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27 June 2024

Committee Secretary
Legislative Council Environment and Planning Committee
Parliament House
Spring Street
East Melbourne VIC 3002

Dear Committee Chair,

## Submission to The Legislative Council Environment and Planning Committee on the Inquiry into Climate Resilience.

The ***ARC Centres of Excellence for Climate Extremes*** and the ***Weather of the 21st Century*** welcome the opportunity to make a joint submission to the Inquiry into Climate Resilience.

The ARC Centre of Excellence for Climate Extremes works to understand and reduce Australia's vulnerability to climate extremes through leading the development of fundamental climate science and improving models which analyse the extremes of the past and predict the extremes of the future.

Weather of the 21st Century is researching how Australia's weather is being reshaped by climate change, and what this means for our weather resources and high impact weather.

Both centres comprise of five partner universities - The University of New South Wales, Monash University, The Australian National University, The University of Melbourne and The University of Tasmania, as well as multiple national and international partner organisations.

As Australian Centres of Excellence in climate research, we recognise the current and future climate risks facing Victoria's people and infrastructure. We have already observed changes in extreme weather events resulting from climate change, and these impacts are expected to continue to worsen. We would like to offer our combined expertise and advice on navigating climate resilience in Victoria.

Thank you for the opportunity to make a submission on this important topic. We stand ready to offer further information on any matters arising from this submission.

Yours sincerely,

[redacted]

Professor Julie Arblaster, Monash University,
Deputy Director at the ARC Centre of Excellence for Climate Extremes,
Chief Investigator at the ARC Centre of Excellence for the Weather of the 21st Century

This submission focuses on points (a), (b), (e) and (f) of the terms of reference;

- *'(a) the main risks facing Victoria's built environment and infrastructure from climate change',*
- *'(b) how the Victorian Government is preparing for and mitigating the impacts of climate change',*
- *'(e) what more could be done to better prepare Victoria's built environment and infrastructure, and therefore the community, for future climate disaster events' and*
- *'(f) whether further inquiries or investigation may be needed into other aspects of climate change adaptation and climate disaster preparedness in Victoria..'.*

## *(a) The main risks facing Victoria's built environment and infrastructure from climate change and the impact these will have on the people of Victoria.*

Climate and weather extremes are already affecting Victorians with far reaching impacts extending to human health, water resources and management, agriculture, energy security, financial security, the natural environment and the built environment. The science is clear that the climate is changing due to human emissions of greenhouse gases, predominantly from the burning of fossil fuels such as coal, oil and gas. It is expected that further climate change will increase the risk of some climate extremes.

At present, Australian surface air temperatures have risen by around 1.5°C[1], and will continue to rise until at least 2050 under all plausible emission scenarios[2], making further increases in climate extremes inevitable (Figure 1). Concerningly, it appears that climate change is causing greater impacts than anticipated, and these impacts are emerging at lower amounts of warming than expected[3].

Continuous observations of temperature and rainfall are available for Victoria since at least 1910, which can be used to understand changes in our climate. In Victoria, the past three decades have been successively warmer than each previous decade. Victoria's mean maximum temperature in 2023 was 0.69°C above the 1961–1990 average, with above average temperatures across the state. Victoria experienced a broad range of extreme events in 2023, including the hottest winter on record, the driest September on record and consecutive fire and floods across the Gippsland region of the state[4].

[1]Bureau of Meteorology and CSIRO (2022). State of the Climate 2022. http://www.bom.gov.au/state-of-theclimate/
[2]Herold et al. (2021). Projected changes in the frequency of climate extremes over southeast Australia, Environmental Research Communications. https://doi. org/10.1088/2515-7620/abe6b1
[3]IPCC (2022). Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/
[4]Bui et al. (2024). The State of Weather and Climate Extremes 2023. https://climateextremes.org.au/the-state-of-weather-and-climate-extremes-2023/

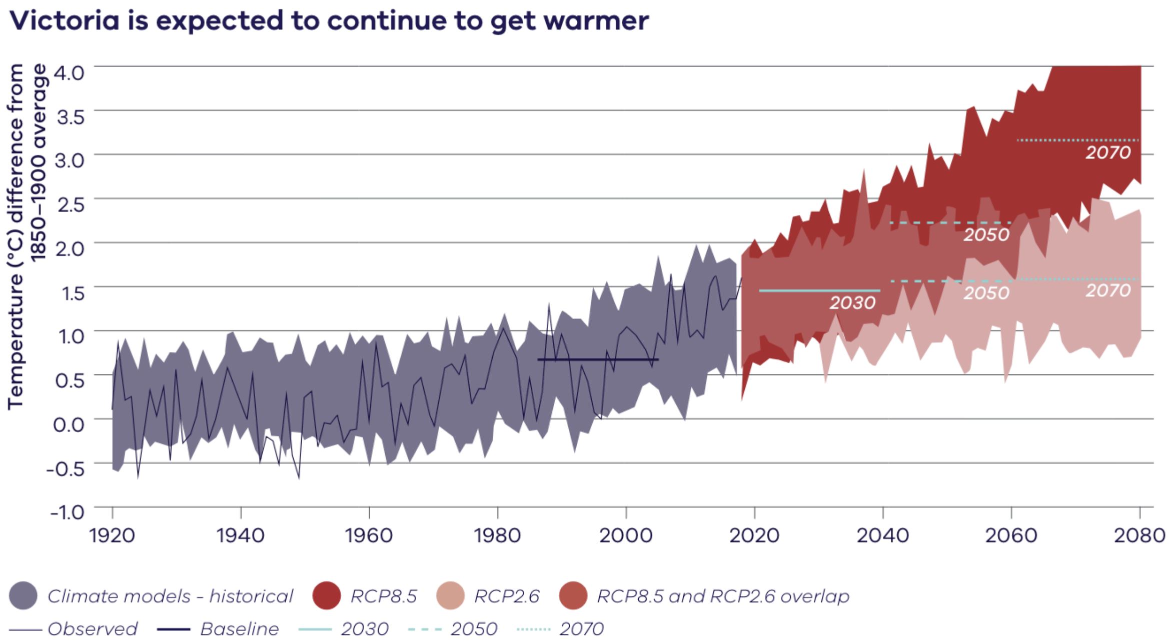


Figure 1: Future projections of warming in Victoria for a very high emissions future (red) compared with climate change stabilisation in a low emissions future (pink). Thick lines show the 20 year average temperature across models. Source: The State of Victoria Department of Environment, Land, Water and Planning, 2019.
https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0029/442964/Victorias-Climate-Science-Report-2019.pdf

The current and future risk of extreme events needs to be considered across Victoria's climate change mitigation and adaptation activities to improve our resilience in a changing climate. For a more targeted look at how to consider the risk to Victoria's built environment and people, we summarise our current understanding of key weather and climate extremes in Victoria:

1. Extreme heat
2. Extreme rainfall
3. Drought
4. Fire
5. Hail
6. Extreme wind
7. Sea level rise
8. Compound events

## 1. Extreme heat

### Heat extremes have already worsened in Victoria, and will continue to increase with climate change.

Heatwaves in Australia have been intensifying, becoming hotter, longer and more frequent and will continue to increase with climate change[5]. Some projections show heatwaves may be up to 85%

[5] Jyoteeshkumar Reddy, P., Perkins-Kirkpatrick, S. E., and Sharples, J.J. (2021). Intensifying Australian heatwave trends and their sensitivity to observational data. https://doi. org/10.1029/2020EF001924

more frequent at 1.5-2°C warming levels[6]. Concerningly, local scale extreme temperatures can increase at a significantly higher rate than the global average temperature[7].

The risks of extreme heat are significant, affecting both people and the built environment;

- Heat causes catastrophic risks to human health, including death, heat stroke, heat exhaustion, dehydration and increased risk of cardiovascular diseases. The heatwaves preceding the Black Summer fires of 2019-20 killed around 417 Australians. Over the past decade, extreme heat accounted for more than three in four weather-related hospitalisations[8].
- Heat extremes can often lead to poor air quality due to the extreme heat and stagnant air increasing the amount of ozone pollution and particulate pollution[9].
- The impacts of heat on the body have flow on effects for wellbeing, workplace productivity and the economy, particularly for industries that work outdoors such as construction and farming[10].
- Heat impacts vulnerable populations disproportionately - particularly the elderly, young children, those with underlying medical conditions and people living in low socio-economic communities[11].
- Extreme heat impacts the built environment, causing the buckling of roads and footpaths, damage to train tracks, the expansion and cracking of building materials and reduced efficiency of transmission lines and generators disrupting energy supply[12]. Increased energy demand for cooling puts further strain on power supplies potentially causing blackouts.

Our Centres research the weather processes involved in heatwaves to better understand how heatwaves start, progress and end. Victorian heatwaves are generally caused by prolonged anticyclonic winds which originate from the south Indian Ocean and bring warm air to the state. Strong cold fronts usually terminate heat waves, dropping temperatures by 6°C or more over a few hours. Other parts of the climate system have been found to be important for modulating heat extremes, for example groundwater can reduce temperatures by up to 3°C during major heat waves[13]. Current work is investigating how the northward progression of fronts is involved in the termination of heatwaves. We are also looking at how the future risk of heatwaves compares to past events and the survivability limits in Australia due to extreme heat and humidity.

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[6]Trancoso et al. (2020). Heatwaves intensification in Australia: A consistent trajectory across past, present and future. https://doi.org/10.1016/j.scitotenv.2020.140521

[7]Lewis et al. (2019). Regional hotspots of temperature extremes under 1.5 °C and 2 °C of global mean warming. https://doi.org/10.1016/j.wace.2019.100233

[8]The Guardian. (2023). Extreme heat caused three in four weather-related hospitalisations in Australia over past decade, data shows. https://www.theguardian.com/australia-news/2023/nov/02/extreme-heat-caused-three-in-four-weather-related-hospitalisations-in-australia-over-last-decade-data-shows

[9]Climate Council. (2019). Sydney Heatwave Affects Air Quality. https://www.climatecouncil.org.au/sydney-heatwave-affects-air-quality/

[10]Mora, C., Dousset, B., Caldwell, I. et al. (2017). Global risk of deadly heat. Nature Clim Change 7, 501–506. https://doi.org/10.1038/nclimate3322

[11]Mora, C., Dousset, B., Caldwell, I. et al. (2017). Global risk of deadly heat. Nature Clim Change 7, 501–506. https://doi.org/10.1038/nclimate3322

[12]KPMG. (2024). Navigating extreme heat in Australia. https://assets.kpmg.com/content/dam/kpmg/au/pdf/2023/navigating-extreme-heat-in-australia.pdf

[13]Mengyuan Mu et al. (2022). How do groundwater dynamics influence heatwaves in southeast Australia? https://doi.org/10.1016/j.wace.2022.100479.

At the local scale, our Centres research how urbanisation impacts the local climate. This is of particular relevance for Victoria, with 72.5% of the state living in metropolitan Melbourne. Effects of urbanisation can amplify extreme heat, with neighbourhood characteristics like vegetation, air flow, building materials and proximity to the coast causing variations in temperature. Temperatures during the first night of a heatwave have been found to increase by up to 3.3°C in Melbourne due to urban heat, increasing the risk of heat stress[14]. Socio-economic advantage is also strongly correlated with urban heat in Melbourne, for example, the City of Brimbank was found to have an urban heat island effect of +10.75°C and has a comparatively low score for socio-economic advantage[15]. Efforts to model the unique urban environments are improving our understanding of urban microclimates and the effectiveness of urban design on reducing exposure to extreme heat which is an essential component of adaptation[16].

Due to the multifaceted nature of heat risk, our Centres advise an interdisciplinary response involving climate scientists, health experts, urban planners, architects, engineers and local councils. The risk of extreme heat for Victorians is already significant, and will continue to worsen with climate change.

## 2. Extreme rainfall

**We expect rainfall variability and intensity will increase, with more frequent swings from flooding rains to extreme droughts.**

Climate change is disrupting the water cycle[17]. It is expected that rainfall variability and intensity will increase, with more frequent swings from flooding rains to extreme droughts[18]. The atmosphere can hold 7% more moisture per 1°C of warming, making heavier rainfall possible[19]. In eastern Australia, low-pressure systems extending deep into the atmosphere are projected to occur less frequently but produce more extreme rainfall when they do occur[20]. Recent research has found that in Sydney, short duration intense rainfall events have increased by 40% over the last 20 years[21]. If a similar trend is found in Victoria, there are important implications for flash flooding for stormwater systems that are not designed for these intense bursts of heavy rainfall. Pooling of fast moving water, landslides and

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[14]Rogers, C.D.W., Gallant, A.J.E. & Tapper, N.J. (2019). Is the urban heat island exacerbated during heatwaves in southern Australian cities? https://doi.org/10.1007/s00704-018-2599-x
[15]Ben Latham. (2023). A Comparison Of Disadvantage and Urban Heat Island Effect In Melbourne, Australia, https://vcoss.org.au/wp-content/uploads/2024/02/UrbanHeartVCOSS2023.pdf
[16] Lipson Mathew J., Nazarian Negin, Hart Melissa A., Nice Kerry A., Conroy Brooke. (2022). A Transformation in City-Descriptive Input Data for Urban Climate Models. https://www.frontiersin.org/articles/10.3389/fenvs.2022.866398/full
[17]Douville, H. et al. (2021). Water Cycle Changes. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-8/
[18]ARC Centre of Excellence for Climate Extremes (2022). Multi-year La Niña events. https://climateextremes.org.au/multi-year-la-nin%cc%83a-events/
[19]Trenberth, K. (2023). How rising water vapour in the atmosphere is amplifying warming and making extreme weather worse. https://theconversation.com/how-rising-water-vapour-in-the-atmosphere-is-amplifying-warming-and-making-extreme-weather-worse-213347
[20]Pepler, A. and Dowdy, A. (2021). Fewer deep cyclones projected for the midlatitudes in a warming climate, but with more intense rainfall.
[21]Ayat, H et al. (2022). Intensification of subhourly heavy rainfall. https://www.science.org/doi/10.1126/science.abn8657

the flow of debris can result, causing damage to infrastructure such as buildings, roads (eg. potholes, hidden snags), bridges and power lines, water supply as well as loss of agricultural crops and livestock.

Our current understanding of how rainfall in Victoria will change is limited, as rainfall is affected by complex, local scale weather processes which are difficult to capture in climate models. Current work at our Centres is looking at the determinants of heavy precipitation in southeast Australia and how rainfall extremes have been changing over time across our major cities. We are also continuing to examine the causes of the extreme rainfall in 2022[22]. Better understanding these processes assists with assessing the future risk of extreme rainfall and enhances the predictability of rainfall on longer timescales. Recent work found that using atmospheric water vapour to predict rainfall improved the forecasting skill for up to one month in advance for some locations of Australia[23].

Despite the uncertainties in how extreme rainfall and floods may behave in the future, there are still ample opportunities to reduce flood risks now. While rainfall and floods are strongly related, understanding flood risk also depends on many non-weather factors such as where we build, the materials used to build and how we manage water. We know the climate is changing, and while we may not know the exact details of the impacts on Victoria, there is still action we can take to build resilience to heavy rainfall events.

## 3. Drought

**We need to prepare for the possibility of increasingly long and intense droughts.**

It is important that Victoria prepares for future droughts, as south-eastern Australia is prone to drought, and drought risk is expected to increase with climate change[24]. Since the late 1990s, April-October rainfall in south-eastern Australia has declined by approximately 10% per decade[25]. Climate change further increases the likelihood of these rainfall declines which may intensify droughts[26]. Studies suggest that the specific weather pattern required to break droughts in southeast Australia, a 'Tasman high + deep low' may decrease with climate change, meaning we may experience prolonged drought[27].

The most recent and exceptionally extreme drought in the south east of Australia preceded the devastating 2019-20 Black Summer Bushfires. Its extent covered the entire Murray-Darling Basin, including a major part of Victoria. Analysis found that climate change worsened the intensity of this drought by 18%[28]. A feature of the drought was a rapid onset and/or intensification of drought in

[22]Reid et al. (in preparation)
[23]Reid, K.J., Hudson, D., King, A.D., Lane, T.P. & Marshall, A.G. (2023). Atmospheric water vapour transport in ACCESS-S2 and the potential for enhancing skill of subseasonal forecasts of precipitation. https://doi. org/10.1002/qj.4585
[24]Anjana Devanand et al. (2024). Australia's Tinderbox Drought: An extreme natural event likely worsened by human-caused climate change. https://www.science.org/doi/10.1126/sciadv.adj3460
[25]Bureau of Meteorology and CSIRO (2022). State of the Climate 2022. http://www.bom.gov.au/state-of-theclimate/
[26]Grose, M. R., Narsey, S., Delage, F. P., Dowdy, A. J., Bador, M., Boschat, G., et al. (2020). Insights from CMIP6 for Australia's future climate. https://doi.org/10.1029/2019EF001469
[27]Holgate et al. (2022). Anthropogenic warming reduces the likelihood of drought-breaking extreme rainfall events in southeast Australia. https://www.sciencedirect.com/science/article/pii/S2212094723000609
[28]Devanand et al., (2024). Australia's Tinderbox Drought. https://www.science.org/doi/full/10.1126/sciadv.adj3460

some regions known as flash droughts. Flash droughts, where conditions rapidly shift from drier than normal to extreme drought conditions may increase with climate change[29]. The rapid intensification has been found to be due to high temperatures, low humidity, strong winds and clear skies.

Other recent work indicates it is possible for Victoria to experience megadroughts in the future; droughts lasting for 20 years or more. Megadroughts were found to be possible in eastern Australia, even without the impacts of climate change[30].

The Centres continue to research what determines the onset, persistence and termination of drought. In particular, the weather processes linking large-scale climate modes (such as El Niño and positive Indian Ocean Dipole events) to increased drought risk in parts of eastern Australia.

Adapting water management strategies to increasing drought risk will be an important aspect of climate resilience in Victoria. Our Centres predominantly study the climate drivers and weather patterns responsible, however there are many other aspects that impact drought, such as hydrology, soil moisture, land use change and water management practices that all need to be considered to understand our resilience to drought.

## 4. Fire weather

**Extreme fire weather has been increasing, and it is expected to worsen with climate change.**

The impacts from bushfires are expected to increase with climate change[31]. In Australia, extreme fire weather days have become more frequent, and the fire season has lengthened since 1950 in various locations, while projections indicate that this trend will continue[32]. The number of days of very high fire danger has increased by 40% and may triple for regions of Victoria by 2100[33].

The extent of the 2019-20 Black Summer fires were consistent with scientific assessments of worsening fire risk in southeastern Australia due to global warming[34,35]. The severity of these fires indicate fire risk may increase more rapidly than previously anticipated[36]. In 2023, Australia observed

[29] Tess Parker et al. (2021). Flash drought in Australia and its relationship to evaporative demand. https://doi.org/10.1088/1748-9326/abfe2c

[30] Falster et al. (2024). Potential for historically unprecedented Australian droughts from natural variability and climate change. https://doi.org/10.5194/hess-28-1383-2024. 2024.

[31] IPCC. (2023). AR6 Synthesis Report: Summary for Policymakers Headline Statements, https://www.ipcc.ch/report/ar6/syr/resources/spmheadline-statements/

[32] IPCC. (2021). 2021: Weather and Climate Extreme Events in a Changing Climate. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg1/

[33] Clark Scott, Mills Graham, Brown Timothy, Harris Sarah, Abatzoglou John T. (2021) Downscaled GCM climate projections of fire weather over Victoria, Australia. Part 2: a multi-model ensemble of 21st century trends. International Journal of Wildland Fire 30, 596-610. https://doi.org/10.1071/WF20175

[34] Reisinger, A. et al. in Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

[35] Hennessy, K. et al. Australia and NewZealand. in Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (eds Parry, M. L. et al.) 507–540 (Cambridge University Press, 2007).

[36] Abatzoglou, J. T., Williams, A. P. & Barbero, R. (2019). Global emergence of anthropogenic climate change in fire weather indices. Geophys. Res. Lett. 46, 326–33

an early onset of the fire season beginning in August in New South Wales and the first week of October in Victoria[37]. The lengthening of the fire season reduces the windows available for prescribed burning.

It is difficult to robustly assess how fire weather will change in the future, as it is impacted by a number of variables such as temperature, rainfall, wind speed and humidity, therefore understanding future risk requires understanding how all of these variables will change. Additionally, fire weather shows large natural variation in the absence of human caused climate change, making it difficult to quantify the impact of climate change[38]. Work across our Centres is building the capacity to model fire weather, for example;

- The modes of climate variability that generally promote fire in southeast Australia have occurred unusually often in recent decades, compared to the pre-industrial era[39].
- Strong cold fronts have been associated with the most catastrophic fires in recent history in southern Australia including the 2019-20 Black Summer bushfires and the 2009 Black Saturday bushfires. These strong cold fronts have been increasing in frequency since the 1950s along the east coast of Australia, which may have contributed to the change in extreme fire conditions[40,41]. Further work investigating these changes in cold fronts and other weather phenomena continues to build our understanding of future fire risk from weather systems.
- The Centre is continuing to analyse the 2019-20 Black Summer bushfires to understand the weather systems that contributed[42].

The best strategy for building resilience to increasing fire risk is rapidly reducing emissions to minimise the risks of climate change, and to prepare local communities for the increasing risk of fire.

## 5. Hail

**Future trends in hailstorms remain uncertain, however it is expected they will be impacted by climate change.**

Hailstorms are a significant weather hazard, with single hailstorms able to cause over $1 billion in damages[43]. Hail is expected to be affected by climate change, however the changes are not yet well

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[37]Bui et al. (2024). The State of Weather and Climate Extremes 2023. https://climateextremes.org.au/the-state-of-weather-and-climate-extremes-2023/
[38]T.P. Lane et al. (2023). Attribution of extreme events to climate change in the Australian region – A review, Weather and Climate Extremes, 100622, ISSN 2212- 0947, https://doi.org/10.1016/j.wace.2023.100622
[39]Abram, N.J., Henley, B.J., Sen Gupta, A. et al. (2021). Connections of climate change and variability to large and extreme forest fires in southeast Australia. Commun Earth Environ 2, 8. https://doi.org/10.1038/s43247-020-00065-8
[40]Cai, D. et al.(2022). Increasing intensity and frequency of cold fronts contributed to Australia's 2019–2020 Black Summer fire disaster. https://doi.org/10.1088/1748-9326/ac8e88
[41]King, M. J., Reeder, M. J., & Jakob, C. (2023). Strong temperature falls as a cold frontal metric in Australian station observations, reanalyses and climate models.
[42] Ayat, H., T. Lane, S. Wales, M. Reeder and Y. Huang: surface drying during the Black Summer bushfires in Australia: insights from high-resolution simulations. (submitted for publication)
[43]Insurance Council of Australia. *Historical Catastrophe Data—February 2023*. https://insurancecouncil.com.au/industry-members/data-hub/

understood and have lots of regional differences. A broad expectation with climate warming is for fewer hailstorms overall, but larger hailstones when it does reach the earth's surface, however a range of outcomes is possible[44]. Recent work at our Centres, the first Australia-wide study of hail trends, examined the changes in hail hazard in Australia over the last 40 years. It found that in Victoria, trends in hail-prone days show large variations with some regions showing increased frequency and others showing decreased frequency[45]. Our Centres continue to look at future trends in hail-prone environments and further develop the capability of climate models to simulate hailstorms to understand future changes.

## 6. Extreme wind

### There is significant uncertainty around the future risk of extreme wind in Victoria, therefore it is important to prepare for these events.

Extreme wind gusts can cause severe damage to infrastructure and pose significant safety risks. The severe thunderstorm that hit Victoria in February 2024 left 530,000 people without power due to damage to the electricity distribution network[46].

Wind gusts should also be considered in bushfire management, while periods of wind drought can disrupt renewable energy supply. Predicting how thunderstorm wind gusts will change into the future is challenging due to the short-lived and localised nature of these events, making them hard to observe and model. Although we expect an increase in the energy available for thunderstorms under climate change, there are significant uncertainties in how locally damaging winds might change into the future. Our Centres continue to investigate the characteristics and types of locally damaging wind events to improve climate predictions, providing better information for risk management and designing infrastructure[47,48]. We are also working on quantifying available wind resources and their susceptibility to climate variability and change to inform the renewable energy transition.

## 7. Sea level rise

### Sea level rise along the Victorian coastline will continue over the coming centuries.

Multiple climate change factors are contributing to sea level rise, including increasing ocean temperatures, the retreat of glaciers and ice caps, and the loss of ice sheets in Antarctica and

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[44] Raupach, T. H., et al. (2021). The effects of climate change on hailstorms. Nature Reviews Earth and Environment, vol. 2, pg. 213-226. https://doi.org/10.1038/s43017-020- 00133-9

[45] Raupach, T.H., et al. (2023). Changes in hail hazard across Australia: 1979–2021. https://doi.org/10.1038/s41612-023-00454-8

[46] State of Victoria Department of Environment, Land, Water and Planning. (2024). Putting Victorians first through Network Outage Review. https://www.energy.vic.gov.au/about-energy/news/news-stories/putting-consumers-first-through-network-outage-review#:~:text=What%20happened%3F,than%20500%2C000%20homes%20and%20businesses

[47] Brown, A and Dowdy, A. (2021). Severe Convective Wind Environments and Future Projected Changes in Australia. https://doi.org/10.1029/2021JD034633

[48] El Rafei, M et al. (2023). Analysis and characterisation of extreme wind gust hazards in New South Wales, Australia. https://link.springer.com/article/10.1007/s11069-023-05887-1?utm_source=getftr&utm_medium=getftr&utm_campaign=getftr_pilot

Greenland. Global mean sea level has risen by over 0.20m[49], and this sea level rise will continue for hundreds of years after emissions cease due to time lags in the ocean's response to greenhouse gases. Sea level is expected to increase by another 10-25cm by 2050 and 40-80 cm by 2100, however sea level rise of 1.5m by 2100 remains possible[50]. Reducing our emissions as soon as possible will reduce future sea level rise. Rising sea levels have severe implications for coastal inundation, erosion and groundwater. The result is damage to properties, roads and various assets along the coastline. Planning for continued sea level rise along the Victorian coastline is an important component of resilience.

## 8. Compound events

### Compound events can increase the risk of severe impacts.

Many weather related disasters are compound events, where multiple weather and climate hazards come together to cause significant impacts[51]. Compound events arise from multiple hazards or drivers, a succession of hazards, hazards in multiple connected locations, or preconditioning. The severe flooding in Victoria during October 2022 was a compound event[52]. This flooding was caused by a combination of weather processes which brought persistent and heavy rainfall to catchments that were already saturated due to months of heavy rainfall. It was the combination of multiple weather processes, in addition to the antecedent conditions that resulted in the severity of the flooding.

The possibility for multiple hazards to combine and compound makes risk assessment challenging. Future climate change will lead to an increase in prolonged hot and dry compound events over all of Australia, while the changes in wet and windy compound events are less certain[53].

### *(b) how the Victorian Government is preparing for and mitigating the impacts of climate change on our built environment and infrastructure;*

We advise two key actions that the Victorian Government can take:

## 1. Reducing emissions to reduce the impacts of climate change

The most important and urgent action for improving climate resilience is reducing greenhouse gas emissions as soon as possible. It is extremely concerning that current global emissions targets put

[49]Fox-Kemper, B. et al. (2021). 2021: Ocean, Cryosphere and Sea Level Change. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-9/
[50]Fox-Kemper, B. et al. (2021).
[51]The ARC Centre of Excellence for Climate Extremes (2022). A new global picture of compounding weather and climate hazards. https://climateextremes.org.au/anew-global-picture-of-compounding-weather-andclimate-hazards/
[52]ARC Centre of Excellence for Climate Extremes. (2023). Inquiry into the 2022 flood event in Victoria. https://www.parliament.vic.gov.au/494849/contentassets/ca92370f5c15477fafb396bd7b895b1e/submission-documents/309.-the-arc-centre-of-excellence-for-climate-extremes_redacted.pdf
[53]ARC Centre of Excellence for Climate Extremes (2022). High impact compound events in Australia. https://climateextremes.org.au/high-impact-compound-events-in-australia/

the world on track to reach around 2.9°C of warming this century[54], far exceeding the goals of the Paris Agreement of limiting global warming to well below 2°C and pursuing efforts to keep warming to 1.5°C. Our Centre acknowledges that the Victorian government has been a national leader in setting strong emissions reduction targets. We urge the Victorian government to keep increasing ambition and delivering the urgent emissions reductions that are required to halt global warming. There is no safe level of warming - every fraction of a degree of warming increases the risks for Victorians. As such, the most effective resilience measure is cutting greenhouse gas emissions.

## 2. Utilise the expertise of climate scientists when interpreting climate information

Climate science is a central component for making informed decisions regarding resilience to Victoria's changing climate. Our Centres recommend utilising the expertise of climate scientists to assist with interpreting complex and often confusing climate information. Our Centres offer our expertise in navigating climate data and climate model projections.

While climate science can provide a strong understanding of the global scale changes we expect from climate change, it is hard to predict what and where events will occur in the future because of the complex nature of the climate and uncertainty in emissions trajectories. Regional information for Victoria is therefore inherently uncertain for variables other than temperature, for which we have a strong understanding. However, decisions must be made in the face of uncertainty and information showing which future outcomes are more likely is extremely valuable. Understanding uncertainties helps to make more informed adaptation decisions.

Uncertainties in future climate risks arise from;

- Natural variability in the climate system: the climate is highly variable, meaning that aspects of the weather, such as temperature and rainfall change naturally year to year which can make it hard to separate natural changes from the impacts of human caused climate change.
- Knowledge gaps in our understanding of various climate and weather phenomena: there are some parts of the climate we have an incomplete understanding of due to both a lack of observations or limitations in theoretical understanding and modelling which contribute to uncertainties in future risk.
- Limitations in model projections of our future climate: climate models simulate the immensely complex climate system and are the best tools available to project future changes. However they have inherent biases that require continued improvement and there are also computing power constraints that limit the scales simulated by model projections, impacting their accuracy.
- Uncertainties in human behaviour: our decisions impact climate risk such as how rapidly emissions are reduced, economic and technological development and policy interventions.

[54]United Nations Environment Programme (2023). Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again). Nairobi. https://doi.org/10.59117/20.500.11822/43922.

Understanding these sources of uncertainty shows why the precision of climate model data can be easily misused, resulting in maladaptation. For example, if we are interpreting future rainfall to 10 decimal places using a single simulation as a future prediction, it is almost certainly going to be wrong. We would like to caution the committee to be wary of products that are being offered to local, state and federal governments that pertain to have accurate and specific data on how extreme rainfall will change at local scales in the future, as this capability is beyond our current scientific understanding. Therefore, we urge decision makers to use caution when navigating climate data. To most appropriately apply climate science to adaptation decisions, we strongly recommend:

1. **Using multiple lines of evidence:** this may involve using historical data to observe past trends in extreme events, using climate models to explore how these extreme events may change in frequency and intensity in the future and utilising knowledge from other disciplines such as social sciences, engineering and economics to inform risks and adaptation options.
2. **Using a storyline approach:** looking at the range in climate model projections for your region of interest can show possible future outcomes from which you can produce 'storylines' of future change. For example, your region of interest may be projected to have a slight drying on average with increased heat, or significant rainfall increases overall with increased rainfall variability. Plausible futures or 'storylines' might bracket the range of outcomes, and your preparedness could result from working through what these cases might mean for risk.
3. **Transparency around data and methodology:** climate information is based on various assumptions which are important to communicate along with uncertainties so that information can be interpreted appropriately. We recommend communicating climate risks through ranges such as severity, likelihood, duration and frequency rather than solely using numbers as quantitative information may provide false confidence.
4. **Keeping up to date with latest climate science research:** our Centres are improving climate models and process based understanding to provide better information about possible future scenarios. This includes benchmarking work which can be used to determine the most appropriate model data to use for a specific application[55], in addition to techniques such as downscaling and machine learning[56] which can produce additional information about local scale changes. We are also developing high resolution global models which will provide information about weather and climate at the km scale.

## *(e) what more could be done to better prepare Victoria's built environment and infrastructure, and therefore the community, for future climate disaster events*

1. **Promote and fund cross disciplinary research:** climate resilience is interdisciplinary by nature, involving the interaction between physical climate risks, socioeconomic factors and our built environment, which determines how these physical risks are realised. As such, funding cross-disciplinary research is an important aspect of building the information we have available to inform climate resilience. At present, research environments do not

[55] Isphording, R. N., L. V. Alexander, M. Bador, D. Green, J. P. Evans, and S. Wales. (2024): A Standardized Benchmarking Framework to Assess Downscaled Precipitation Simulations. https://doi.org/10.1175/JCLI-D-23-0317.1.
[56] The ARC Centre of Excellence for Climate Extremes. (2023). Using Machine Learning to Cut the Cost of Downscaling Global Climate Models. https://climateextremes.org.au/using-machine-learning-to-cut-the-cost-of-downscaling-global-climate-models/

promote this type of research, as funding sources are primarily discipline based. For example, research that looks holistically at system wide climate impacts might consider: climate related health impacts, the effectiveness of urban design strategies for extreme rainfall and heat or how weather resource availability will impact renewable energy.

2. **Promote and fund public-private partnerships:** encouraging collaborations between the government, private sector, and non-profit organisation is important to leverage resources and expertise for climate resilience projects.
3. **Support the National Partnership for Climate Projections:** this federally led initiative brings together key stakeholders responsible for all aspects of climate projections from technical experts involved in the production of projections, to the operational staff and communication experts that are sharing this information. The partnership facilitates knowledge sharing across states to maximise progress and bring together a coordinated response. Providing more opportunities for different agencies to come together in a collaborative environment is essential to leverage progress made by various groups.
4. **Advocate for a National Climate Science Strategy:** continuing to build Australia's capability to provide high quality climate information urgently requires a national strategy. This would be useful to bring together a disjointed community to carry out the research required, build the operational systems to provide a seamless predictive capability and the services that translate the prediction data into actionable information for markets to act on. The climate research, operations, and service need to be considered as a well-connected continuum rather than separate, disconnected pieces. A strategy that integrates investments in observations, scientific understanding, and the development of scientifically rigorous models is vital, and this strategy needs to be ambitious. This will allow for a coordinated plan to maximise the advancement of climate information for decision making. It is important that the Victorian government is a stakeholder in this national strategy to advocate for the state's unique climate risks.

### *(f) whether further inquiries or investigation may be needed into other aspects of climate change adaptation and climate disaster preparedness in Victoria…*

Our Centres recommend ongoing inquiries to continue to address current and emerging climate risks in Victoria. As climate change, adaptation challenges and technological developments continue to evolve rapidly, keeping up to date with this information is important to coordinate a targeted response. Further inquiries that look into particular challenges faced by different sectors would be useful, for example looking at climate impacts on urban planning, agriculture, water security, energy security, emergency response or human health. This will help to address the far reaching impacts of climate change and locate priority areas for action.

There is an urgent need to build a workforce equipped to adapt to climate change. An inquiry focusing on workplace planning would be beneficial to ensure that there is a pipeline for professionals that have a diverse range of skills and expertise that are relevant to resilience. Climate literacy across sectors is improving, however this needs to move at speed to increase our preparedness. Facilitating public awareness campaigns and community workshops are a way to achieve this and improve the broader public's understanding of climate resilience issues. It is important that these initiatives also provide targeted support for diverse communities, including communities of multicultural and multilingual backgrounds.

One important element of preparing our workforce is encouraging students to study climate science in both school and university. It is important that positive attitudes are built around science beginning in school, as this is a key determinant of whether a student will continue to pursue further study and work in this field. Incorporating context-based learning to demonstrate how maths and physics are applied in climate science adds meaningful relevance to these subjects[57]. This may include demonstrating cultural relevance of these skills for First Nations students, as done by the organisation Deadly Science[58]. Further, demonstrating the varied career paths available in climate science, such as those in government, consulting, insurance and research would assist to overcome barriers caused by a lack of awareness of the opportunities in climate science. These actions will assist with building a workforce that has the capability to contribute towards a resilient Victoria.

[57]ARC Centre of Excellence for Climate Extremes. (2022). Climate Classrooms. https://climateextremes.org.au/climate-classrooms-2/
[58]Deadly Science. (2024). About us. https://deadlyscience.org.au/about-us/#two-column-block_624643a080ec9