessment*, 1, pp. 331-338.

36. König U 1998, 'Tourism in a warmer world: implications of climate change due to enhanced greenhouse effect for the ski industry in the Australian Alps', Geographisches Institut, Universität Zürich.

37. Antarctic Climate & Ecosystems Cooperative Research Centre 2016, 'The Potential Impacts of Climate Change on Victorian Alpine Resorts', Hobart, Tasmania http://www.arcc.vic.gov.au/uploads/publications-and-research/The%20Potential%20Impact%20of%20Climate%20Change%20on%20Victorian%20Alpine%20Resorts%20Study_FINAL.pdf Accessed 4 December 2018.

Flora and fauna reliant on snow are unlikely to adapt to the loss of natural snow, and some species are highly likely to be lost. An example is the mountain pygmy possum – an endangered species that is only found in alpine and subalpine regions above 1,400 metres on Mount Buller and the Bogong High Plains in Victoria, and on Mount Kosciuszko in New South Wales.³⁸ Declining snow cover and earlier snow melting will likely mean the possums awake from hibernation before some of their food sources (for example, bogong moths) are available.³⁹

While man-made snow may be able to mitigate the economic effects of a reduced snow cover on the ski industry, it is not expected to ease the stresses on flora and fauna.⁴⁰ Snow-making is unlikely to contribute to the survival of snow-dependent flora and fauna, because the area covered by man-made snow is too small, and subject to unusual conditions of management and use, relative to what the species are adapted to. If natural snow is lost, many snow-dependent species will be lost.

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- 38. Museum Victoria, 'Mountain Pygmy-possum', Melbourne, Victoria, <https://museums.victoria.com.au/website/melbournemuseum/discoverycentre/wild/victorian-environments/alps/mountain-pygmy-possum/index.html> Accessed 4 December 2018.
 - 39. Broome L, Archer M, Bates H, Shi H, Geiser F, McAllen B, Heinze D, Hand S, Evans T, Jackson S 2012, 'A brief review of the life history of, and threats to, *Burrhamys parvus* with a pre-history based proposal for ensuring that it has a future', *Wildlife and Climate Change: towards robust conservation strategies for Australian fauna*, Royal Zoological Society of NSW, Mosman, New South Wales, pp. 114-126.
 - 40. SGS Economics and Planning 2017, 'Alpine Resort Futures Vulnerability Assessment (Social and Economic)', https://www.forestsandreserves.vic.gov.au/_data/assets/pdf_file/0014/215141/Alpine-Resorts-Vulnerability-Assessment-FINAL_Report-Aug-17.pdf Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:03 Observed surface temperature						
Data custodian BoM						Good

Victoria's climate has been warming since the 1950s (Figure CC.4). Since the publication of SoE 2013, every year has been among the top 10 warmest on record for Victoria, with 2014 the second-warmest year on record, behind 2007.⁴¹ The greatest warming, measured as the linear trend across Victoria from 1910 to 2018, has been observed in summer (+0.14°C per decade), with the least warming observed in winter (+0.06°C per decade).⁴² The warming has been observed in both maximum (daytime) and minimum (overnight) temperatures. Based on this data, the trend for this indicator has been assessed as deteriorating (warming).

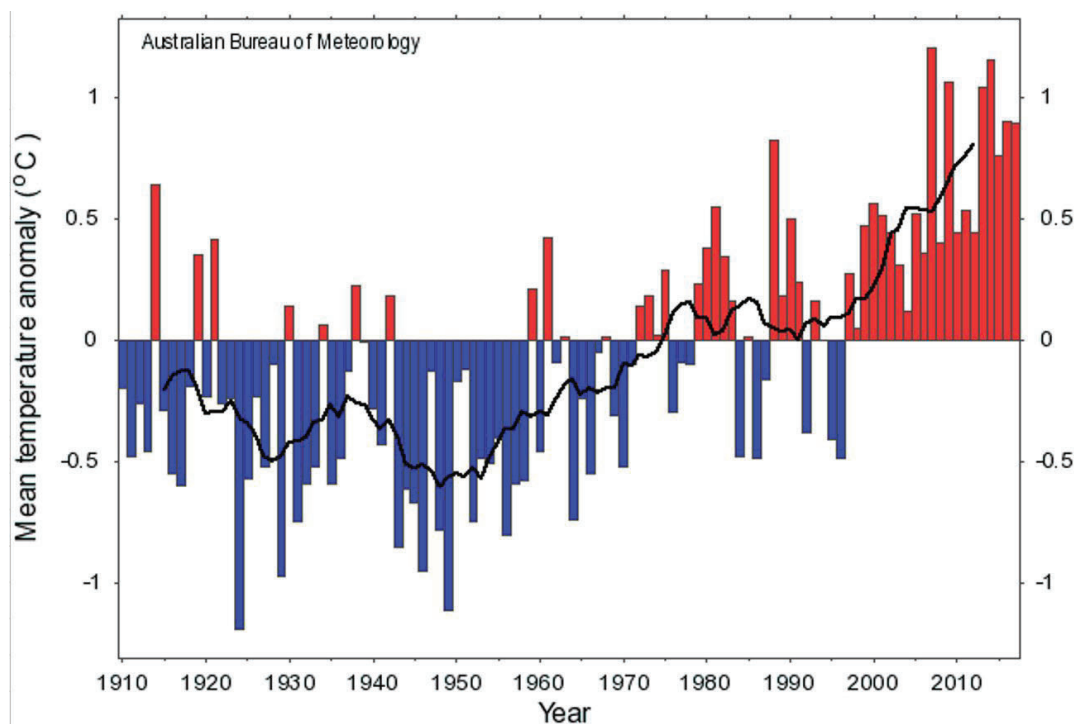


Figure CC.4 Victorian mean temperature anomaly, 1910–2017⁴³

Note: 11-year running averages shown by black curve,
Based on a 30-year climatology (1961–1990).

41. BoM, 'Climate Change and Variability – Time series graphs', Melbourne, Australia <http://www.bom.gov.au/climate/change/> Accessed 4 December 2018.
42. Ibid
43. Ibid

All parts of Victoria have warmed, with the most warming in central and southern parts of the state (Figures CC.5 to CC.7). Daytime temperatures have increased uniformly, except in the far west and in parts of Gippsland and the north-east, where there has been a slightly slower increase. Overnight temperatures have warmed the most in southern coastal areas.

There has been no significant upward trend in night-time temperatures during the cool part of the year (April to October).⁴⁴ This is likely due to the reduction in rainfall since the mid-1990s, and hence reduced cloudiness, which allows for greater night-time heat loss from the surface.⁴⁵ Decreasing rainfall and cloud cover in the cool season appears to have somewhat offset the overall global warming signal in inland parts of Victoria, which explains the lesser night-time warming in this region: clearer night-time skies are generally associated with cooler minimum temperatures.

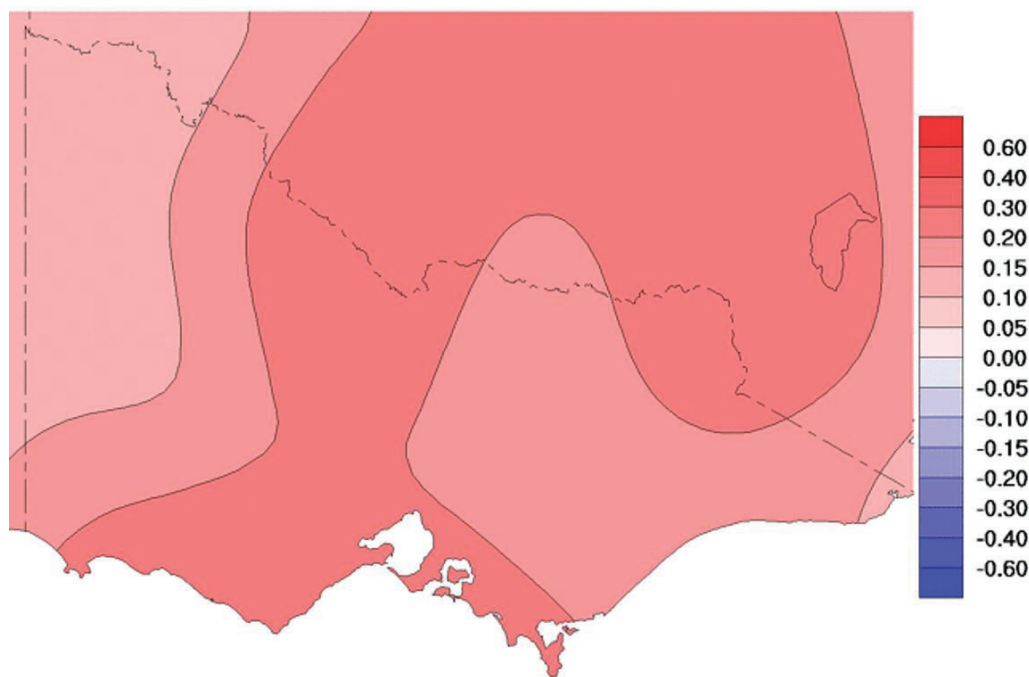


Figure CC.5 Trends in Victorian mean temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

44. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.
45. Ibid

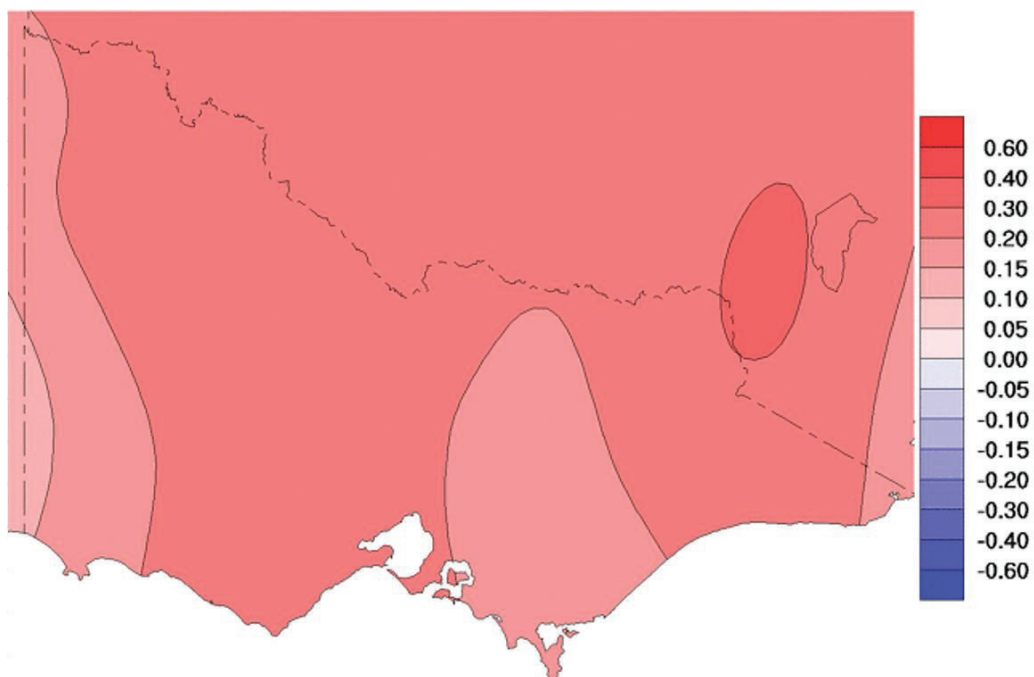


Figure CC.6 Trends in Victorian maximum temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

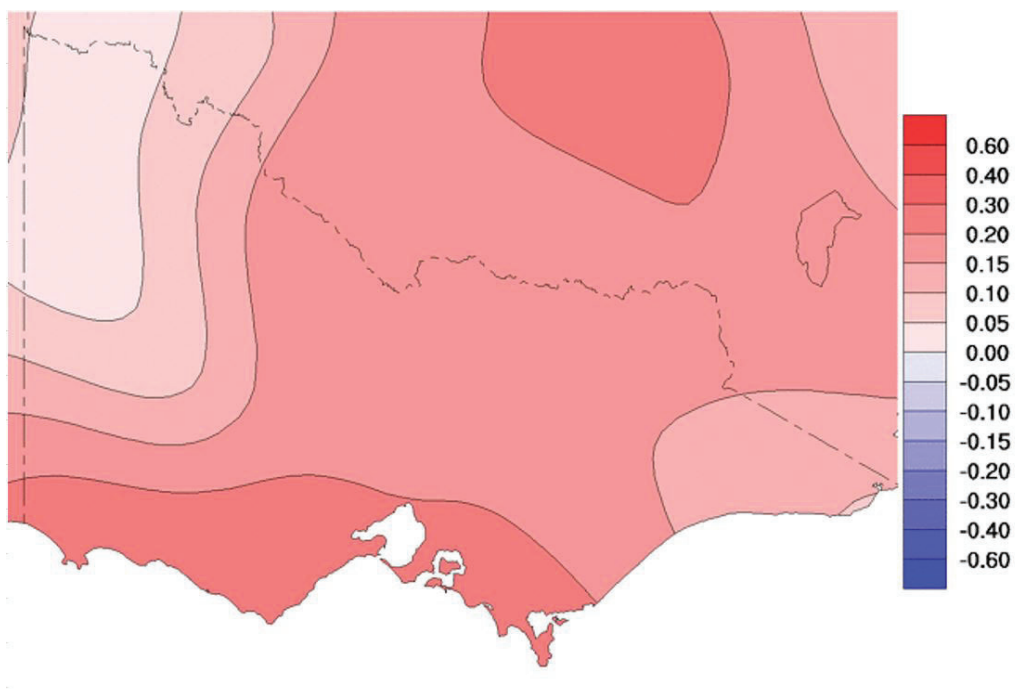



Figure CC.7 Trends in Victorian minimum temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

Climate – Projections

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:04 Projected changes in temperature						 DATA QUALITY Good
Data custodian BoM, CSIRO						

Temperatures are expected to be an average of 0.4 to 1.3°C warmer across Victoria by 2030, relative to the 1986 to 2005 baseline. Warming is projected to increase further by 2090, in proportion to the scale of emissions from human activity. From the 1986 to 2005 baseline, Victorian temperatures are expected to increase by 2.5 to 4.5°C in 2090 under a high ongoing emissions scenario, by 1.1 to 2.4°C under an intermediate emissions scenario, and by 0.4 to 1.5°C under a lower emissions scenario, which aligns most closely with the Paris Agreement targets.^{46,47} The magnitude of the warming is projected to be slightly greater in the Murray Basin region of Victoria than across the Southern Slopes (Table CC.1).⁴⁸

It is important to note that the projection of a 0.4 to 1.3°C temperature increase by 2030 (relative to the 1986 to 2005 average) is likely to be an underestimate, as the observed average temperature for Victoria from 2008 to 2017 is already 0.6°C warmer than the 1986 to 2005 average.⁴⁹

Increases in the magnitude, frequency and duration of extreme temperatures across Victoria are expected to occur at a similar rate to the rises in average temperature. Frost-risk days (minimum temperatures under 2°C) are projected to decrease across the state, possibly halving in northern Victoria by the end of the century.⁵⁰ In

the short-to-medium term, other factors, such as an increase in clear nights, may lead to increases in frost risk in some places, but in the long term the warming is expected to drive a decrease in frost risk. A decrease in frost days is expected to help the broadacre agricultural sector, which loses an estimated \$120 million to \$700 million each year in Australia due to frost events.⁵¹ For more information on extreme heat impacts, see indicator CC:12 (Occurrence and impacts of extreme weather).

Physical evidence, past trends and various models all suggest Victoria will continue warming this century, so an ongoing warming is projected with very high confidence, with the full range of projected change considered plausible.

46. Grose M et al 2015, 'Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.

47. Timbal B et al 2015, 'Murray Basin Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.

48. Climate Change in Australia, 'Projections for Australia's NRM Regions', <https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters> Accessed 4 December 2018.

49. BoM, 'Climate Change and Variability – Time series graphs', Melbourne, Australia <http://www.bom.gov.au/climate/change/> Accessed 4 December 2018.

50. Climate Change in Australia, 'Projections for Australia's NRM Regions', <https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters> Accessed 4 December 2018.



51. Crimp SJ, Zheng B, Khimashia N, Gobbett DL, Chapman S, Howden M, Nicholls N 2016, 'Recent changes in southern Australian frost occurrence: implications for wheat production risk', *Crop & Pasture Science*, 67, pp. 801–811.

Table CC.1 Projected temperatures across Victoria

Scenario	Victoria °C
2030 annually averaged warming relative to the climate of 1986–2005 for all emissions scenarios	0.4 to 1.3
2090 annually averaged warming relative to the climate of 1986–2005 for a low emissions scenario (RCP2.6)	0.4 to 1.5
2090 annually averaged warming relative to the climate of 1986–2005 for an intermediate emissions scenario (RCP4.5)	1.1 to 2.4
2090 annually averaged warming relative to the climate of 1986–2005 for a high emissions scenario (RCP8.5)	2.5 to 4.5

Note: Data derived from results for the three Victorian regions (Murray Basin, Southern Slopes West and Southern Slopes East) reported by Climate Change in Australia.⁵²

52. Climate Change in Australia, 'Projections for Australia's NRM Regions', <https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters> Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:05 Projected changes to average rainfall						 DATA QUALITY Fair
Data custodian BoM, CSIRO						

The observed reduction in cool-season (April to October) rainfall in the past 20 years is projected to continue and possibly intensify. While rainfall reduction was more pronounced in autumn during the millennium drought, reductions are expected to be more even across the cool season.⁵³

In the short term (until 2030), there is high confidence that natural climate variability will remain the major driver of rainfall changes, compared with the climate of 1986 to 2005.⁵⁴ However, by 2090, there is high confidence that cool-season rainfall will continue to decline. There will be no clear leaning towards wetter or drier conditions in the warm season.⁵⁵

Figure CC.8 shows that under a high emissions scenario, Victoria's annual average rainfall at the end of the century is expected to have declined. This decline is expected to be characterised by longer periods of dry weather, interspersed with more frequent extreme rainfall events.⁵⁶

Table CC.2 Projected rainfall across Victoria^{57,58}

Scenario	Victoria (annual) %	Victoria (winter) %	Victoria (summer) %
Percentage change in rainfall in 2030 relative to the climate of 1986–2005 for all emissions scenarios	–11 to 5	–17 to 9	–20 to 16
Percentage change in rainfall in 2090 relative to the climate of 1986–2005 for a low emissions scenario (RCP2.6)	–19 to 5	–13 to 9	–27 to 8
Percentage change in rainfall in 2090 relative to the climate of 1986–2005 for an intermediate emissions scenario (RCP4.5)	–16 to 4	–21 to 7	–24 to 11
Percentage change in rainfall in 2090 relative to the climate of 1986–2005 for a high emissions scenario (RCP8.5)	–27 to 9	–38 to 6	–28 to 27

Note: Data derived from the results for the three Victorian regions (Murray Basin, Southern Slopes West and Southern Slopes East) reported by Climate Change in Australia.

53. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.
54. Timbal B, Ekström B, Fiddes S, Grose M, Kirono D, Lim E-P, Lucas C and Wilson L 2016, 'Climate change science and Victoria: Bureau Research Report No. 14', Report issued by the Bureau of Meteorology.
55. Ibid

56. Australian Climate Change Science Programme 2015, 'Weather extremes and climate change - the science behind the attribution of climatic events', http://www.cawcr.gov.au/projects/Climatechange/wp-content/uploads/2015/11/Weather_Extremes_Report-FINAL.pdf Accessed 4 December 2018.
57. Grose M et al 2015, 'Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.
58. Timbal B et al 2015, 'Murray Basin Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports', CSIRO and BoM, Australia.

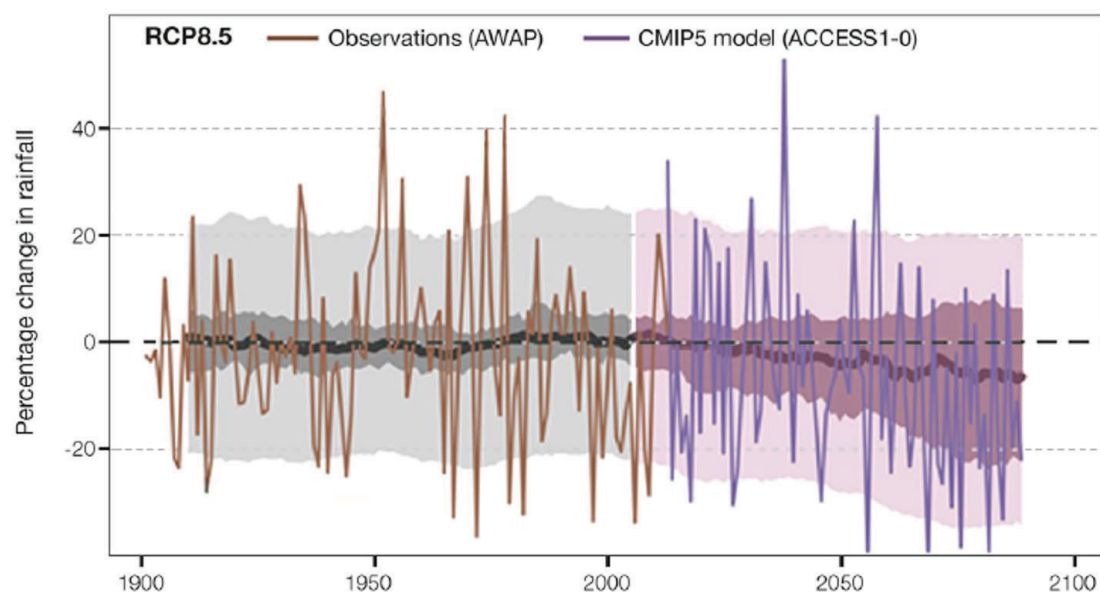


Figure CC.8 Observed annually averaged and simulated historical Victorian rainfall ⁵⁹

Note: Observed annually averaged Victorian rainfall (in brown), and simulated historical Victorian rainfall (in grey), with the deeper shade showing the variability across all available CMIP5 models in the 20-year average. Projections of Victorian rainfall from RCP8.5 are in purple, with shading illustrating the spread across all available CMIP5 models. Dark purple shows the median response. One model's output (ACCESS-1.0) is shown to highlight the year-to-year variability observed in all models.⁶⁰

59. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.

60. Ibid

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:06 Regional climate projections						 DATA QUALITY Good
Data custodian BoM, CSIRO						

As presented in indicators CC:04 (Projected changes in temperature) and CC:05 (Projected changes to average rainfall), climate projections for Victoria have been provided based on data available for three classified regions in Victoria.

Climate Change in Australia projections are reasonably consistent across the three Victorian regions.⁶¹ There is a very high confidence that average temperatures will continue to increase in all seasons, with more hot days and warm spells, while fewer frosts are projected with high confidence.

In south-west Victoria, generally less rainfall is expected in winter and spring, while in the northern areas of the Murray Basin, and in the south-east of the state, changes to rainfall are not expected to exceed natural variability for another few decades. Despite the likely reductions in average rainfall, increased intensity of extreme rainfall events is projected with high confidence.

In 2015, the Department of Environment, Land, Water and Planning (DELWP) produced local data and fact sheets for Victorian towns and regions, based on the climate projections in indicators CC:04 (Projected changes in temperature) and CC:05 (Projected changes to average rainfall).⁶² The fact sheets report on the projected annual number of hot days (over 35°C) and frost days (under 2°C) in selected major Victorian towns and cities, according to different emissions scenarios. These projected hot and frost days are shown in Table CC.3. The number of hot days in most cities and major towns in Victoria is expected to double by 2070, while the number of frost days is expected to halve.

61. Climate Change in Australia, 'Projections for Australia's NRM Regions', <https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters> Accessed 4 December 2018.

62. DELWP, 'Fact sheets about climate change impacts by region', East Melbourne, Victoria <https://www.climatechange.vic.gov.au/information-and-resources> Accessed 4 December 2018.

Table CC.3 Average number of hot and frost days per year for current, 2030 and 2070 scenarios^{63,64,65,66,67,68}

Town	Current hot days	Hot days in 2030	Hot days in 2070		Current frost days	Frost days in 2030	Frost days in 2070	
			(medium emissions – RCP4.5)	(high emissions – RCP8.5)			(medium emissions – RCP4.5)	(high emissions – RCP8.5)
Ballarat	5	8	10	13	36	25	18	10
Bendigo	13	19	23	29	35	25	20	12
Geelong	6	9	11	13	4	2	1	0
Hamilton	8	11	13	16	20	12	8	4
Horsham	18	25	29	36	33	23	17	10
Melbourne	8	12	14	17	3	1	1	0
Mildura	36	46	54	66	14	9	6	3
Orbost	6	9	11	14	6	3	2	1
Shepparton	15	23	29	37	37	27	21	13
Traralgon	6	9	10	14	20	13	8	3
Wodonga	21	31	39	47	40	29	23	13

63. DELWP 2015, 'Barwon South West', East Melbourne, Victoria https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0020/60743/Barwon-South-West.pdf Accessed 4 December 2018.

64. DELWP 2015, 'Gippsland', East Melbourne, Victoria https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0021/60744/Gippsland.pdf Accessed 4 December 2018.







65. DELWP 2015, 'Grampians', East Melbourne, Victoria https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0018/60741/Grampians.pdf Accessed 4 December 2018.

66. DELWP 2015, 'Greater Melbourne', East Melbourne, Victoria https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0019/60742/Greater-Melbourne.pdf Accessed 4 December 2018.

67. DELWP 2015, 'Hume', East Melbourne, Victoria https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0022/60745/Hume.pdf Accessed 4 December 2018.

68. DELWP 2015, 'Loddon Mallee', East Melbourne, Victoria https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0023/60746/Loddon-Mallee.pdf Accessed 4 December 2018.

Sea Level

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:07 Observed sea level						 DATA QUALITY Fair
Data custodian BoM						

Global sea levels rose by about 1.7 mm per year on average last century, with a greater rate of increase observed in recent decades.⁶⁹ Victorian tide gauges show the mean sea level has been increasing around the Victorian coastline, with average increases between 1.59 cm and 3.89 cm per decade between 1993 and 2016.⁷⁰ Melbourne (recorded at Williamstown), which has the longest continuous record of observations in Victoria, has reported an average increase in mean sea level of 1.97 cm per decade (that is, ~2 mm per year) since 1966.⁷¹ This equates to a total rise of 10.2 cm over the past 52 years, which has been accompanied by increases in the frequency of extreme sea-level events.⁷²

Higher maximum annual sea levels increase the hazards of extreme sea levels, such as coastal erosion and flooding, created by natural variability and climate conditions. This is especially the case when large astronomical tides combine with strong winds and low pressures that produce storm surges. There is also significant variability across seasonal-to-interannual timescales associated with drivers such as the El Niño–Southern Oscillation.⁷³

The highest sea level recorded in Melbourne between 1966 and 2016 occurred on 24 June 2014, when the Williamstown gauge recorded values of up to 62 cm above Highest Astronomical Tide (the highest sea level that can be reached by astronomical tides).⁷⁴ This event occurred in

conjunction with a severe storm and caused inundation of many bayside foreshore reserves and coastal infrastructure such as shared-use paths, beach access points and some roads (Figure CC.9).



Figure CC.9 Sand deposited over the bicycle path at Middle Brighton on 24 June 2014

(Photo: Andrew Watkins)

69. BoM and CSIRO 2016, 'State of the Climate 2016', Melbourne, Victoria <http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf> Accessed 4 December 2018.
70. BoM, 'Tide Gauge Metadata and Observed Monthly Sea Levels and Statistics', Melbourne, Australia <http://www.bom.gov.au/oceanography/projects/ntc/monthly/> Accessed 4 December 2018.
71. Ibid
72. Ibid
73. CSIRO and BoM 2015, 'Climate Change in Australia: Technical Report'.
74. BoM, 'Tide Gauge Metadata and Observed Monthly Sea Levels and Statistics', Melbourne, Australia <http://www.bom.gov.au/oceanography/projects/ntc/monthly/> Accessed 4 December 2018.

Annual maximum sea levels at Melbourne have increased, on average, at a rate of 3.37 cm per decade between 1966 and 2016 – a total of 17 cm over the period. However, observed trends have been higher in recent years, with 12 cm of the total 17 cm occurring since 1993 at an average of 5 cm per decade. Similar trends have also been observed at Geelong (2.3 cm per decade from 1965 to 2016). Data collected from shorter-term Australian Baseline Sea Level Monitoring gauges from 1993 to 2016 shows increases at Portland (2.7 cm per decade) and Stony Point (4.2 cm per decade)⁷⁵

The frequency of very high sea levels has also increased, with statistically significant increases in the frequency at which the Highest Astronomical Tide is exceeded at Geelong, Melbourne and Portland.

Recent tidal inundation has mainly occurred when observed sea-level rise has coincided with high astronomical tides (for example, king tides or spring tides).

75. BoM, 'Australian Baseline Sea Level Monitoring Project', Melbourne, Australia <http://www.bom.gov.au/oceanography/projects/abslmp/abslmp.shtml> Accessed 4 December 2018.

Sea Level – Projections

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:08 Projected sea level						 DATA QUALITY Good
Data Custodian BoM, CSIRO						

Sea-level rise is one of the biggest threats associated with climate change to coastal areas. Significant impacts experienced this century are expected to intensify. These include:

- more frequent and extensive inundation of low-lying areas
- loss of coastal habitat, such as roosting and nesting sites for shorebirds and seabirds
- cliff, beach and foreshore erosion
- altered saltmarsh and mangrove habitats.⁷⁶

Thermal expansion of the ocean and melting glaciers and ice caps have been the main causes of rising sea levels worldwide in the past century – a trend that is expected to continue. Australian sea levels are projected to rise for the rest of this century, most likely at a faster rate than for the past four decades.⁷⁷ Higher sea-level rise, driven by the accelerated melting and disintegration of ice shelves and ice sheets in Greenland and Antarctica, is also possible, meaning the ‘worst case’ scenario is sea levels above the high-end of projections presented here.

For Victoria, sea-level projections have been produced for Geelong and Williamstown (Table CC.4). Depending on the emissions scenario, sea levels are likely to rise between 3 cm (low emissions scenario) and 10 cm (high emissions scenario) per decade at Geelong and Williamstown during the rest of this century.

To visualise the possible impacts of coastal inundation, Figure CC.10 shows the areas that would be flooded at Queenscliff in 2100 in a high tide under a high emissions scenario, which assumes a median sea-level rise of 0.74 m.

Table CC.4 Likely ranges for projections of regional sea-level rise (m) relative to 1986–2005 under all emissions scenarios⁷⁸

Locations	2030 m	2050 m	2070 m	2090 m
Geelong	0.06–0.17	0.12–0.33	0.18–0.54	0.22–0.82
Williamstown	0.06–0.17	0.12–0.32	0.17–0.54	0.22–0.81

76. Victorian Coastal Council 2018, ‘Victoria’s coast and marine environments under projected climate change: Impacts, research gaps and priorities’, East Melbourne, Victoria http://www.vcc.vic.gov.au/assets/media/files/Victorian_Coastal_Council_Science_panel_report_WEB.pdf Accessed 4 December 2018.

77. CSIRO and BoM 2015, ‘Climate Change in Australia: Technical Report – Projections for Australia’s NRM regions’, https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/168/CCIA_2015_NRM_TechnicalReport_WEB.pdf Accessed 4 December 2018.

78. Ibid



Figure CC.10 Coastal inundation at Queenscliff in high tide and assuming 0.74 m sea-level rise⁷⁹

An increase in mean sea level will result in a larger increase in the frequency of extreme inundation events. For Australia to maintain the current level of exposure of coastal assets to extreme sea levels, protective barriers would need to be raised by at least 0.7 to 1.0 m by 2100 for a high emissions scenario.⁸⁰

79. CRC for Spatial Information and NGIS, 'Coastal Risk Australia', <http://www.coastalrisk.com.au/>, Accessed 4 December 2018.

80. Climate Change in Australia, 'Projections for Australia's NRM Regions', <https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters>, Accessed 4 December 2018.

Sea Temperature

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:09 Sea-surface temperature						 DATA QUALITY Good
Data custodian BoM, CSIRO						

Oceans play an important role in the global climate system, absorbing more than 90% of the excess heat trapped by GHGs.⁸¹

Globally, the temperature of the ocean near the surface (upper 75 m) has been steadily increasing, by about 0.11°C per decade from 1971 to 2010.⁸² The sea-surface temperature has warmed across the Australian region, with the greatest warming since 1950 around the south-east and to the south-west of Australia (Figure CC.11).

The ocean off the south-east coast of Australia, including the region near eastern Bass Strait, is one of the world's most rapidly warming locations, with a strengthening of the East Australian Current adding to the overall warming trend.^{83, 84}

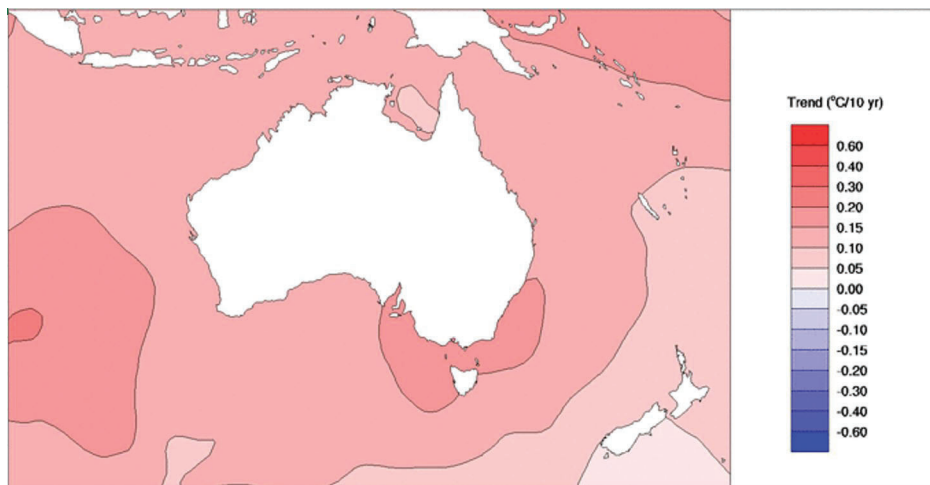


Figure CC.11 Trends in annual Australian region sea-surface temperatures, annual 1950–2017 (°C/10yr)

(Data source: BoM, 2018)

81. Rhein M, Rintoul SR, Aoki S, Campos E, Chambers D, Feely RA, Gulev S, Johnson GC, Josey SA, Kostianoy A, Mauritzen C, Roemmich D, Talley LD, Wang F 2013, 'Observations: Ocean. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change', Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

82. Ibid

83. Hobday AJ, Pecl GT 2014, 'Identification of global marine hotspots: sentinels for change and vanguards for adaptation action', *Reviews in Fish Biology and Fisheries*, 24(2), pp. 415–425.

84. Ridgway KR 2007, 'Long-term trend and decadal variability of the southward penetration of the East Australian Current', *Geophysical Research Letters*, 34(13).

Record-warm sea-surface temperatures have been observed in the Australian region in recent years, with 2016 the warmest year on record.⁸⁵ In the southern region (30°S–46°S, 94°E–174°E), recent years have also been warmer than average, with every year since 2010 in the top 10 warmest years on record for the region (Figure CC.12).

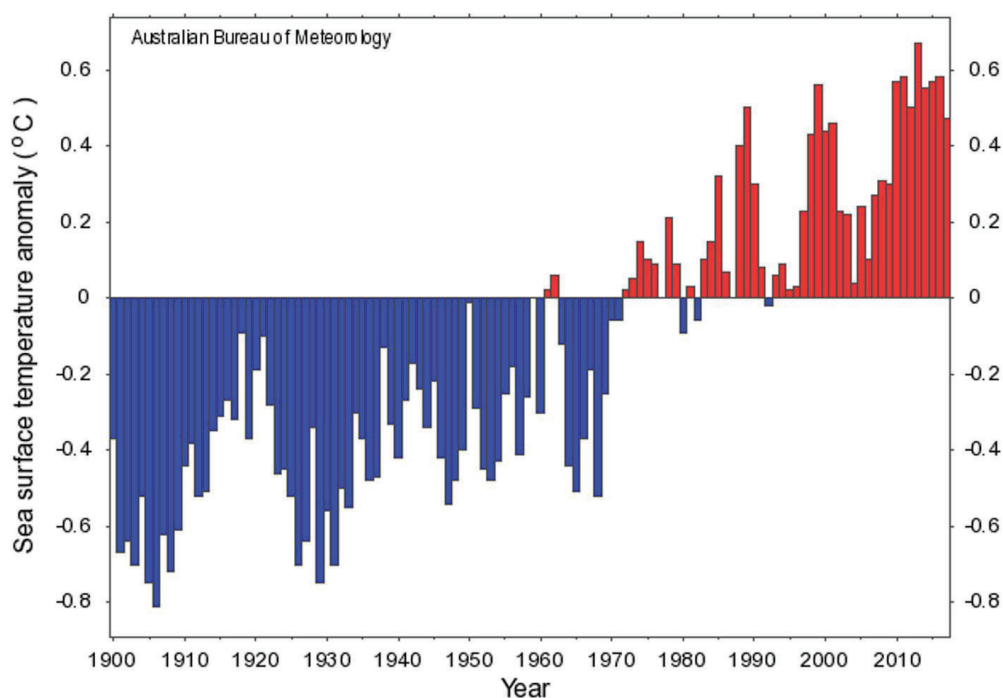


Figure CC.12 Australian sea-surface temperature anomaly – Southern Region, 1900–2017⁸⁶

Background warming of the oceans has led to an increased frequency of marine heatwaves.⁸⁷ Over the summer of 2015 to 2016, an extreme heatwave was observed to the south-east of Victoria in the Tasman Sea. The intensity and duration of the heatwave was increased by climate change and linked to outbreaks of Pacific Oyster Mortality Syndrome in Pacific oysters off the coast of Tasmania.⁸⁸ Background warming and the warmer and less nutrient-dense water from the East Australian Current has led to other impacts in the region, such as an almost complete loss of cold-water kelp forests off Tasmania’s east coast.⁸⁹

85. BoM, ‘Climate change and variability’, Melbourne, Australia <http://www.bom.gov.au/climate/change> Accessed 4 December 2018.
86. Ibid
87. Oliver ECJ et al 2018, ‘Longer and more frequent marine heatwaves over the past century’, *Nature Communications*, 9.
88. Oliver ECJ, Benthuysen JA, Bindoff NL, Hobday AJ, Holbrook NJ, Mundy CN, Perkins-Kirkpatrick SE 2017, ‘The unprecedented 2015/16 Tasman Sea marine heatwave’, *Nature communications*, 8.
89. Bennett S, Wernberg T, Connell SD, Hobday AJ, Johnson CR, Poloczanska ES 2016, ‘The ‘Great Southern Reef’: social, ecological and economic value of Australia’s neglected kelp forests’, *Marine and Freshwater Research*, 67(1), pp.47-56.

Greenhouse Gas Emissions

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:10 Annual greenhouse gas emissions						
Data custodian DELWP	Stable for land sector and Unknown for marine and coastal ecosystems					Good

Despite a relatively small population, Australia is the world's 13th biggest GHG emitter, ahead of countries such as the United Kingdom and France.⁹⁰ Australia's contribution is even more significant at a per capita level: no other country from the Organisation for Economic Co-operation and Development emits more GHGs per person than Australia.⁹¹ Victoria's annual per capita emissions are lower than the national figure of 22 tonnes CO₂-e per person (in 2016), and Victorian per capita emissions have dropped from 24 tonnes CO₂-e per person in 1990 to 18 tonnes CO₂-e per person in 2016 (Figure CC.13).⁹²

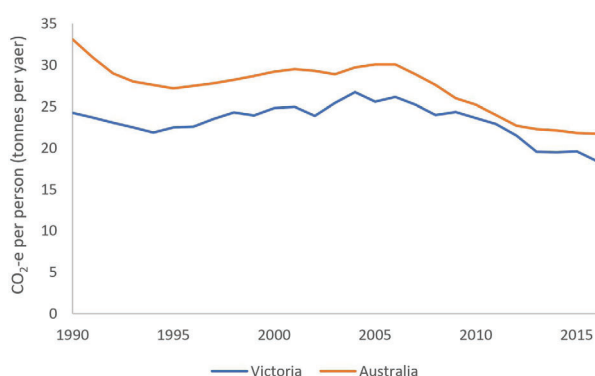


Figure CC.13 Victorian and Australian per capita annual GHG emissions, 1990–2016, including land use, land-use change, and forestry (LULUCF)

(Data source: DELWP, 2018)

In Victoria, carbon dioxide is the most significant GHG, contributing 79% of total emissions in 2016.⁹³ The majority of carbon dioxide emissions come from industry, transport and energy generation. Emissions of methane and nitrous oxide in 2016, mainly from land management and agriculture, also made contributions of 14% and 4% respectively to the total GHG emissions.⁹⁴

The Victorian Government has committed to reducing the state's emissions by 15 to 20% of 2005 levels by 2020.⁹⁵ In 2016, the state's total net GHG emissions were 10.8% lower than in 2005 (but 7.3% higher than in 1990) (Figure CC.14). The reduction on 2005 levels means this indicator has been assessed as improving.

Reductions since 2005 are largely due to improvements in energy efficiency, higher electricity prices (which have reduced electricity demand) and a decline in manufacturing activity.^{96,97} There was a 3.5% reduction between 2015 and 2016 alone, primarily because of an increase in carbon sequestration from the land sector, and a reduction in emissions from the generation of electricity.

90. World Resources Institute, 'Climate Analysis Indicators Tool (CAIT) Climate Data Explorer Historical emissions', Washington, DC, <http://cait.wri.org/historical> Accessed 4 December 2018.
91. Organisation for Economic Co-Operation and Development, 'OECD.stat Greenhouse gas emissions', Paris, France, https://stats.oecd.org/Index.aspx?DataSetCode=AIH_GHG Accessed 4 December 2018.
92. DELWP 2018, 'Victorian Greenhouse Gas Emissions Report 2018', East Melbourne, Victoria https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0033/395079/Victorian-Greenhouse-Gas-Emissions-Report-2018.pdf Accessed 4 December 2018.

93. Australian Department of the Environment and Energy, 'Australian Greenhouse Emissions Information System', Canberra, Australia <http://ageis.climatechange.gov.au> Accessed 4 December 2018.
94. Ibid
95. Department of Environment, Land, Water and Planning, 'Emissions reduction targets', Melbourne, Victoria, <https://www.climatechange.vic.gov.au/reducing-emissions/emissions-targets> Accessed 4 December 2018.
96. DELWP 2017, 'Independent Expert Panel: Interim Emissions Reduction Targets for Victoria (2021-2030)', East Melbourne, Victoria https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0019/121924/Issues-Paper-28-03-2018.pdf Accessed 4 December 2018.
97. DELWP 2018, 'Victorian Greenhouse Gas Emissions Report 2018', East Melbourne, Victoria https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0033/395079/Victorian-Greenhouse-Gas-Emissions-Report-2018.pdf Accessed 4 December 2018.

By 2020, net GHG emissions in Victoria are expected to have dropped by 18% relative to 2005 levels.⁹⁸ The closure in March 2017 of the Hazelwood power station, which emitted about 15 Mt CO₂-e per year, is expected to be the biggest contributor to the reductions between 2005 and 2020.⁹⁹

For further discussion, see the Energy chapter.

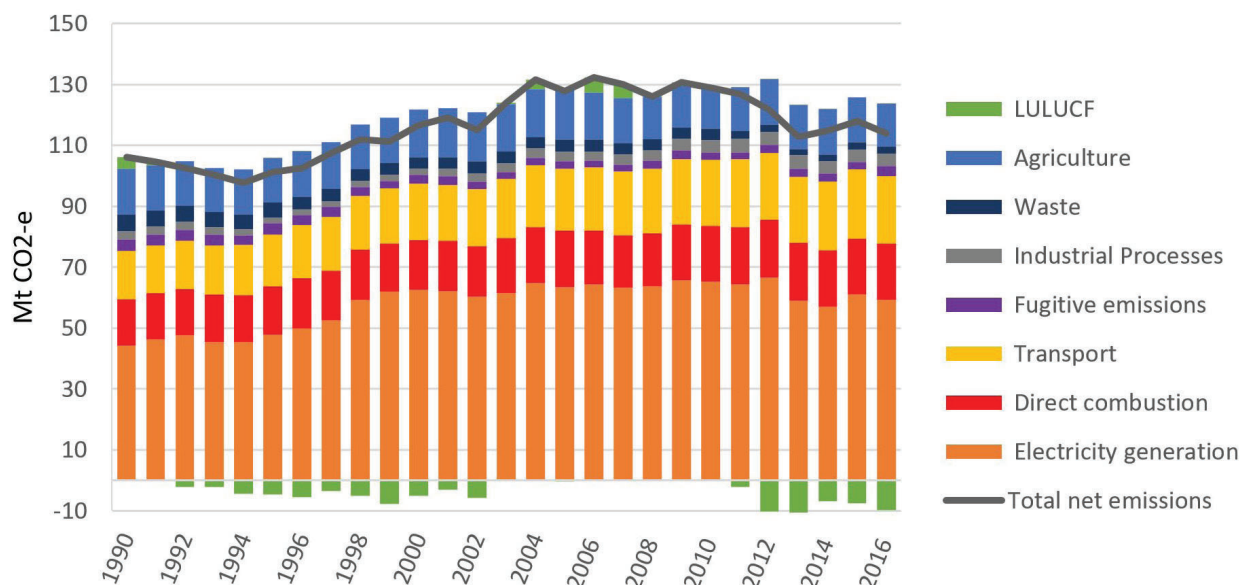


Figure CC.14 Victoria's annual GHG emissions, 1990–2016

(Data source: DELWP, 2018)

The highest contributor to GHG emissions in Victoria in 2016 was the production of electricity, which was responsible for 52% of the state's total emissions (Figure CC.15). The transport sector had the second largest share (20%) and the greatest increase since 1990. The direct combustion of stationary fuels had the third largest share (15%) followed by the agriculture sector (12%). Carbon sequestration from Victoria's land sector offset 9% of total emissions in 2016.

98. Ibid

99. Ibid

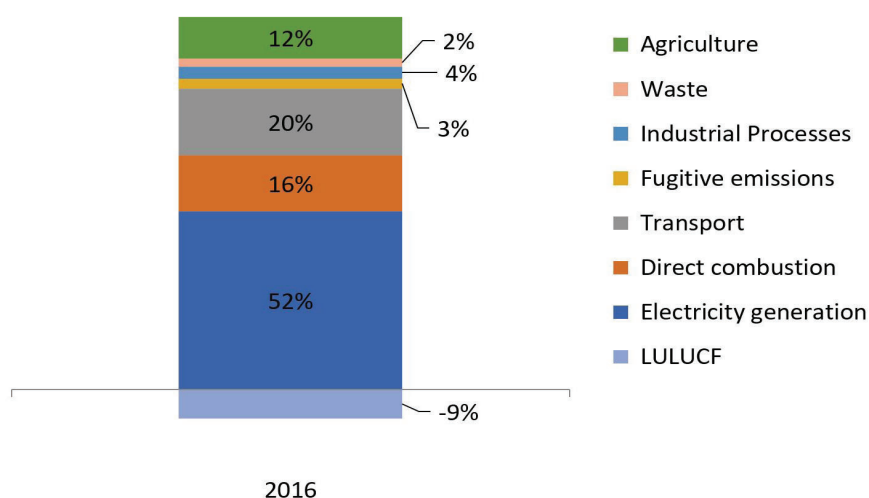


Figure CC.15 Sector GHG emissions percentage contributions in Victoria, including LULUCF, in 2016

(Data source: DELWP, 2018)

Figure CC.16 compares 2016 emissions by sector with emissions in 1990, and the baseline year of 2005 (against which Victoria's emission reduction targets are assessed).¹⁰⁰ Emissions from the electricity, direct combustion, transport and industrial processes sectors all increased between 1990 and 2016. Direct combustion, transport, fugitive and industrial processes emissions were higher in 2016 than in 2005, whereas emissions from other sectors were lower.

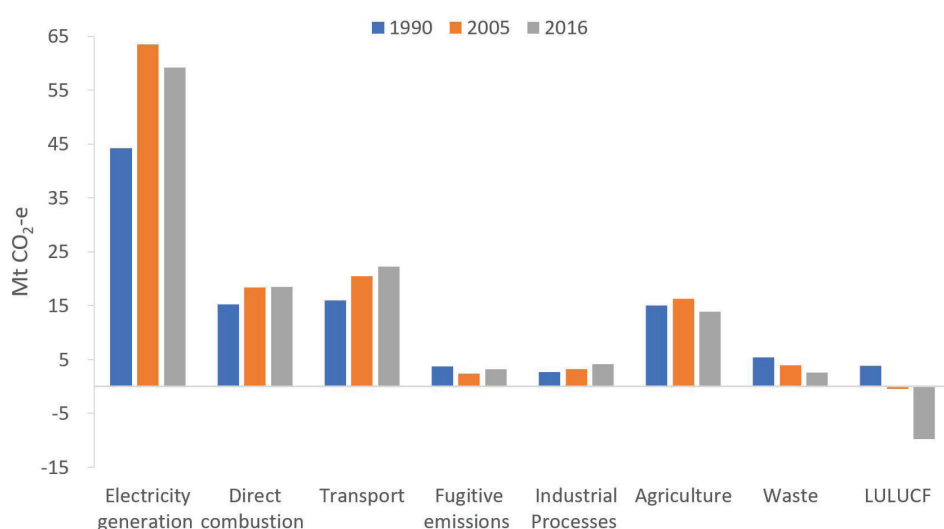


Figure CC.16 Sector GHG emissions in Victoria in 1990, 2005 and 2016

(Data source: DELWP, 2018)

100. Office of the Chief Parliamentary Counsel Victoria 2017, 'Climate Change Act 2017', Melbourne, Victoria [http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/\\$FILE/17-005aa%20authorised.pdf](http://www.legislation.vic.gov.au/Domino/Web_Notes/LDMS/PubStatbook.nsf/f932b66241ecf1b7ca256e92000e23be/05736C89E5B8C7C0CA2580D50006FF95/$FILE/17-005aa%20authorised.pdf) Accessed 4 December 2018.

Transport emissions have grown by 39% in the past 26 years. The sector had the highest proportional increase in emissions in Victoria over this period (Figure CC.17). Road transportation is the major source of emissions from this sector, accounting for 90% of transport emissions in 2016. This is a result of the use of motor vehicles as the main mode of transport for passengers and freight. For further detail about energy and GHG emissions, see the Energy and Transport chapters.

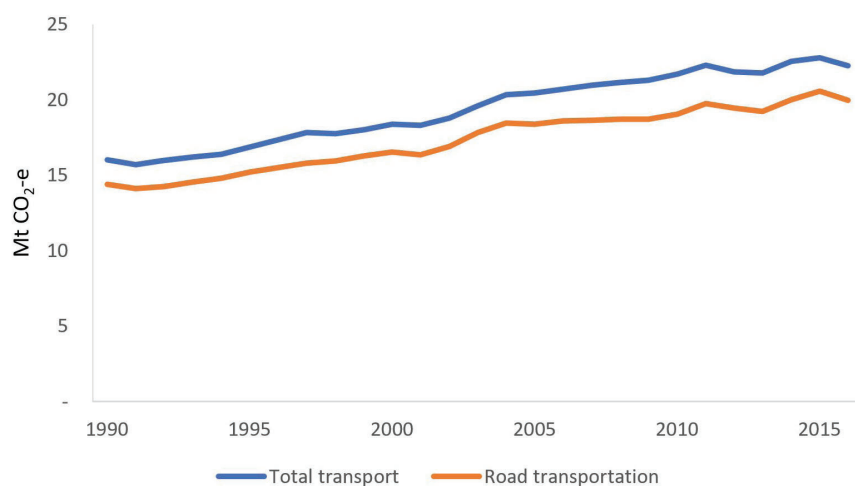


Figure CC.17 Transport GHG emissions in Victoria, 1990–2016

(Data source: DELWP, 2018)

Carbon Storage

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:11 Victorian ecosystem carbon stocks	●	○	●	○	→	<div><div></div></div>
Data custodian DELWP	Stable for land sector and Unknown for marine and coastal ecosystems					DATA QUALITY Fair

This indicator looks at the important role ecosystems play in the global carbon cycle and global GHG balance by storing carbon in both trees and soil. Carbon stocks in Victoria are vulnerable to climatic variation and bushfires, which have temporarily decreased carbon stocks in some areas. This has important implications for the management of Victoria's carbon stocks with the ability of forests to take up carbon vital for the mitigation of climate change.

Victoria's forests store a considerable amount of carbon, but carbon stocks are likely to be impacted by climate change, with increased periods of drought and fire risk. Figure CC.18 shows declines in land sector carbon stocks from 2002 to 2003, and 2006 to 2007, directly attributable to bushfire events – although there has been a consistently upward trend in land sector carbon stocks since 2007.¹⁰¹ The y-axis of the graph in Figure CC.18 has been enlarged to show changes in greater detail, and it is important to note that despite the consistent increase in carbon stocks, the growth from 2007 to 2016 has only been 1%. Based on this small increase, the trend for land sector carbon stocks has been assessed as stable. The growth has been due to net growth of carbon stocks in forests, which is currently occurring at a rate of nearly 2% per year. There has been a decay of carbon stocks in non-forests.

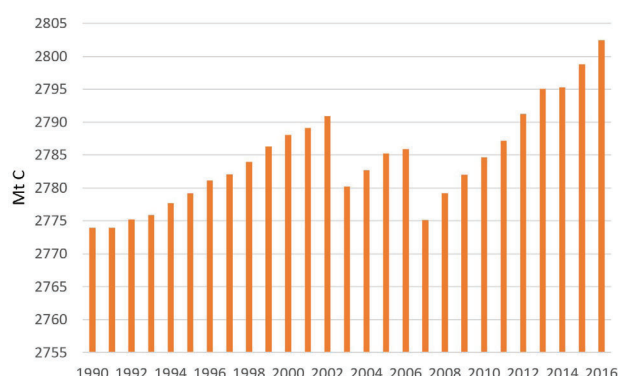


Figure CC.18 Victorian land sector carbon stocks, 1990–2016¹⁰²

Carbon stored in coastal and marine ecosystems is referred to as 'blue carbon'. Potential blue carbon stocks have been estimated at 1,000,000 t in the Port Phillip and Westernport catchment.¹⁰³ For further detail on blue carbon, see the Marine and Coastal Environments chapter.

101. Australian Department of the Environment and Energy, 'State and Territory Greenhouse Gas Inventories 2016', Canberra, Australia <http://www.environment.gov.au/system/files/resources/a97b89a6-d103-4355-8044-3b123e8bab6/files/state-territory-inventories-2016.pdf> Accessed 4 December 2018.

102. Ibid

103. Carnell P et al 2015, 'The distribution and abundance of 'Blue Carbon' within Port Phillip and Westernport', Deakin University, Melbourne, Victoria.

Impacts of Climate Change

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:12 Occurrence and impacts of extreme weather						
Data custodian BoM, CSIRO, DHHS, EMV						Good

Extreme weather affects the frequency and intensity of natural disasters in Australia. The types of natural disasters that occur in Australia are many and varied, ranging from severe thunderstorms, hail storms and floods to heatwaves, bushfires and droughts.

Research has found that heatwaves cause more deaths than any other natural disaster in Victoria,¹⁰⁴ with another study estimating there will be an extra 400 deaths per year in Victoria by 2050 due to heatwaves, if no adaptation measures are taken.¹⁰⁵ A warmer climate has coincided with an increase in the number of extreme heat events in Victoria. There has been a significant increase in the number of days per year when Victorian temperatures are unusually warm (Figure CC.19) – defined as those above the 99th percentile of each month from the years 1910 to 2015.¹⁰⁶

This century has not seen a year without at least one extreme heat event, compared to the start of the record, which contains many years without extreme events. As described in indicator CC:06 (Regional climate projections), the number of hot days (over 35°C) per year in most cities and major towns in Victoria is expected to double by 2070.

The Department of Health and Human Services (DHHS) operates a heat health alert system.¹⁰⁷ During the summer of 2016 to 2017 (between the start of November 2016 and the end of March 2017), DHHS issued 23 heat health alerts for six

days of extreme heat across multiple districts. In the summer of 2015 to 2016, DHHS issued 33 heat health alerts for 10 days of extreme heat.¹⁰⁸ The impacts of extreme heat can be catastrophic, particularly during multiday heatwaves with oppressive overnight weather. In Victoria, during a January 2009 heatwave, there were 374 'excess' deaths (over what would be expected). The majority of those deaths occurred in people aged 75 and older. There were also an estimated 167 excess deaths during a January 2014 heatwave.^{109, 110}

Heat stress can also significantly affect tree-dwelling and nocturnal wildlife such as possums, koalas and birds, while grey-headed flying foxes are particularly prone to heat stress.¹¹¹

Increased probability of extreme rainfall events in a given season can be predicted with reasonable accuracy months in advance when La Niña, negative Indian Ocean Dipole and high Southern Annular Mode align in spring. These predictions can be used for improved management of Victorian water resources.

BoM predicted the extreme rainfall across eastern Australian in spring 2010 up to one season in advance.¹¹² BoM also issues more immediate flood watches and warnings for most major rivers in Australia. A flood watch provides early advice of potential flooding, while a flood warning is issued when flooding is occurring or expected to occur. From July 2015 to June 2017, BoM issued

104. Steffen W, Hughes L, Perkins S 2014, 'Heatwaves: Hotter, Longer, More Often', Climate Council of Australia Limited, Potts Point, New South Wales.
105. Keating A, Handmer J 2013, 'Future potential losses from extremes under climate change: the case of Victoria, Australia', Victorian Centre for Climate Change Adaptation Research, Melbourne, Victoria.
106. BoM and CSIRO 2016, 'State of the Climate 2016', Melbourne, Victoria <http://www.bom.gov.au/state-of-the-climate/State-of-the-Climate-2016.pdf> Accessed 4 December 2018.
107. Department of Health and Human Services 2017, 'Heat health alert system', Melbourne, Victoria.

108. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, <https://files-em.vic.gov.au/public/EMV-web/OpsReview2017.pdf> Accessed 4 December 2018.
109. Department of Human Services 2009, 'January 2009 Heatwave in Victoria: an Assessment of Health Impacts', Melbourne, Victoria.
110. Department of Health 2014, 'The health impacts of the January 2014 heatwave in Victoria', Melbourne, Victoria.
111. DELWP, 'Heat stress in wildlife', East Melbourne, Victoria <https://www.wildlife.vic.gov.au/wildlife-emergencies/heat-stress-in-wildlife2> Accessed 4 December 2018.
112. Hope P, Timbal B, Hendon H, Ekström M, Potter N 2017, 'A synthesis of findings from the Victorian Climate Initiative (VicCI)', BoM, Australia.

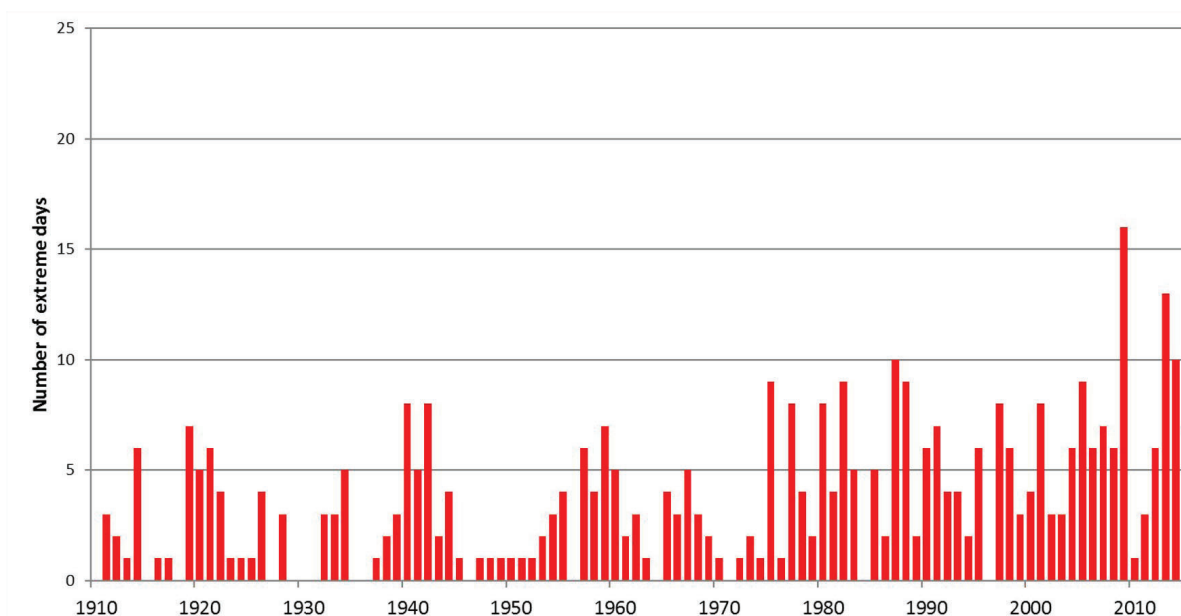


Figure CC.19 Days per year when Victorian averaged daily mean temperature is 'unusually warm' – above the 99th percentile of each month, 1910–2015

(Data source: BoM)

nearly 1,300 flood watches and flood warnings for Victoria. About two-thirds of these flood watches and warnings were issued in spring 2016, when substantial amounts of rain fell across the state and led to flooding.¹¹³ No trend on flood watches and flood warnings could be determined based on the limited period of this dataset.

With increased nutrient runoff from land practices, warmer temperatures and reduced flows, the prevalence of algal blooms is expected to increase. A recent example of such an event is the blue-green algae event in the Murray River in February 2016.¹¹⁴

Environmental conditions that encourage mosquito breeding, such as heavy rainfall, floods, high tides and warm temperatures, can lead to outbreaks of Ross River virus, a disease spread by mosquitos that can cause joint inflammation and pain, fatigue and muscle aches.¹¹⁵ The recent wetter rainfall years have been linked to increased

incidences of Ross River virus. A record number of notifications of Ross River virus infection were recorded in 2017 (mostly during January and February) associated with a wetter 2016 in Victoria.¹¹⁶ A similar spike was recorded in the early months of 2011, coinciding with heavy rainfall during the summer of 2010 to 2011.

There is a clear trend towards more dangerous weather conditions for bushfires in south-east Australia, including significant increases in the frequency and magnitude of extreme conditions in some regions. The Forest Fire Danger Index (FFDI) is used throughout Victoria by fire agencies to plan and manage resources in response to the risk of bushfires. The FFDI is based on temperature, rainfall, humidity and wind speed. FFDI patterns have changed over recent decades, with the strongest increases in fire danger generally in summer and spring. Changes to the springtime pattern indicate a shift towards an earlier start to the fire season. These changes are attributable, at least in part, to increasing temperatures associated with anthropogenic climate change.¹¹⁷

113. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, <https://files-em.vic.gov.au/public/EMV-web/OpsReview2017.pdf> Accessed 4 December 2018.

114. Emergency Management Victoria 2016, 'Year in Review 2015-16', Melbourne, Victoria, <https://files-em.vic.gov.au/public/EMV-web/EMV-Year-in-Review-2015-2016.pdf> Accessed 4 December 2018.

115. Department of Health and Human Services 2018, 'Ross River virus disease', Melbourne, Victoria <https://www.betterhealth.vic.gov.au/health/ConditionsAndTreatments/ross-river-virus-disease?viewAsPdf=true> Accessed 4 December 2018.

116. Australian Department of Health, 'National Notifiable Diseases Surveillance System', Canberra, Australia <http://www9.health.gov.au/cda/source/cda-index.cfm> Accessed 4 December 2018.

117. Dowdy AJ 2018, 'Climatological variability of fire weather in Australia', *Journal of Applied Meteorology and Climatology*, 57(2), pp. 221-234.

Currently, natural disasters cost Victoria an estimated \$1 billion per year, on average. Population growth, concentrated infrastructure density and migration to more vulnerable parts of the state means this expense is forecast to grow by 3.4% per year. By 2050, the estimated cost is expected to be \$3.2 billion. This projection does not include the impacts of climate change, so the actual cost is likely to be much higher.¹¹⁸

Since publication of SoE 2013, notable natural disasters due to extreme weather have included:

- January 2014 heatwave. Across four consecutive days from 14 to 17 January 2014, Melbourne recorded maximum temperatures above 41°C, while other parts of the state recorded temperatures of 45°C or more on three consecutive days. There were an estimated 167 excess deaths during the heatwave – a 24% increase in mortality. By contrast, during a heatwave in January 2009, a 62% increase in mortality was observed. The introduction of a heatwave plan for Victoria in 2011 may have contributed to the decrease in estimated excess mortality in 2014.¹¹⁹
- December 2015 and January 2016 bushfire in Wye River. A fire that started by lightning strike in the Otway National Park near Lorne broke containment lines during strong northerly winds on Christmas Day, travelling rapidly towards coastal townships. During the next week, communities from Wye River, Separation Creek, Kennett River, Grey River and Wongarra were evacuated and the Great Ocean Road was closed. The fire remained active until 15 January 2016; 116 properties were destroyed.¹²⁰
- Spring 2016 floods. Extensive rainfall was experienced across the state on 8 September 2016, with significant impacts to communities on 13 and 14 September 2016. Widespread flooding occurred in the following catchments: Barwon South West, Grampians, Loddon Mallee, and Hume, and parts of the Metropolitan Regions. The cost of damage to essential public assets was estimated to be more than \$115 million.¹²¹
- November 2016 epidemic thunderstorm asthma event. Epidemic thunderstorm asthma is thought to be triggered by an uncommon combination of high grass-pollen levels and a certain type of thunderstorm. On the evening of 21 November 2016, a severe thunderstorm moved from Geelong and passed through Melbourne. An epidemic thunderstorm asthma event, unprecedented in size and severity, occurred immediately following the storm. The event was associated with a 681% increase in asthma-related admissions to all Victorian public hospitals in the 30 hours from 6 pm on 21 November 2016. It is thought to have contributed to the deaths of 10 people.^{122, 123, 124}

118. Deloitte Access Economics 2017, 'Building resilience to natural disasters in our states and territories', Sydney, New South Wales <https://www2.deloitte.com/content/dam/Deloitte/au/Documents/Economics/deloitte-au-economics-building-resilience-natural%20disasters-states-territories-161117.pdf> Accessed 4 December 2018.

119. Department of Health 2014, 'The health impacts of the January 2014 heatwave in Victoria', Melbourne, Victoria.







120. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, <https://files-em.vic.gov.au/public/EMV-web/OpsReview2017.pdf> Accessed 4 December 2018.

121. Ibid

122. Department of Health and Human Services 2017, 'The November 2016 Victorian epidemic thunderstorm asthma event: an assessment of the health impacts – The Chief Health Officer's Report, 27 April 2017', Melbourne, Victoria.

123. Emergency Management Victoria 2017, 'Emergency Management Operational Review 2016-17', Melbourne, Victoria, <https://files-em.vic.gov.au/public/EMV-web/OpsReview2017.pdf> Accessed 4 December 2018.

124. The Age, 'Coronial investigation uncovers tenth thunderstorm asthma death', <https://www.theage.com.au/national/victoria/coronial-investigation-uncovers-tenth-thunderstorm-asthma-death-20171018-gz3j59.html> Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:13 Extent and condition of key climate-sensitive ecosystems						 DATA QUALITY Fair
Data custodian DELWP, Parks Victoria						

Some ecosystems are more sensitive to a changing climate than others. Vulnerable ecosystems include those in the mountains, along the coast, in cool-temperature rainforests and in freshwater and wetlands. Species such as seagrass, and certain fish, birds and plants, are particularly sensitive to a changing climate. Changes in the extent and condition of these ecosystems could serve as an indicator of changes in climate risk to natural ecosystems.¹²⁵

As climate change intensifies, existing pressures on Victoria's biodiversity will be amplified and new threats will emerge. The primary climate change impacts expected to affect biodiversity are:

- increased frequency and severity of some types of extreme weather events
- increased frequency and intensity of bushfires and drought
- rising sea levels
- changes in ocean temperatures, currents and ocean acidification
- changes to waterway flows, levels and regimes
- shifts in the range, distribution, abundance and seasonality of species, particularly in association with phenology changes
- changes in the range, distribution and impacts of introduced plants and animals, including the introduction of new pests taking advantage of a changed climate.¹²⁶

Victoria has been experiencing biodiversity loss, partly due to reduced resilience under climate change. An example of this is repeated fires in the Victorian alpine region inhibiting the regrowth of alpine ash trees.¹²⁷ The increase in fire danger weather in recent decades has been linked to anthropogenic climate change.¹²⁸ At a national level, changes to phenology are now being measured, with the plant and flowering cycle starting earlier by 9.7 days per decade.¹²⁹ Earlier and prolonged flowering of Victoria's plants has been linked to an increase in the occurrence of asthma, hay fever, allergic conjunctivitis and eczema.¹³⁰

Recent research has found climate change is likely to exacerbate the impacts of invasive terrestrial and inland aquatic species.¹³¹ See the Biodiversity chapter for discussion of how climate change has been found to be contributing to ecological declines at some Ramsar sites.

125. Australian Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education 2013, 'Climate Adaptation Outlook: A proposed national adaptation assessment Framework', Canberra, Australia <https://www.environment.gov.au/system/files/resources/e70b19e5-e378-499b-8ae3-cbb42875328c/files/climate-adaptation-outlook.pdf> Accessed 4 December 2018.

126. DELWP 2017, 'Protecting Victoria's Environment – Biodiversity 2037', East Melbourne, Victoria https://www.environment.vic.gov.au/_data/assets/pdf_file/0022/51259/Protecting-Victorias-Environment-Biodiversity-2037.pdf Accessed 4 December 2018.

127. Bassett OD, Prior LD, Slijkerman CM, Jamieson D, Bowman DMJS 2015, 'Aerial sowing stopped the loss of alpine ash (*Eucalyptus delegatensis*) forests burnt by three short-interval fires in the Alpine National Park, Victoria, Australia', *Forest Ecology and Management*, 342, pp. 39–48.

128. Dowdy AJ 2018, 'Climatological variability of fire weather in Australia', *Journal of Applied Meteorology and Climatology*, 57(2), pp. 221–234.

129. Chambers LE et al 2013, 'Phenological Changes in the Southern Hemisphere', *PLoS ONE*, 8(10).

130. Commissioner for Environmental Sustainability 2012, 'Climate Change Victoria: the science, our people and our state of play', Melbourne, Victoria.

131. White M, Cheal D, Carr GW, Adair R, Blood K, Meagher D 2018, 'Advisory list of environmental weeds in Victoria', *Arthur Rylah Institute for Environmental Research Technical Report Series No. 287*, DELWP, Heidelberg, Victoria.

Surveys of species richness and species' ecological attributes at multiple sites (including Ramsar) over different years conclude that native fauna have little if any predictable resilience to significant changes in crucial environmental factors. Examples of this research include a 2015 study that found the majority of bird species in floodplain forest in south-eastern Australia declined substantially during drought conditions between 1998 and 2009, with only a very small minority increasing in prevalence by 2013 after the drought broke and rainfall increased.¹³²

A 2018 study found bird species in locations with high vegetation greenness are more resistant to severe drought.¹³³ This research discusses the effectiveness of prioritising conservation investments in areas with locally high vegetation productivity to increase the resistance of bird species to extreme drought.¹³⁴

Efforts to ensure the ecological health of Corner Inlet by protecting the broadleaf seagrass species *Posidonia australis* is an example of recent work to protect Victoria's biodiversity against the impacts of climate change. Corner Inlet is the only area of Victoria where *Posidonia australis* forms. A native purple sea urchin species – *Heliocidaris erythrogramma* – had been multiplying at Nooramunga Marine and Coastal Park in Corner Inlet. The sea urchin species was eating the seagrass at Coastal Park and creating bare patches that were expected to increase in size without management action.¹³⁵ Parks Victoria undertook work to reduce the number of sea urchins in the affected area, most notably working with the Victorian Fisheries Authority and a dedicated group of volunteers to snorkel through the shallow waters and hand-cull more than 57,000 urchins.¹³⁶ This work was deemed successful,

with evidence of seagrass returning in the areas where the urchins were culled.¹³⁷ The distributional range of black sea urchins is also believed to be expanding, driven by climate-related changes to the East Australian Current.¹³⁸

Another example of research of a climate-sensitive ecosystem can be found in Victoria's alpine region, where Arthur Rylah Institute have been mapping alpine sphagnum bogs across their 10,000 km² range in the high country for more than a decade.¹³⁹ Alpine sphagnum bogs contribute to plant and animal diversity in Australia's high country and provide significant benefits to the environment by storing carbon and filtering out sediments, nutrients and pathogens from water.¹⁴⁰ Alpine sphagnum bog mapping has been produced as a spatial dataset. This dataset is a key resource for land managers that are mitigating and adapting to the challenges posed by climate change and other threats, especially increased fire, deer and feral horses.¹⁴¹ However, very few vegetation communities are mapped as comprehensively as alpine sphagnum bog, so this degree of informed land management is not available for other parts of the state.¹⁴² The value of alpine sphagnum bog mapping was shown during the 2018 Tamboritha fire, when Parks Victoria accessed mapping to minimise damage to bogs during fire suppression activities, preserving the internationally significant Caledonia Fen.¹⁴³

132. Selwood KE, Clarke RH, Cunningham SC, Lada H, McGeoch MA, Mac Nally R 2015, 'A bust but no boom: responses of floodplain bird assemblages during and after prolonged drought', *Journal of Animal Ecology*, 84(6), pp. 1700-1710.

133. Selwood KE, McGeoch, Clarke RH, Mac Nally R 2018, 'High-productivity vegetation is important for lessening bird declines during prolonged drought', *Journal of Applied Ecology*, 55(2), pp. 641-650.

134. Ibid

135. Crockett P, Johnson K, Brenker M, Ierodiaconou D, Carnell P 2017, 'Undaria pinnatifida in Port Phillip Bay Marine Sanctuaries: Removal strategies and interactions with the native algal canopy', *Parks Victoria Technical Series No. 113*, Parks Victoria, Melbourne, Victoria.

136. Parks Victoria, 'Protecting seagrass meadows from sea urchin attack', Melbourne, Victoria, <http://parkweb.vic.gov.au/about-us/news/protecting-seagrass-meadows-from-sea-urchin-attack> Accessed 4 December 2018.

137. Ibid

138. Victorian Fisheries Authority, 'Sea urchin', <https://vfa.vic.gov.au/about/publications-and-resources/status-of-victorian-fisheries/sea-urchin> Accessed 4 December 2018.

139. Arthur Rylah Institute, 'Alpine Sphagnum bogs: if we map them we can manage them', Heidelberg, Victoria, <https://www.ari.vic.gov.au/research/wetlands-and-floodplains/alpine-sphagnum-bogs-if-we-map-them-we-can-manage-them> Accessed 4 December 2018.

140. Ibid

141. Ibid

142. Ibid

143. Ibid

Further research completed since SoE 2013 shows birds are more resistant to severe drought in locations with high vegetation productivity.¹⁴⁴ Floodplains are potential refuge areas for biota during drought, as they have greater water availability through shallow groundwater and flooding.¹⁴⁵ The white-naped honeyeater (*Melithreptus lunatus Vieillot*), grey currawong (*Strepera versicolor Latham*) and golden whistler (*Pachycephala pectoralis Latham*) are examples of species that have shown a tendency to use floodplain forests for drought refuge.¹⁴⁶ Vegetation greenness is an important factor for biodiversity due to a more reliable water availability and sheltering from topography, with the provision of environmental water an important part of this process.^{147, 148}






144. Selwood KE, McGeoch, Clarke RH, Mac Nally R 2018, 'High-productivity vegetation is important for lessening bird declines during prolonged drought', *Journal of Applied Ecology*, 55(2), pp. 641-650.

145. Selwood KE, Thomson JR, Clarke RH, McGeoch MA, Mac Nally R 2015, 'Resistance and resilience of terrestrial birds in drying climates: do floodplains provide drought refugia?', *Global Ecology and Biogeography*, 24, pp. 838-848.

146. Ibid

147. Selwood KE, Clarke RH, McGeoch MA, Mac Nally R 2017, 'Green Tongues into the Arid Zone: River Floodplains Extend the Distribution of Terrestrial Bird Species', *Ecosystems*, 20(4), pp. 745-756.

148. Horner GJ, Cunningham SC, Thomson JR, Baker PJ, MacNally R 2016, 'Recruitment of a keystone tree species must concurrently manage flooding and browsing', *Journal of Applied Ecology*, 53, pp. 944-952.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:14 Community awareness of climate risks and associated responsibilities					?	
	Good (for awareness of climate risks and mitigation) and Unknown (for adaptation to climate change)					DATA QUALITY Fair
Data custodian Sustainability Victoria						

Victorians' knowledge and awareness of climate change and its associated risks is an important marker of the state's successful climate change adaptation and mitigation. Public engagement and participation are crucial to create change to address global problems such as climate change.¹⁴⁹ This indicator also describes current actions of Victorians to reduce the effects of climate change.

Sustainability Victoria commissioned a social research study, conducted over 2016 and 2017, that aimed to gain baseline data on Victorian residents' attitudes, beliefs and behaviours in relation to climate change.¹⁵⁰ The results of this study have been used to inform the assessment of this indicator.

The study suggested most Victorians accept that climate change is influenced by human activities. More than 90% of those surveyed agreed there is some level of human causation. The other respondents believed that either climate change is due entirely to natural processes or there has been no climate change.

Nearly 80% of respondents were concerned about climate change. Their main areas of concern were:

- water shortage and drought (72% of respondents were concerned about this)
- crop failures (71%)
- severe bushfires (68%)
- air pollution (68%)
- heatwaves (67%)
- severe storms and floods (65%)
- coastal erosion (51%).

Most respondents (78%) supported the Victorian Government's target of net zero GHG emissions by 2050. Even more (84%) supported the associated targets of 25% of power to be generated by renewable energy sources by 2020 and 40% by 2025.

The survey results also point to the opportunity and incentive for businesses to act on climate change, with nearly three-quarters of respondents preferring to buy goods and services from businesses that show they care about climate change.

149. Weaver C et al 2014, 'From global change science to action with social sciences', *Nature Climate Change*, 4, pp. 656-659.

150. Sustainability Victoria 2017, 'Victorians' perceptions of climate change', Melbourne, Victoria <http://www.sustainability.vic.gov.au/-/media/SV/Publications/About-Us/Research/Victorians-perceptions-of-climate-change/Victorians-Perceptions-of-Climate-Change.pdf> Accessed 4 December 2018.

Management

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:15 Councils (or other organisations) with urban forestry plans or urban greening or cooling-related strategies						 DATA QUALITY Fair
Data custodian: Resilient Melbourne, The Nature Conservancy						

Rezoning and infill development are resulting in less green space and higher population densities across major population centres in Victoria, particularly in inner and middle Melbourne. On Melbourne's fringes, new suburbs are being built on arable land and areas of remnant native vegetation. Where rain once soaked easily into permeable soils, reducing peak streamflows and the risk of flash floods, hard surfaces such as roofs and roads now dominate. These same hard surfaces, unshaded by vegetation, also absorb the sun's heat and contribute to daily inner metropolitan temperatures that can peak up to 7°C higher than those in surrounding rural areas.¹⁵¹

This urban expansion is occurring in the context of climate change, which is likely to cause greater impacts from heatwaves, droughts and extreme rainfall. While the effects of these phenomena will be widespread, they can disproportionately affect those already vulnerable, including older residents, people who are unwell, and the financially disadvantaged.

Urban forestry planning is an emerging area of research in Victoria. Of the 32 councils in metropolitan Melbourne, 13 councils have developed, or are developing, urban forestry strategies. Some regional councils, such as Geelong and Ballarat, have also developed urban forestry strategies. The need for these plans and strategies is clear: some of Melbourne's local government areas already have among the lowest urban tree canopy ratios in Australia.¹⁵²

The development of urban forestry plans by some councils is encouraging. But work by The Nature Conservancy and Resilient Melbourne on a Melbourne Metropolitan urban forest strategy is expected to bring widespread benefits that cannot be achieved by individual councils, suburbs, infrastructure operators or neighbourhoods in isolation. The strategy is expected to be launched in 2019.

Discussion of green infrastructure was prominent throughout Infrastructure Victoria's 30-year infrastructure strategy, released in 2016.¹⁵³ Green infrastructure is described in that strategy as the network of natural and built landscape assets, including green spaces and water systems within and between settlements. The strategy noted that the delivery of green infrastructure can often be ad hoc and opportunistic. It recommended an increase in the amount and quality of green infrastructure in urban settings over the next 30 years and the production of a statewide green infrastructure plan in partnership with local government, leveraging opportunities to unlock restricted public land held by, for example, water or transport authorities.¹⁵⁴

151. AM Coutts, J Beringer, S Jimi, NJ Tapper 2009, 'The Urban Heat Island in Melbourne: Drivers, Spatial and Temporal Variability, and the Vital Role of Stormwater', https://www.clearwater.asn.au/user-data/resource-files/Urban_Heat_Island_in_Melbourne2009.pdf Accessed 4 December 2018.

152. Horticulture Australia Ltd 2014, 'Benchmarking Australia's Urban Tree Canopy: An i-Tree Assessment', Sydney, New South Wales.

153. Infrastructure Victoria 2016, 'Victoria's 30-year infrastructure strategy', Melbourne, Victoria, <http://www.infrastructurevictoria.com.au/sites/default/files/images/IV%2030%20Year%20Strategy%20WEB%20V2.PDF> Accessed 4 December 2018.

154. Ibid

In addition to a range of amenity and biodiversity benefits, a greener Melbourne means:

- shadier, cooler metropolitan areas
- lower flood risk for people and assets
- less storm water and nutrients entering waterways, including Port Phillip Bay.

A greener environment also benefits human health. Research has shown that greener cities can reduce mortality, improve general health and wellbeing, increase physical activity and reduce violence.^{155, 156}

155. Kondo MC, Fluehr JM, McKeon T, Branas CC 2018, 'Urban Green Space and Its Impact on Human Health', *International Journal of Environmental Research and Public Health*, 15(3), 445.

156. Bowen KJ, Parry M 2015, 'The evidence base for linkages between green infrastructure, public health and economic benefit', *Paper prepared for the project Assessing the Economic Value of Green Infrastructure*.

Indicator	Status	Trend	Data Quality
	UNKNOWN POOR FAIR GOOD		
CC:16 Considering climate change risks in land use planning (including in the coastal zone)	<div> <div></div> <div></div> <div></div> <div></div> </div> <p>Generally Poor for inland councils and Fair for coastal councils</p>	?	<div> <div></div> <div></div> </div> <p>DATA QUALITY Fair</p>
Data custodian DELWP			

This indicator is designed to report on management actions to reduce the impacts of climate change. DELWP has supplied data that categorises each Victorian council's incorporation of climate change into land-use planning decisions. The data was generated by making qualitative assessments of publicly available corporate governance documents. Figure CC.20 shows that 14% of all Victorian councils integrate climate change into land-use planning at a level considered high or advanced, while 65% of councils consider climate change at only a basic level, or not at all, during land-use planning. There is a strong pattern when comparing inland and coastal councils, with coastal councils three times more likely to have an intermediate, high or advanced consideration of climate change in land-use planning than inland councils (Figure CC.20).

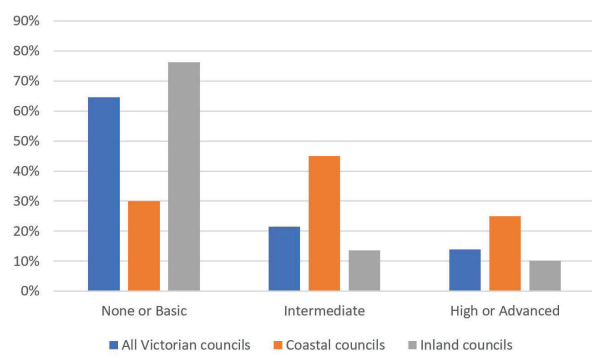


Figure CC.20 Percentage of Victorian councils that integrate climate change into land-use planning

Note: Results are shown by council type (coastal or inland) and level of integration (none or basic, intermediate, high or advanced).

(Data source: DELWP, 2018)

Further information on the integration of climate change into land-use planning was generated as part of DELWP's engagement with local governments during the development of the *Victorian Climate Change Adaptation Plan 2017–2020*.¹⁵⁷







There is strong agreement across local councils, particularly coastal councils, that land-use planning needs to be informed by up-to-date climate science. As part of this feedback provided by councils, DELWP commissioned a Victorian Coastal Hazard Assessment that analysed the likely impacts of anticipated climate change on the Victorian coastline.¹⁵⁸ The assessment provided ratings for vulnerability to coastal erosion, sea-level rise and storm surge across Victorian coastal areas and coastal priority assets.

Council planners have also expressed strong support for regulatory change to allow for better consideration of climate change impacts in land-use planning.¹⁵⁹ Despite the absence of quantitative data, this support suggests that councils are already aware of the importance of climate change considerations in land-use planning.

The links between climate change and land-use planning extend to the alpine regions. As discussed in indicator CC:02 (Snow cover), a decline in snow accumulation has been observed at several locations across the Victorian Alps, with further reductions expected this century. The alpine resort community is already adapting to the changing landscape, with more focus on year-round activities to ensure long-term business viability. These activities include the development of mountain-biking and walking trails. There have also been developments of other sustainable operations including water recycling and treatment systems, waste recovery processes, renewable energy systems and programs to protect the sensitive alpine ecosystems.

157. Department of Environment, Land, Water and Planning 2016, 'Local Government Engagement on Victoria's Climate Change Adaptation Plan 2017 – 2020', Melbourne, Victoria, https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0015/73050/2017-Local-Government-Input-in-Adaptation-Plan_final.pdf.

158. Spatial Vision 2017, 'Victorian Coastal Hazard Assessment 2017', https://www.coastsandmarine.vic.gov.au/_data/assets/pdf_file/0021/122709/VCHA2017_R1_Victorian_Coastal_Hazard_Assessment_2017_Final_R1compressed.pdf Accessed 4 December 2018.

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
CC:17 Percentage of agri-businesses using long-term weather and climate change projections						 DATA QUALITY Fair
Data custodian DEDJTR						

This indicator aims to provide a measure of agricultural management actions to adapt to a changing climate.

Victoria has a large agricultural sector, valued at more than \$13 billion. There are almost 31,000 farm businesses employing about 80,000 people and operating across more than 12 million hectares of farmland.¹⁶⁰ The agricultural industry is sensitive to changes in climate: Victorian agriculture yields are generally forecast to decline in coming years in the absence of climate change adaptation measures.¹⁶¹

Understanding climate variability can assist growers to take financial advantage of better-than-average years and manage risk in drier years. Since 2005, Agriculture Victoria has published a newsletter explaining climate conditions to primary producers. The newsletter, distributed to more than 3,000 subscribers, helps farmers to make better use of seasonal climate forecasts. As of 2018, Agriculture Victoria is also providing seasonal climate updates for Victoria on YouTube.¹⁶²

The number of subscribers to the newsletter has increased nearly fivefold during the past decade, indicating the value of the information provided in the newsletter. DEDJTR conducts periodic surveys of the newsletter readers, and the last survey in 2016 found that more than half of subscribers share the newsletter with others, which increases its reach and value. More than 90% of respondents also 'strongly agreed' or 'somewhat agreed' that

the newsletter improved their ability to make decisions to manage seasonal risk, and improved their knowledge and understanding of seasonal climate variability. The main management decisions made due to information provided in the newsletter included changing sowing plans and crop types, changing nitrogen and urea application, and changing stocking numbers.

These results should be interpreted with caution: businesses subscribing to the newsletter and participating in the survey may be more proactive than others in the agricultural sector. Nonetheless, the survey results are a sign of the sector's increasing 'climate literacy' and decisiveness in relation to climate change. In the future, the newsletter survey could be supplemented by a broader study to provide a more holistic understanding of how Victorian agricultural businesses are adapting to climate change.

159. DELWP 2016, 'Local Government Engagement on Victoria's Climate Change Adaptation Plan 2017 – 2020', East Melbourne, Victoria https://www.climatechange.vic.gov.au/_data/assets/pdf_file/0015/73050/2017-Local-Government-Input-in-Adaptation-Plan_final.pdf Accessed 4 December 2018.

160. DEDJTR 2017, 'Agriculture Victoria Strategy', Melbourne, Victoria http://agriculture.vic.gov.au/_data/assets/pdf_file/0011/385949/Agriculture-Victoria-Strategy_FINAL.pdf Accessed 4 December 2018.

161. Victorian Department of Environment and Primary Industries 2013, 'Climate Change Adaptation in Agriculture: Technical Report'.

162. DEDJTR, 'The Very Fast Break', <https://www.youtube.com/channel/UCIDCIII7gRZhUs03opGqH1g> Accessed 4 December 2018.

Future Focus

Improve localised climate projections

Localised climate projections at a finer spatial resolution, and more accurate rainfall projections, are required to improve management outcomes. Greater detail in climate projections can improve the proactive planning for many natural assets and sectors, including agriculture, with rainfall projections a particularly valuable tool for long-term policy development. An excellent example of this is the runoff projections that have been produced at river-basin level in indicator WR:02 (Projected runoff to dams and catchments). Rainfall projections are currently associated with reasonably large uncertainties (relative to other climate variables such as temperature) and reducing these uncertainties would enhance environmental management, planning and outcomes.

Recommendation 2: That DELWP, in coordination with research partners, conduct further analysis to improve localised climate projections (particularly in agricultural regions). These projections would aim to reduce the uncertainties associated with rainfall projections as a minimum.

Note: refer to Recommendation 15: Monitoring and reporting on the targets for Victoria's energy transition regarding obligations under the *Climate Change Act 2017*.

AIR (A)

SCIENTIFIC ASSESSMENTS Part III



Commissioner
for Environmental
Sustainability
Victoria



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 2017² 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.

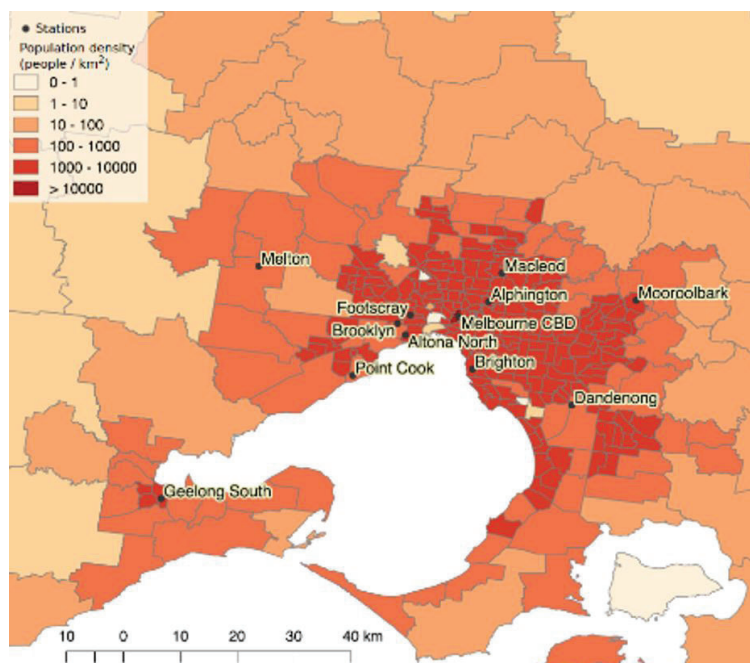


Figure A.1 EPA Victoria air-monitoring stations in Melbourne and Geelong

(Image source: EPA Victoria, 2018)

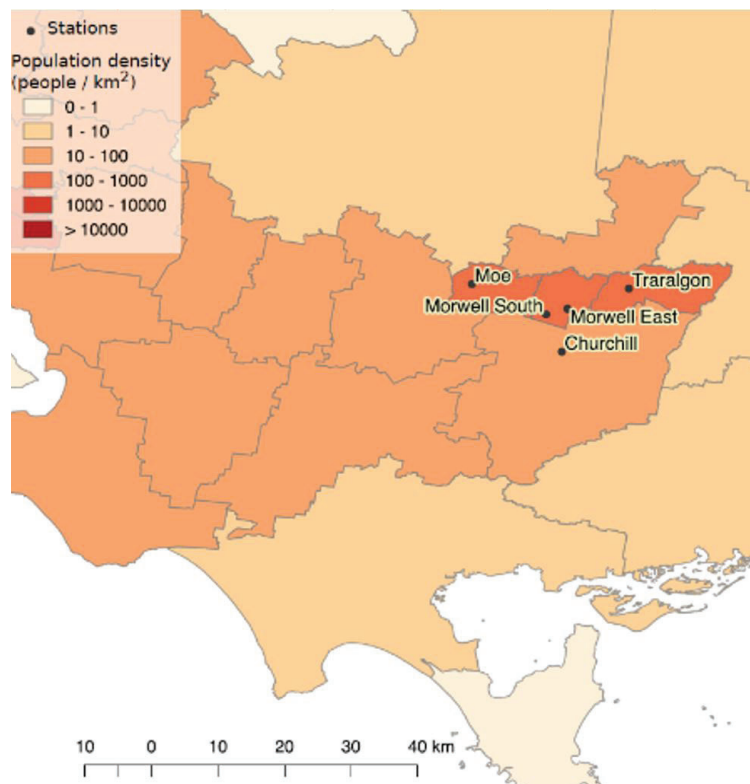


Figure A.2 EPA Victoria air-monitoring stations in the Latrobe Valley

(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 Accessed 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 PM₁₀ standard.¹⁷ The Victorian annual PM₁₀ 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.qshx?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.

Indicator Assessment

Legend




Status

N/A Not Applicable The indicator assessment is based on future projections or the change in environmental condition and providing a status assessment is not applicable. Only a trend assessment is provided.	 Unknown Data is insufficient to make an assessment of status and trends.	 Poor Environmental condition is under significant stress, OR pressure is likely to have significant impact on environmental condition/human health, OR inadequate protection of natural ecosystems and biodiversity is evident.	 Fair Environmental condition is neither positive or negative and may be variable across Victoria, OR pressure is likely to have limited impact on environmental condition/human health, OR moderate protection of natural ecosystems and biodiversity is evident.	 Good Environmental condition is healthy across Victoria, OR pressure is likely to have negligible impact on environmental condition/human health, OR comprehensive protection of natural ecosystems and biodiversity is evident.
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Trend

N/A Not applicable This indicator assessment is based on current environmental condition only and it is not applicable to provide a trend assessment. Only a status assessment is provided.	 Unclear	 Deteriorating	 Stable	 Improving
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Data quality

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



















Summary






Indicator A:01 Ambient ozone levels (summer smog)	Ozone standards have only been exceeded on a small number of days in Victoria since 2000.
Region Melbourne, Geelong, Latrobe Valley	
Measures Ambient ozone concentrations (measured in ppb)	
Data custodian EPA Victoria	

Status	Trend
UNKNOWN POOR FAIR GOOD	
	
	
DATA QUALITY Good	

Summary		Status	Trend		
		UNKNOWN	POOR	FAIR	GOOD
Indicator A:02 Carbon monoxide and nitrogen dioxide	Carbon monoxide and nitrogen dioxide concentrations rarely exceed air quality standards and peak concentrations are still reducing in Victoria, albeit at a slower rate during the 21st century than during the 1980s and 1990s.				
Region Melbourne, Geelong, Latrobe Valley					
Measures Ambient carbon monoxide (measured in ppm) and nitrogen dioxide (measured in ppb) concentrations					
Data custodian EPA Victoria		DATA QUALITY Good			
Indicator A:03 Particle pollution (PM ₁₀ and PM _{2.5})	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. PM ₁₀ pollution remains an issue in Brooklyn in Melbourne's inner west associated with dust emissions generated by industry and vehicles.				
Region Melbourne, Geelong, Latrobe Valley					
Measures Ambient concentrations (measured in µg/m³) of particles less than 2.5 micrometres in size (PM _{2.5}) and less than 10 micrometres in size (PM ₁₀).					
Data custodian EPA Victoria		DATA QUALITY Fair (lacking coverage in regional Victoria and near major Roads)			
Indicator A:04 Sulfur dioxide	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.				
Region Melbourne, Geelong, Latrobe Valley					
Measures Ambient sulfur dioxide concentrations (measured in ppb)					
Data custodian EPA Victoria		DATA QUALITY Good			

Summary		Status	Trend			
		UNKNOWN	POOR	FAIR	GOOD	
Indicator A:05 Stratospheric ozone	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. Melbourne's ultraviolet levels have generally been stable since the 1980's.					
Region Melbourne						
Measures (i) Ultraviolet radiation (UV index) (ii) Average total column ozone (Dobson Units) (iii) Emissions of ozone depleting substances (M tonnes)		DATA QUALITY Good				
Data custodian DEE, BoM						
Indicator A:06 Odour and noise	Odour is the type of pollution most frequently reported to EPA and noise is the second most. Apart from a spike in 2014, odour reports have generally increased from 2013-17 and noise reports were generally stable until a spike of reports in 2017.					
Region Victoria						
Measures (i) Odour pollution reports (ii) Noise pollution reports		DATA QUALITY Fair (No compatibility between data collected by EPA and councils – so the data presented here is just EPA data)				
Data custodian EPA Victoria, local councils						
Indicator A:07 Light pollution	Artificial lighting has reduced bat activity and species richness in Victoria as well as affecting bird survival patterns on Phillip Island.					
Region Victoria						
Measures Artificial sky brightness as a ratio to the natural sky brightness (assumed to be 174 $\mu\text{cd}/\text{m}^2$)		DATA QUALITY Poor - (data mainly collected as case-studies or at a national level)				
Data custodian None						

Summary		Status				Trend
		UNKNOWN	POOR	FAIR	GOOD	
Indicator	Motor vehicles and large industry are estimated to account for the majority of carbon monoxide, oxides of nitrogen and sulfur dioxide emissions across Victoria.					
A:08 Emissions of major air pollutants by sector						
Region	Victoria	DATA QUALITY				
Measures	Emissions by source in t/yr inventories	Fair (current emissions data unable to be compared to historical emissions data)				
Data custodian	EPA Victoria					
Indicator	Associations between adverse health effects and exposure to PM _{2.5} have been found in Victoria.					
A:09 Health impacts of air pollution						
Region	Victoria	DATA QUALITY				
Measures	(i) Number of respiratory illnesses related to adverse air quality (ii) Cost (in \$) associated with health effects due to adverse air quality	Poor (a limited amount of local research and exposure studies)				
Data custodian	None					
Indicator	Melbourne has a lower percentage of its population exposed to excessive night time noise than many of Europe's major cities.					
A:10 Health impacts of noise pollution						
Region	Melbourne	Fair for Melbourne and Unknown for the rest of Victoria				
Measures	The proportion of population exposed to high levels of road traffic noise in Melbourne	DATA QUALITY				
Data custodian	EPA Victoria	Poor (a limited amount of local research and exposure studies)				

Summary		Status				Trend
		UNKNOWN	POOR	FAIR	GOOD	
Indicator	Relatively little research has been done on the quality of air in our homes, schools, recreational buildings, restaurants, public buildings, offices, or inside cars.					
A:11 Indoor air quality						
Region						
Victoria						
Measures						
Indoor air quality concentrations of common indoor air pollutants (e.g. volatile organic compounds)						
Data custodian						
None						



DATA QUALITY






Poor (a limited amount of local research and exposure studies)

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 custodian EPA Victoria						Good

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 Traralgon⁴⁰ and Warrnambool⁴¹ 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.

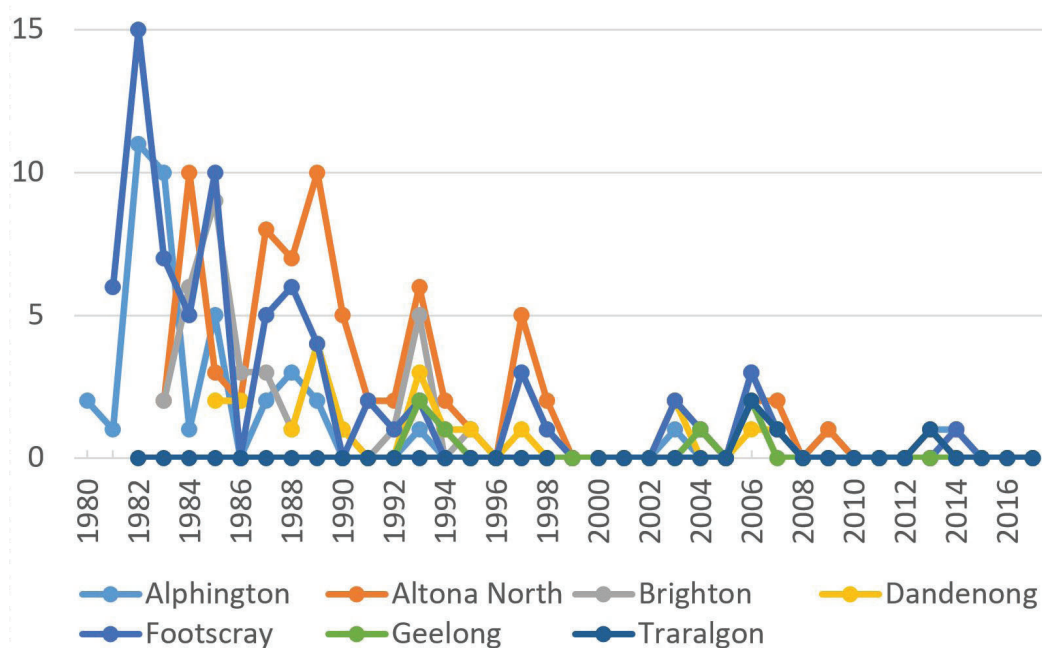


Figure A.3 Number of days exceeding the ozone (4-hour average) standard at monitored sites in Victoria, 1980–2017

(Data source: EPA Victoria, 2018)

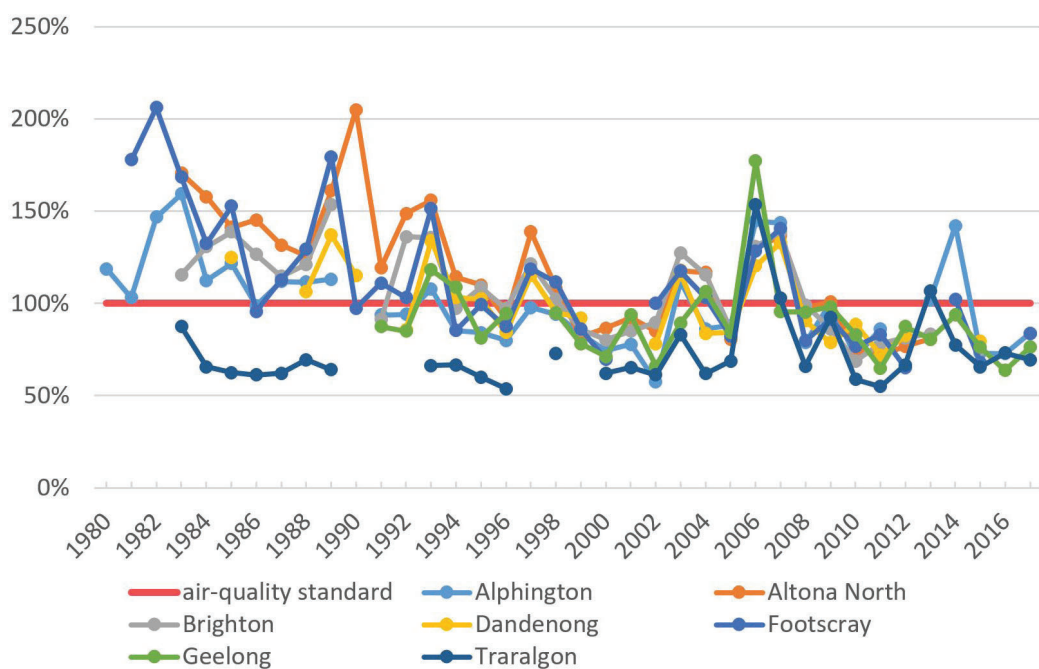


Figure A.4 Annual maximum ozone (4-hour average) concentrations at monitored sites in Victoria, 1980–2017

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

(Data source: EPA Victoria, 2018)

Indicator	Status				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:02 Carbon monoxide and nitrogen dioxide						
Data custodian EPA Victoria						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 similar levels of carbon monoxide in populated areas was more than 25 years ago, when motor vehicle carbon monoxide emissions were much higher.

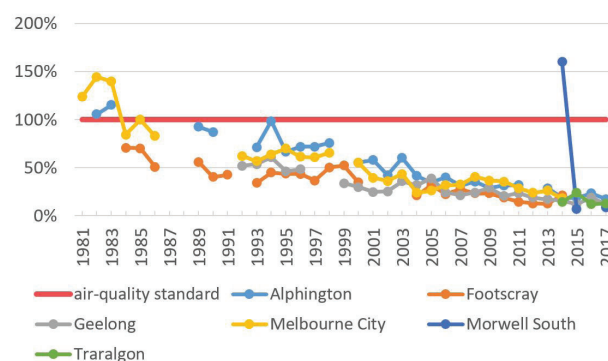


Figure A.5 Annual maximum carbon monoxide (8-hour average) concentrations in Victoria, 1981–2017

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.

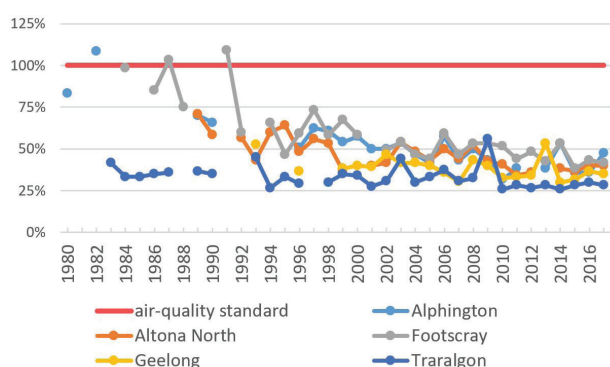


Figure A.6 Annual maximum nitrogen dioxide (1-hour average) concentrations in Victoria, 1980–2017

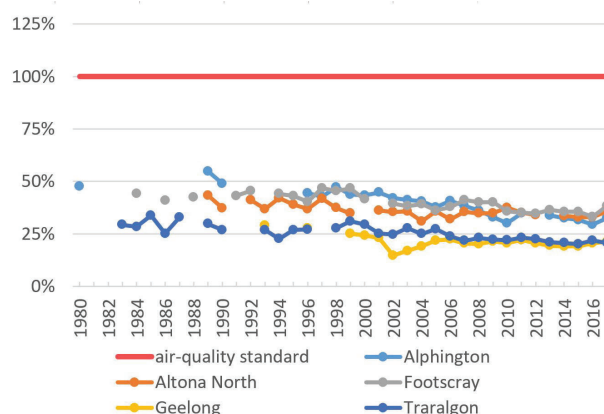




Figure A.7 Annual average nitrogen dioxide concentrations in Victoria, 1980–2017

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})						
Data custodian EPA Victoria	Elsewhere in Victoria	Brooklyn	Geelong, the Latrobe Valley and most of Melbourne			Fair

Two main particle pollutants are measured in Victoria: PM_{2.5} (particles less than 2.5 micrometres in diameter) and PM₁₀ (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 PM₁₀, so the PM_{2.5} dataset is shorter and, until recently, quite limited in spatial coverage.

Greater concentrations of PM_{2.5} and PM₁₀ 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 PM₁₀ 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.

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 PM₁₀ 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.

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.

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

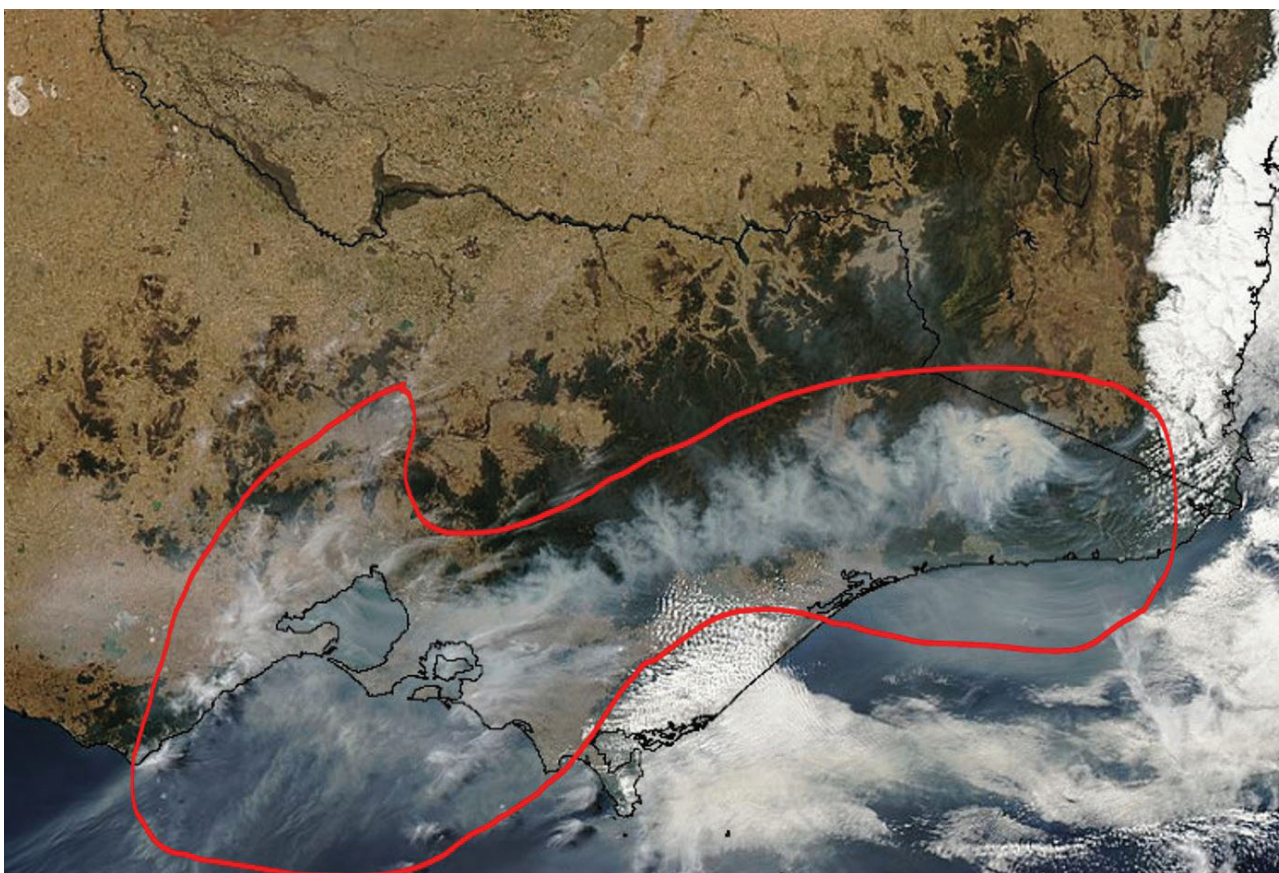


Figure A.8 NASA satellite image, 11 February 2014⁵⁰

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).

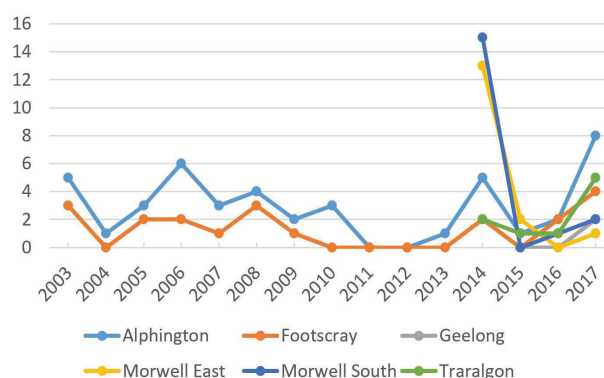


Figure A.9 Number of days exceeding the PM_{2.5} (daily average) standard in Victoria, 2003–2017

(Data source: EPA Victoria, 2018)

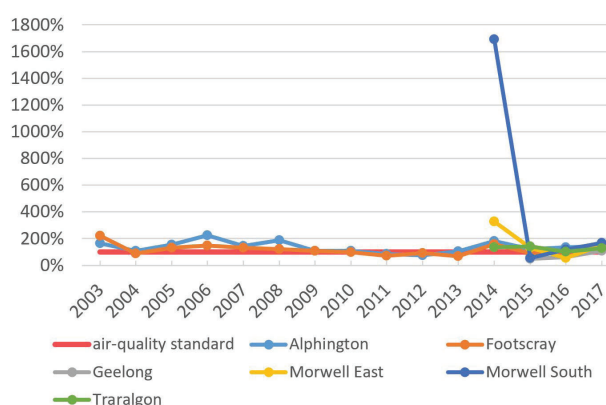


Figure A.10 Annual maximum PM_{2.5} (daily average) concentrations in Victoria, 2003–2017

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.

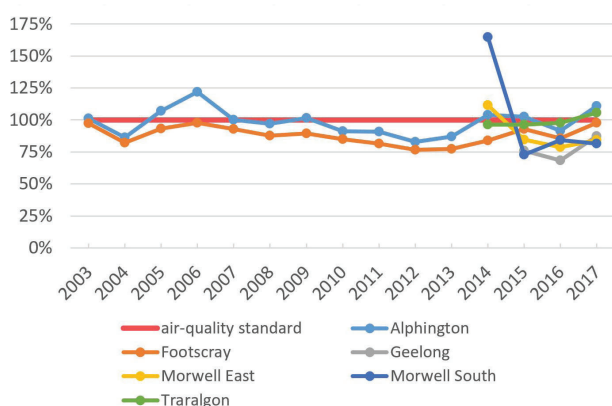


Figure A.11 Annual average PM_{2.5} concentrations in Victoria, 2003–2017

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

(Data source: EPA Victoria, 2018)

PM₁₀

The pattern of days exceeding the PM₁₀ standard has traditionally aligned with that for PM_{2.5}, although more days generally exceed the PM₁₀ 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 PM₁₀ standard, except at dust hotspots in Brooklyn and, to a lesser extent, Geelong (Figure A.12). Peak PM₁₀ 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).

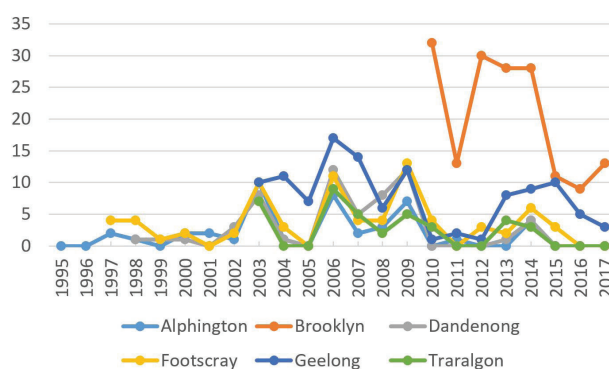


Figure A.12 Number of days exceeding the PM₁₀ (daily average) standard in Victoria, 1995–2017

(Data source: EPA Victoria, 2018)

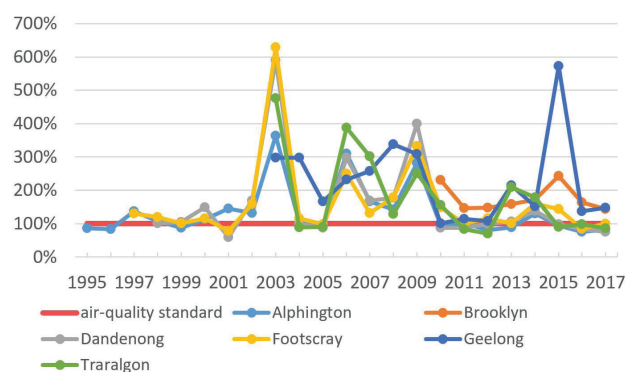


Figure A.13 Annual maximum PM₁₀ (daily average) concentrations in Victoria, 1995–2017

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

(Data source: EPA Victoria, 2018)

Due to PM₁₀ 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 PM₁₀ standard was adopted in Victoria in 2016; previously, there had been no annual average PM₁₀ standard at state or national level.⁵⁹ The Victorian annual PM₁₀ standard of 20 µg/m³ is significantly more stringent than the national standard of 25 µg/m³. Annual average PM₁₀ concentrations have been trending slightly down across Victorian this decade (Figure A.14), with 2014 the only year when monitoring sites exceeded the PM₁₀ annual standard since 2009 (except for Brooklyn). The higher annual average PM₁₀ readings from 2000 to 2009 may be due to drier conditions associated with the millennium drought. To demonstrate the recent improvement in annual PM₁₀ 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.

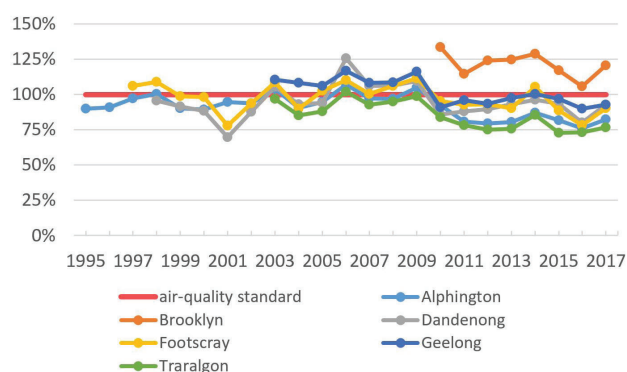


Figure A.14 Annual average PM₁₀ concentrations in Victoria, 1995–2017

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				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:04 Sulfur dioxide						
Data custodian EPA Victoria						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.

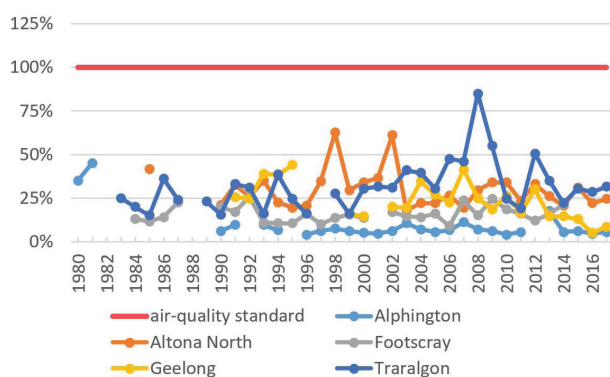


Figure A.15 Annual maximum sulfur dioxide (hourly average) concentrations in Victoria, 1980–2017

(Data source: EPA Victoria, 2018)

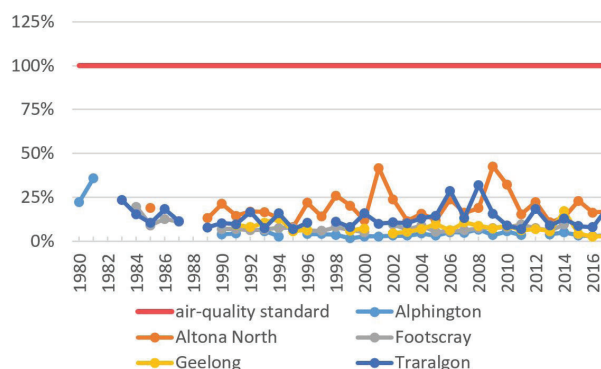


Figure A.16 Annual maximum sulfur dioxide (daily average) concentrations in Victoria, 1980–2017

(Data source: EPA Victoria, 2018)

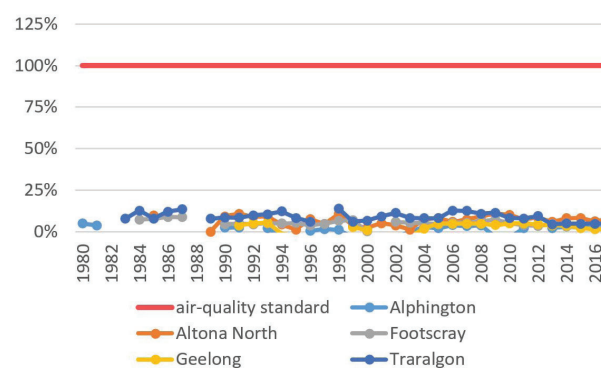


Figure A.17 Annual average sulfur dioxide concentrations in Victoria, 1980–2017

(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				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:05 Stratospheric ozone						
Data custodian DEE, BoM						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.

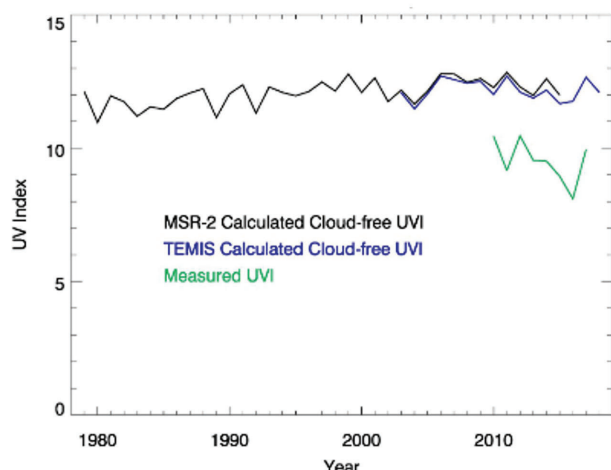


Figure A.18 Average UV index for Melbourne, 1979–2017

(Data source: BoM, 2018)

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).

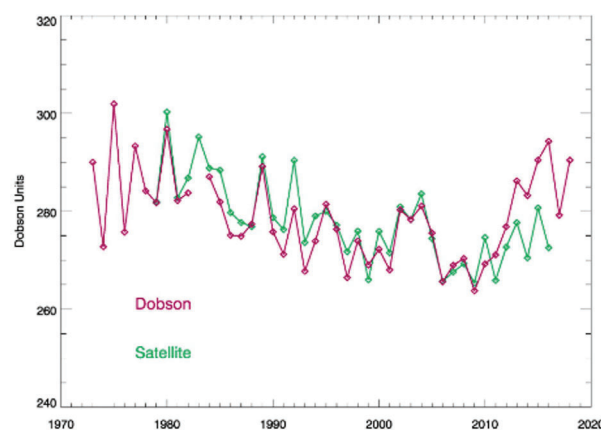


Figure A.19 Average total column ozone for Melbourne, 1973–2018

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.

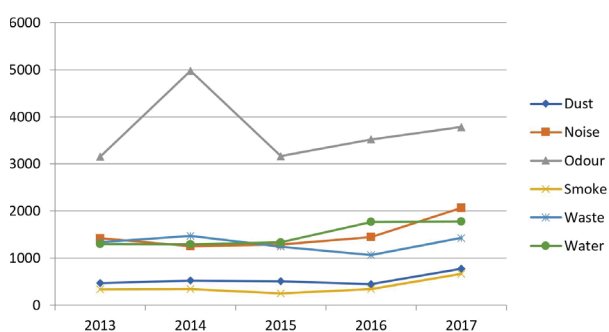


Figure A.20 Pollution reports received by EPA Victoria, 2013–17

(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)	LGA	Noise reports 2013–2017	Rank (per capita)
Hobsons Bay	1,791	1	Hepburn	315	1
Central Goldfields	247	2	Glenelg	74	2
Moyne	304	3	Banyule	459	3
Kingston	2,550	4	Warrnambool	126	4
Hepburn	256	5	Corangamite	55	5

(Data source: EPA Victoria, 2018)

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

(Data source: EPA Victoria, 2018)

LGA	Odour reports 2013–2017	Rank	LGA	Noise reports 2013–2017	Rank
Kingston	2,550	1	Banyule	459	1
Melton	2,082	2	Moreland	424	2
Hobsons Bay	1,791	3	Brimbank	418	3
Casey	1,397	4	Whitehorse	413	4
Brimbank	1,337	5	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

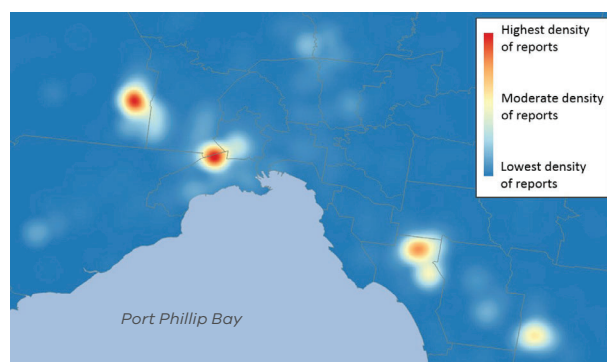


Figure A.21 Odour pollution reporting hotspots in Melbourne, 2013–17

(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.

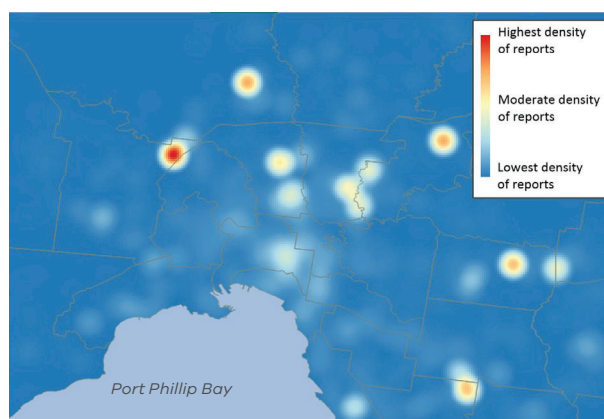





Figure A.22 Noise pollution reporting hotspots in the Melbourne metropolitan area, 2013–17

(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				Trend	Data Quality
	UNKNOWN	POOR	FAIR	GOOD		
A:07 Light pollution						 DATA QUALITY Poor
Data custodian	None					

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

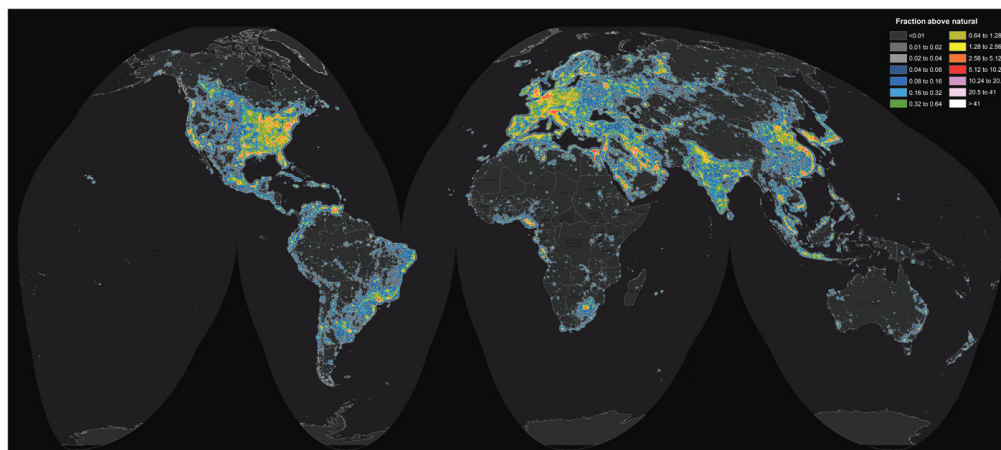


Figure A.23 World map of artificial sky brightness based on data collected in 2014⁷²

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.nso.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, Wasiaik 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 QUALITY Fair
Data custodian EPA Victoria						

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
	UNKNOWN	POOR	FAIR	GOOD		
A:09 Health impacts of air pollution						
Data custodian None						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 (PM_{2.5}) 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

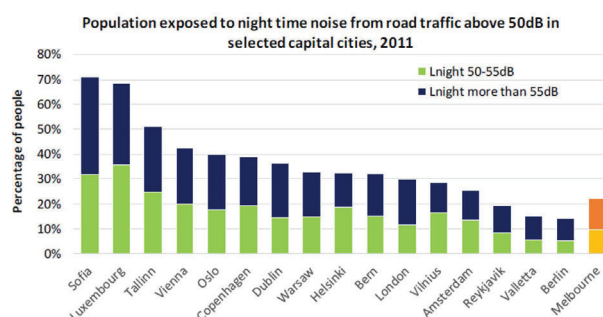


Figure A.24 Indicative comparison of the night-time exposure to road traffic noise for metropolitan Melbourne (2011) compared with selected capital cities of the European Union^{101,102}

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?uq=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/aa-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_campaign=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/aqa-nepm-draft-variation-impact-statement.pdf> Accessed 3 December 2018.

Table A.3 Air quality regulation in an environmental-economic accounting framework¹²⁵

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*