Climate Change Adaptation Gap Analysis
Part One

Document Control

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1. Introduction

The Department of Environment, Land, Water and Planning (DELWP) is conducting a climate change adaptation regional gap analysis to develop regional priorities for adaptation based on the climate change impacts the region is likely to experience, the needs and values of regional communities, and work undertaken to date. The DELWP Port Phillip Region team have asked the Northern Alliance for Greenhouse Action (NAGA), working with the other inner-city Alliances (WAGA, SECCCA and EAGA), to deliver part of this analysis by February 2018.

2. Scope

The gap analysis to be delivered by NAGA consists of the following defined pieces of work:

Part One

- Regional Snapshot
- Stakeholder Analysis
- Climate Change Impact Assessment

Part Two

- Vulnerability Mapping

Part Three

- Existing Adaptation Responses

This report forms the output from Part One of this work.

3. Port Phillip region

The DELWP Port Phillip region consists of 31 local government areas, all within Metropolitan Melbourne. These can be divided into six LGAs within growth areas, and 25 LGAs within the inner-middle, as outlined in Table 1. Metropolitan Melbourne consists of residential, industrial and commercial land use. Consequently, the region faces a range of challenges due to the diversity of landscapes, communities and sectors found across the region.

Classification	LGAs (C = City council; S = Shire council)
Metropolitan Melbourne (Inner-Middle)	Banyule (C), Bayside (C), Boroondara (C), Brimbank (C), Darebin (C), Frankston (C), Glen Eira (C), Greater Dandenong (C), Hobsons Bay (C), Kingston (C), Knox (C), Manningham (C), Maribyrnong (C), Maroondah (C), Melbourne (C), Monash (C), Moonee Valley (C), Moreland (C), Mornington Peninsula (S), Nillumbik (S), Port Phillip (C), Stonnington (C), Whitehorse (C), Yarra (C), Yarra Ranges (S)
Metropolitan Melbourne (Growth Areas)	Cardinia (S), Casey (C), Hume (C), Melton (S), Whittlesea (C), Wyndham (C)

Table 1 Port Phillip region councils by Inner-Middle and Growth Area classifications.

All of the growth area councils and some of the inner-middle councils also contain green wedge areas. Green wedges are non-urban areas of the region that contain a mix of agriculture and low-density activities. Unfortunately, data for this report is not readily available broken down by green wedge vs non-green wedge. Further work would need to be done to go through the individual green wedge plans to identify information for the regional snapshot. The map in *Appendix A* displays the green wedges overlaid on LGAs.

4. Regional Snapshot

The *Regional Snapshot* took the form of a desktop review of publicly available data and provides essential background information on key factors relevant to climate change adaptation within the Port Phillip region.

Different communities have various levels of vulnerability to climate change. Several communities more vulnerable to climate change are outlined below. However this list should not be considered exhaustive. It should also be noted that people often have multiple complex overlapping needs and vulnerabilities.

See *Appendix B* for links to maps of some of these demographics.

4.1 Population

The total population number for Metropolitan Melbourne (estimated resident population) in 2016 is 4,653,078 persons.[1] Victoria in Future 2016 project that by 2051, the population for Metropolitan Melbourne will be 8.0 million.[2]

Metropolitan Melbourne (Inner Middle) population number (estimated resident population) in 2016 was: 3,456,384. The population forecast for 2031 is 4,096,556, with 10-year Average Annual Population Forecast Growth Rate 2021-2031 of 1.32% per annum. Population density in 2016 for persons per square kilometre is 681.

Metropolitan Melbourne (Growth Areas) population number (estimated resident population) in 2016 was: 1,196,694. The population forecast for 2031 is 1,834,4511, with the 10-year Average Annual Population Forecast Growth Rate 2021-2031 being 3.31% per annum. Population density in 2016 for persons per square kilometre is 319.

Description	**Metropolitan Melbourne (Inner-Middle)**	**Metropolitan Melbourne (Growth Areas)**	**Source**
Population number 2016	3,456,384 Estimated Resident Population	1,196,694 Estimated Resident Population	ABS Cat 3218.0
Population Forecast 2031	4,096,556	1,834,4511	ViF 2016
10-year Average Annual Population Forecast Growth Rate 2021-2031	1.32%	3.31%	Calculation based
Population density (persons/km2) 2016	680.671931310187	318.676501917341	ABS Cat 3218.0

Table 2 Population number and forecast

Population growth is faster in the Metropolitan Melbourne region, when compared to regional Victoria, due to the majority of overseas migrants attracted to Metropolitan Melbourne, and its proportionally younger population. This trend is expected to continue to 2051[3]. Population growth is

[1] Sum of Metropolitan Melbourne (Inner Middle) and Metropolitan Melbourne (Growth areas), collated by Regional Development Victoria.

[2] The baseline year for Victoria in Future projections is 2015 (ABS Estimated Resident Population). Department of Environment, Land, Water and Planning, 2016. *Victoria in Future 2016*, State Government of Victoria, Melbourne. P. 6.

[3] Ibid. P. 9

projected to be the greatest in the designated growth areas and five inner LGAs, with approximately two-thirds of population growth to 2031 expected in these areas[4].

Appendix C outlines this data by LGA.

4.2 Age of Population

Older people are more vulnerable to the impacts of climate change for a number of reasons, which can include decreased mobility and changes in physiology. Older people are more vulnerable to temperature extremes and have significantly higher mortality rates during extreme weather events. They are also more susceptible to diseases - a concern under conditions of stressed food and water supplies.

Babies and young children are more vulnerable to impacts such as heat, and are more susceptible to environmental risks and vector-borne diseases - a concern under conditions of stressed food and water supplies. Due to developmental levels, children can also be more vulnerable in emergency situations.

Metropolitan Melbourne (Inner-Middle) has a higher proportion of older people, compared to Metropolitan Melbourne (Growth Areas). Metropolitan Melbourne (Growth Areas) has a higher proportion of children and young people, when compared to Metropolitan Melbourne (Inner-Middle).

Description	**Metropolitan Melbourne (Inner-Middle)**	**Metropolitan Melbourne (Melbourne Growth)**	**Source**
Population 0-14 (percentage) 2015	16.76% Percentage of Total Population Aged Between 0 and 14	23.61% Percentage of Total Population Aged Between 0 and 14	ABS Cat 3235.0
Population 65-74 (percentage) 2015	8.17% Percentage of Total Population Aged Between 65 and 74	6.11% Percentage of Total Population Aged Between 65 and 74	ABS Cat 3235.0
Population 75-84 (percentage) 2015	4.86% Percentage of Total Population Aged Between 75 and 84	2.88% Percentage of Total Population Aged Between 75 and 84	ABS Cat 3235.0

[4] Ibid

Population 85+ (percentage) 2015	2.27% Percentage of Total Population Aged 85 and Over	1.00% Percentage of Total Population Aged 85 and Over	ABS Cat 3235.0

Table 2 Population age – children an older people

The percentage share of the population, person aged 0-19 years for the Metropolitan Melbourne area is projected to decrease from 24.3% (2011) to 22.5% (2051). The percentage share of the population, persons aged 65 and over for the Metropolitan Melbourne area is projected to increase from 13.0% (2011) to 20.5% (2051)[5].

Appendix C outlines this data by LGA.

4.3 Aboriginal and Torres Strait Islander (ATSI) Peoples

Aboriginal and Torres Strait Islander peoples have typically poorer health outcomes than Victorians (and people across Australia), including preventable chronic health conditions; higher instances of mental illness, typically linked to grief, trauma and loss; lower incomes; and less access to quality housing, all factors which can contribute to vulnerability to climate change.

Proportionally, Metropolitan Melbourne has a lower proportion of people who identify as ATSI, when compared with the Victorian average, which is 0.8% of the population. Metropolitan Melbourne (Growth Areas) has a proportionally higher ATSI population (0.77%) than Metropolitan Melbourne (Inner-Middle) (0.44%). The LGAs, proportionally on par with the Victorian population are Cardinia; Mornington; Wyndham; Whittlesea and Darebin. Frankston (1.0%); Melton (0.9%) and the Yarra Ranges (0.9%) have a slightly higher than average ATSI population than the Victorian average.[6]

Appendix C outlines this data by LGA.

4.4 CALD and migrant community

Culturally and linguistically diverse (CALD) communities can be particularly vulnerable to extreme heats for a number of reasons such as lack of support networks. Due to overlapping factors which are more prevalent within refugee and newly arrived migrant populations such as low socioeconomic

[5] Department of Environment, Land, Water and Planning, 2016. *Victoria in Future 2016*, State Government of Victoria, Melbourne. P. 13

[6] ABS 2016 Census data; calculation based for metropolitan regions (inner-middle and growth) from individual council data through ABS

status and poor housing, this compounds vulnerability to climate change. Linguistic barriers also exist for emergency communications and health and other related advice.

Languages Spoken

More than 200 languages are spoken across the Port Phillip region[7]. In Metropolitan Melbourne (Growth Areas) 39.51% of the population spoke a language other than English at home. In Metropolitan Melbourne (Inner-Middle Areas) 33.04% of the population spoke a language other than English at home. Other languages spoken at home, ranked in size for Metropolitan Melbourne are: Mandarin (4.19%); Greek (2.4%); Vietnamese (2.3%); Italian (2.29%); Cantonese (1.72%); and Arabic (1.72%)[8].

English Proficiency[9]

Metropolitan Melbourne (Growth Areas) has a higher proportion of resident who speak another language, and English not well or not at all, then does Metropolitan Melbourne (Inner-Middle).

- Metropolitan Melbourne (Inner-Middle): 179,118 persons, or 5.18%
- Metropolitan Melbourne (Growth Areas): 66,112 persons, or 5.52%

The five LGAs with the highest proportion of residents who speak another language, and English not well or not at all, are listed below.

- Greater Dandenong: 25,541 persons, or 16.8%
- Brimbank: 25,989 persons, or 13.4%
- Maribyrnong: 7,576 persons, or 9.2%
- Monash: 15, 254 persons, or 8.4%
- Hume: 15,972 persons or 8.1%

Appendix C outlines this data by LGA.

First generation migrants

Melburnians have family origins in more than 230 countries.[10] As discussed, people who are newly arrived into the country may be more vulnerable to climate change. More work would need to be done on these figures to identify potentially vulnerable communities within these communities i.e.

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[7] Plan Melbourne 2017 – 2050 Metropolitan Planning Strategy http://www.planmelbourne.vic.gov.au/__data/assets/pdf_file/0007/377206/Plan_Melbourne_2017-2050_Strategy_.pdf

[8] ABS 2016 census data; calculation based by LGA data

[9] ABS 2016 Census data; calculation based for metropolitan regions (inner-middle and growth) from individual council data through ABS.

[10] Plan Melbourne 2017 – 2050 Metropolitan Planning Strategy http://www.planmelbourne.vic.gov.au/__data/assets/pdf_file/0007/377206/Plan_Melbourne_2017-2050_Strategy_.pdf

newly arrived immigrants from English-speaking countries could be less vulnerable than first generation immigrants who also have low English proficiency.

Description	Metropolitan Melbourne (Growth Areas)	Metropolitan Melbourne (Inner-Middle)	Source
Percentage Born overseas 2016	37.67%	36.11%	RDV calculation based on ABS Census 2016 (TableBuilder Cultural Diversity)

Table 3 Percentage born overseas

4.5 Disability

People with a disability are heterogenous, and will be impacted by climate change in different ways. Here, the ABS measure for people who require assistance with core activity was used. For those who require assistance with their core assistance, disruptions to environmental networks and support services could be detrimental. People who require core assistance may also have difficulty accessing emergency facilities, and emergency communications may not be suitable for different individuals.

While the ABS data can be used as a measure for the number of people residing in an area with disabilities, the Survey of Disability, Aging and Carers provides more comprehensive information for people with a disability, while the measure of core activity assistance provides an indication of persons with a disability who require assistance in their day-to-day activities.[11]

Description	Metropolitan Melbourne (Growth Areas)	Metropolitan Melbourne (Inner-Middle)	Source
Percentage with need for assistance core activity 2016	5.31%	5.17%	ABS Census 2016 (TableBuilder Cultural Diversity)

Table 4 Percentage of people with need for assistance with core activities

4.6 Employment

[11] ABS 2012, 'Core Activity Need for Assistance, ' *Person*, viewed 20.12.17. http://www.abs.gov.au/websitedbs/censushome.nsf/4a256353001af3ed4b2562bb00121564/ee5261c88952cf90ca257aa10005f567!OpenDocument

By 2046, the region is predicted to provide nearly 80% of state's jobs.[12]

There is a higher labour force participation rate in Metropolitan Melbourne (Growth Areas), when compared to Metropolitan Melbourne (Inner-Middle). Metropolitan Melbourne as a whole has a higher labour force participation rate than Victoria (60.5%) and Australia (60.3%).[13]

Labour Force Participation Rate	**Metropolitan Melbourne (Inner-Middle)**	**Metropolitan Melbourne (Growth Areas)**	**Description**	**Source**
2016	65.51%	66.57%	People in the labour force as a percentage of total population both in and not in the labour force	Calculation based on ABS Census 2016 (Table Builder, Employment, Income and Education)

Table 5 Labour force participation rate

Metropolitan Melbourne (Growth Areas) has a higher unemployment rate, when compared to Metropolitan Melbourne (Inner-Middle).

Unemployment Rate	**Metropolitan Melbourne (Inner-Middle)**	**Metropolitan Melbourne (Growth Areas)**	**Description**	**Source**
Unemployment Rate (Quarterly) 2017 (Q2)	5.50%	7.77%	The unemployment rate (percentage of unemployed persons to total labour force)	Department of Employment, Small Area Labour Markets data aggregated by RDV

Table 6 Unemployment rate

[12] Victoria's 30 Year Infrastructure Strategy (2016), Infrastructure Victoria http://www.infrastructurevictoria.com.au/sites/default/files/images/IV%2030%20Year%20Strategy%20WEB%20V2.PDF

[13] ABS Cat. 6202.0

Appendix C outlines this data by LGA. *Appendix D* shows a map of national employment and innovation clusters

4.7 Housing Tenure

People who lack secure housing are more vulnerable in emergency situations, and emergency situations can contribute to homelessness. People who own their own homes are also better placed to protect against the impacts of climate change, through insulation; flood-proofing; and other measures to increase resilience.

Home ownership (owned outright or through mortgage by occupant) declined across Metropolitan Melbourne between 2011 and 2016, both for Growth Areas (2.99%) and Inner-Middle (2.90%). There is a higher proportion of home ownership in Metropolitan Melbourne (Growth Areas) when compared to Metropolitan Melbourne (Inner-Middle). There is also a higher proportion of low-income households in mortgage stress for the Melbourne Metropolitan (Growth Areas) when compared to Metropolitan Melbourne (Inner-Middle).

Housing	**Metropolitan Melbourne (Inner-Middle)**	**Metropolitan Melbourne (Growth Areas)**	**Description**	**Source**
Percentage Home ownership 2016	66.14%	74.80%	Percentage of dwellings owned outright or owned with mortgage by occupant	Calculation based on ABS Census 2016 (TableBuilder Selected Dwelling Characteristics)
Percentage Low income households with mortgage stress 2011	10.06%	14.93%	Low income households (households in bottom 40% of income distribution) with mortgage stress (spending more than 30% of income on mortgage repayments)	PHIDU Australia 2013
Low income households with rental stress 2011	78,676	17,953	Low income households (households in bottom 40% of income distribution) with	PHIDU Australia 2013

			rental stress (spending more than 30% of their income on rent)	

Table 7 Home ownership, and mortgage and rental stress

Appendix C outlines this data by LGA.

4.8 Socio-economic disadvantage (SEIFA)

Poverty can compound vulnerability to climatic shocks and stressors, and the relationship between poverty and climate change vulnerability is influenced by many direct and indirect avenues. For example, they are more likely to live in areas vulnerable to climate impacts, they typically have work that is hourly and informal, and they are less likely to be insured for climatic events.

Poverty is increasingly understood as being influenced by social, and not solely economic considerations. The SEIFA index is a measure of socio-economic disadvantage,[14] calculated using several variables, to provide an indication of socioeconomic disadvantage in geographical areas. The lower a SEIFA score, the higher the level of socioeconomic disadvantage. The LGAs with the greatest disadvantage in the Port Phillip region are:

- Greater Dandenong (895)
- Brimbank (925.8)
- Hume (951.8)
- Maribyrnong (974)
- Whittlesea (988.6)

Appendix C outlines this data by LGA.

4.9 Major Infrastructure

Transport
The outer suburbs of this region are the fastest growing in Australia, especially in the north and west. There is a mismatch between job and population growth, for example Central Melbourne has 48% of jobs growth vs 8% of population growth, whereas the West of the region has 9% of jobs growth vs

[14] ABS Census data 2011

24% of population growth. Therefore, transport infrastructure becomes crucial to a functioning economy[15].

In 2013, public transport use across Melbourne accounted for 9% of all weekday trips taken compared to 72% of trips taken by private vehicle. When traveling to the CBD, residents of Melbourne use public transport for 57%of all trips. Inner Melbourne residents are more than twice as likely to use active modes of transport (walking and cycling) than those who live in the outer suburbs. Public transport modes are also used more often in inner Melbourne compared to outer Melbourne[16].

Melbourne is served by a suburban rail network of 15 suburban passenger lines and more than 200 stations[17] Melbourne originates 8 regional rail lines[18], plus freight lines in the west of the city. In 2016, Victoria's railway track infrastructure spanned 830 km in metropolitan areas[19]. The Metro tunnel project will consist of two 9 km rail tunnels and create five new train stations[20]. Metropolitan bus services carried 118.0 million passengers for the 12 months to 30 June 2017.[21] The Metropolitan train services carried 236.8 million passengers for the 12 months to 30 June 2017. Train patronage grew by 0.5 per cent for the twelve months ending June 2017[22]. 50 levels crossings are being removed across the region between 2016 and 2022[23].

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15 Victoria's 30 Year Infrastructure Strategy (2016), Infrastructure Victoria http://www.infrastructurevictoria.com.au/sites/default/files/images/IV%2030%20Year%20Strategy%20WEB%20V2.PDF

16 VISTA Survey (2013) Department of Transport http://economicdevelopment.vic.gov.au/__data/assets/pdf_file/0003/1269291/VISTA-2013-Travel-in-metropolitan-Melbourne.PDF

17 Department of Transport http://www1.transport.vic.gov.au/VTSP/homepage.html?geoName=State%20Regions&areaName=Metropolitan%20Melbourne&topicGroupName=Public%20transport%20use Retrieved 19/12/17

18 PTV Victorian Train Lines map https://static.ptv.vic.gov.au/Maps/1482457134/PTV_Train-Network-Map_2017.pdf Retrieved 19/12/17

19 Victorian Infrastructure Plan 2017 https://www.premier.vic.gov.au/wp-content/uploads/2017/10/2017_Victorian_Infrastructure_Plan.pdf

20 Ibid

21 PTV Annual Report 2016-17 https://static.ptv.vic.gov.au/PTV/PTV%20docs/AnnualReport/1508726494/PTV_Annual-Report-2017_accessible-version.pdf

22 PTV Annual Report 2016-17 https://static.ptv.vic.gov.au/PTV/PTV%20docs/AnnualReport/1508726494/PTV_Annual-Report-2017_accessible-version.pdf

23 http://levelcrossings.vic.gov.au Retrieved 21.12.17

Melbourne has the world's largest tram network with 250km of double track[24]. Annual patronage is more than 203 million boardings (2015-16) and Yarra Trams employs more than 2000 employees[25]

Tram services carried 204.0 million passengers for the 12 months to 30 June 2017, an increase of 0.2 per cent for the year[26].

The Port of Melbourne is Australia's busiest port and largest container and general cargo port.[27] The region has three main airports. Melbourne Tullamarine, is the second busiest airport in Australia. It is located in the north west of the region, passenger and cargo flights. Essendon in the north west services regional flights and general aviation. Moorabin in the south east services general aviation.[28]

Appendix E shows a map of current transport infrastructure. *Appendix F* is a summary of the Department of Transport VISTA survey in 2013, showing the results of the survey into transport habits of Melburnians.

Water

Ten major reservoirs with a total capacity of 1,810 billion litres are operated by Melbourne Water and provide water for the region. Seven of these reservoirs are located within the region. Maroondah (east) O'Shanassy (east) and Yan Yean (north) are fed by uninhabited water catchments in the north and east of the region and beyond. Sugarloaf (east), Greenvale (north), Silvan (east) and Cardinia (south east) are fed by the water catchment reservoirs, and in turn provide the Port Phillip region with their water.[29]. In 2016 and 2017, these reservoirs had a generally lower capacity than the previous 3 years, and the 1997 – 2010 average in-flow levels were around a third lower than the 1984 – 1996 levels[30].

There are two water treatment plants in the east (Carrum Downs) and the west (Werribee) of the city, providing recycled water for fire-fighting, irrigation, and watering amongst other non-drinking uses.

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[24] http://www.yarratrams.com.au/about-us/who-we-are/facts-figures Retrieved 15.12.17

[25] Ibid

[26] PTV Annual Report 2016-17 https://static.ptv.vic.gov.au/PTV/PTV%20docs/AnnualReport/1508726494/PTV_Annual-Report-2017_accessible-version.pdf

[27] Port Phillip Bay Environmental Management Plan 2017 – 2027 https://www.coastsandmarine.vic.gov.au/__data/assets/pdf_file/0024/88710/PPB-EMP-2017-Main-Doc.pdf

[28] DELWP 2017, 'Airports and Planning, *Policy and Strategy,* retrieved 12.21.17, https://www.planning.vic.gov.au/policy-and-strategy/airports-and-planning

[29] https://www.melbournewater.com.au/community-and-education/about-our-water/water-storage-reservoirs Retrieved 19.12.17

[30] https://www.melbournewater.com.au/community-and-education/about-our-water/history-and-heritage/history-our-water-supply-system-0 Retrieved 22.12.17

Class A is the highest grade for recycled water, and these two treatment plants produce the largest amount of Class A recycled water in Australia [31].

Appendix G is a map of the water catchment areas in the region.

Communications

In 2016 in the inner-middle of the region, 87.63% of households had the internet connected. In the growth area of the region it was slightly lower during 2016, with 88.59% of households with internet connected[32]. There are many mobile phone blackspots all around the outer parts of the region.[33]

Energy

The gas thermal power station in Newport (west) produces up to 510MW of power,[34] whilst gas turbine power stations in Laverton North (west) produce up to 320 MW fuelled by natural gas from the Brooklyn – Lara pipeline[35], and Somerton (north)[36] has a capacity of 150MW[37]. Both are peaking back-up supplies. A number of smaller, landfill gas sites also exist. Cardinia and Silvan reservoirs also produce hydroelectricity. The government are planning for 100MWh of general battery storage to be installed by 2018[38].

4.10 Landscapes and biodiversity

The Port Phillip region spans 9,993 km2. It encompasses flat volcanic plain country and grassland reserve out towards the west, north west along the Maribyrnong river and tributaries, north through the woodland and bushland valleys of the Yarra river tributaries, east along the Yarra river to the Dandenong and Yarra Ranges, and south east along the shores of Port Phillip and Bay and Westernport. Melbourne has more than 600 kilometres of coast, including Port Phillip Bay and

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31 https://www.melbournewater.com.au/community-and-education/about-our-water/water-supply Retrieved 19.12.17

32 RDV calculated based on ABS Census 2016 (TableBuilder Selected Dwelling Characteristics)

33 Australian Government https://data.gov.au/dataset/community-reports-of-poor-or-no-mobile-coverage/resource/c6b211ad-3aa2-4f53-8427-01b52a6433a7?filters=RegionalDevelopmentAuthority%3AMelbourne+East%7CRegionalDevelopmentAuthority%3ANorthern+Melbourne%7CRegionalDevelopmentAuthority%3ASouthern+Melbourne%7CRegionalDevelopmentAuthority%3AWestern+Melbourne Retrieved 19.12.17

34 https://ecogen.com.au/home Retrieved 19.12.17

35 http://www.snowyhydro.com.au/our-energy/gas/laverton-north/ Retrieved 19.12.17

36 https://www.agl.com.au/about-agl/how-we-source-energy/thermal-energy/agl-somerton Retrieved 19.12.17

37 http://globalenergyobservatory.org/geoid/43151 Retrieved 19.12.17

38 Victorian Infrastructure Plan 2017 https://www.premier.vic.gov.au/wp-content/uploads/2017/10/2017_Victorian_Infrastructure_Plan.pdf

Western Port.[39] It has 8,400 kilometres of waterways— including the Yarra, Maribyrnong and Werribee rivers.[40]

The largest use of land in growth areas is primary production, while in inner city areas it is parkland – see Table 8.

[39] Plan Melbourne 2017 – 2050 Metropolitan Planning Strategy http://www.planmelbourne.vic.gov.au/__data/assets/pdf_file/0007/377206/Plan_Melbourne_2017-2050_Strategy_.pdf pg 121

[40] Ibid

Type of land use	Growth Areas	Inner-Middle	Source
Commercial	1.42%	1.50%	RDV calculated using ABS Cat 1270.0.55.003, July 2017
Education	0.54%	0.91%	RDV calculated using ABS Cat 1270.0.55.003, July 2017
Hospital/Medical	0.02%	0.08%	RDV calculated using ABS Cat 1270.0.55.003, July 2017
Industrial	2.52%	3.28%	RDV calculated using ABS Cat 1270.0.55.003, July 2017
Other	10.94%	8.88%	RDV calculated using ABS Cat 1270.0.55.003, July 2017
Parkland	12.26%	37.08%	RDV calculated using ABS Cat 1270.0.55.003, July 2017
Primary Production	55.44%	24.56%	RDV calculated using ABS Cat 1270.0.55.003, July 2017
Residential	16.12%	22.84%	RDV calculated using ABS Cat 1270.0.55.003, July 2017
Transport	0.13%	0.42%	RDV calculated using ABS Cat 1270.0.55.003, July 2017
Water	0.61%	0.46%	RDV calculated using ABS Cat 1270.0.55.003, July 2017

Table 8 Land use

National parks in the region include Yarra Ranges, Dandenong Ranges, Churchill, King Lake, Mornington Peninsula, Point Nepean, plus Port Phillip Heads Marine National Park.
A 15,000 hectare reserve is being created to protect critically endangered natural temperate grasslands in the west of the region. This will protect some of Victoria's most endangered ecosystems, and provide habitat for a number of listed rare or endangered species, including the Golden Sun Moth, Striped Legless Lizard, Growling Grass Frog, Spiny Rice-flower, and Button Wrinklewort[41].

The Convention on Wetlands, known as the Ramsar Convention, is an intergovernmental treaty for the conservation and wise use of wetlands and their resources[42]. Ramsar-listed wetlands lie in Port

[41] LeadWest http://www.leadwest.com.au/Melbournes-West/Liveability-and-Sustainability-in-Melbournes-west/Western-Grasslands Retrieved 19/12/17
[42] https://www.ramsar.org/ Retrieved 21.12.17

Phillip Bay to the west, Westernport in the south east, and Edithvale and Seaford in the south east suburbs[43]

Tree canopy cover is particularly low in the west of the region, being only 0.0% to 9.9%[44]. Average tree canopy cover can be broken down by the six Metropolitan Partnerships area as per Table 9. Please note, the Northern Metro region also covers a part of Mitchell Shire, which is outside of the Port Phillip region.

Area	**LGAs**	**Average tree canopy cover**
Inner Metro	Melbourne, Port Phillip, Yarra	15%
Inner South East	Stonnington, Boroondara, Bayside, Glen Eira	24%
Northern Metro Region	Hume, Moreland, Darebin, Whittlesea, Nillumbik, Banyule, Mitchell Shire	24%
Eastern Metro Region	Yarra Ranges, Manningham, Whitehorse, Monash, Maroondah, Knox	70%
Western Metro Region	Melton, Brimbank, Moonee Valley, Maribyrnong, Hobsons Bay, Wyndham	5%
Southern Metro Region	Kingston, Greater Dandenong, Frankston, Cardinia, Mornington Peninsular, Casey	26%

Table 9 Average tree canopy cover

There are 12 designated green wedge areas across 17 municipalities which form a ring around the city. Green wedge areas contain a mix of agriculture and low-density activities such as:

- major infrastructure that supports urban areas, including:
    - Melbourne and Moorabbin airports
    - the western and eastern water treatment facilities
- major quarries used in the building industry
- cultural heritage sites
- biodiversity conservation areas
- water catchments

[43] Plan Melbourne 2017 – 2050 Metropolitan Planning Strategy http://www.planmelbourne.vic.gov.au/__data/assets/pdf_file/0007/377206/Plan_Melbourne_2017-2050_Strategy_.pdf Map 22

[44] Victoria's 30 Year Infrastructure Strategy (2016), Infrastructure Victoria, page 192 http://www.infrastructurevictoria.com.au/sites/default/files/images/IV%2030%20Year%20Strategy%20WEB%20V2.PDF

About one third of the total green wedge area is public land, including national parks, other parks, reserves, and closed protected water catchments[45].

Appendix A shows areas of green wedge and high biodiversity.

4.11 Dominant Industries

The largest industries by employment in the Metropolitan Melbourne area, ranked in size, are: health care and social assistance, retail, professional, scientific and technical services, education and training, construction and manufacturing.

The first three industries combined (health care and social assistance, retail, professional, scientific and technical services) employ 650,361 people in total.

Table 10 shows this information broken down by sub divisions of the region.

RDV Sub Region	**LGA**	**Industry**
Eastern Melbourne	Boroondara, Knox, Manningham, Maroondah, Monash, Whitehorse and Yarra Ranges	Melbourne's East Gross Regional Product is: GRP: **$54.694 billion**. The largest industries in terms of value added for Eastern Melbourne are: - Rental, hiring and real estate services - $8,217.620 M - Manufacturing - $5,462.921 M - Wholesale trade - $4,509.769 M[46]
Northern Melbourne	Banyule, Darebin, Moreland, Yarra, Hume, Nillumbik and Whittlesea.	The largest industries in terms of value added (given in per cent of Gross Regional Product), for Northern Melbourne are:[47] - Transport, Postal & Warehousing (10.7%) - Manufacturing (10.6%) - Healthcare and social assistance (10.5%)

[45] DELWP Planning Policy and Strategy https://www.planning.vic.gov.au/policy-and-strategy/green-wedges Retrieved 18/12/17

[46] RDA Australia 2017, 'Economy Profile,' *RDA Melbourne East,* http://www.economyprofile.com.au/rdamelbourneeast/industries Retrieved 21.12.17

[47] RDA Australia 2016, Northern Melbourne RDA Committee Regional Plan 2016-2019, Melbourne.

Western Melbourne (without CBD)	Brimbank, Maribyrnong, Melton, Moonee Valley, Hobsons Bay and Wyndham.	Melbourne's West Gross Regional Product is: **$31.795 billion** The largest industries in terms of value added for Western Melbourne are: - Rental, hiring & real estate services ($5,226.100 M) - Manufacturing ($5,226.100 M) - Transport, Postal & Warehousing ($2,622.006 M) [48]
Southern Melbourne	Bayside, Cardinia, Casey, Frankston, Glen Eira, Greater Dandenong, Kingston, Mornington Peninsula, Port Phillip, Stonnington.	The largest industries given in per cent of Gross Regional Product, for Southern Melbourne are:[49] - Manufacturing ($7,283.5 M) - Construction ($6,289 M) - Retail Trade ($6,146.4)
City of Melbourne	Melbourne	The City of Melbourne is a major contributor to the Victorian economy. Gross Local Product in 2016 for the City of Melbourne was $92.12 billion, and makes up 25% of the Victorian Gross State Product. The largest industries in terms of value added for the City of Melbourne are: - Financial and Insurance Services ($32.85 B) - Healthcare and social assistance ($25.76 B) - Professional, scientific and technical services ($15.08 B)

Table 10 Dominant industries by sub-region

Port Phillip and Westernport Bay

[48] RDA Australia 2017, 'Economy Profile,'
LeadWest, http://www.economyprofile.com.au/melbourneswest/industries Retrieved 21.12.17
[49] RDA Southern Melbourne 2016, Regional Development Plan 2016-2019.

The Port of Melbourne is Australia's busiest port, and handles over a third of Australia's container trade.[50]

Commercial fishing and aquaculture is also an important industry for the Port Phillip and Westernport Bays, with the average market value for finfish averaging $3.5 per annum, for the 35 years to 2012. While with the buyback of commercial licences, commercial fishing is projected to decline in the value added to industry, aquaculture is projected to be a growth industry[51].

Melbourne Food Bowl

Agricultural land within metropolitan Melbourne is largely located in the LGAs of: Cardinia, Casey, Hume, Melton, Mornington Peninsula, Nillumbik, Whittlesea, Wyndham and Yarra Ranges. It tends to produce larger volumes of vegetables, poultry and fruit. Agriculture in this area accounts for 2.0% of employment.[52] While the land availability in this region is lower than in regional areas of Victoria – accounting for just 3% of agricultural land, it produces a relatively high share of agricultural product (see Image 1).

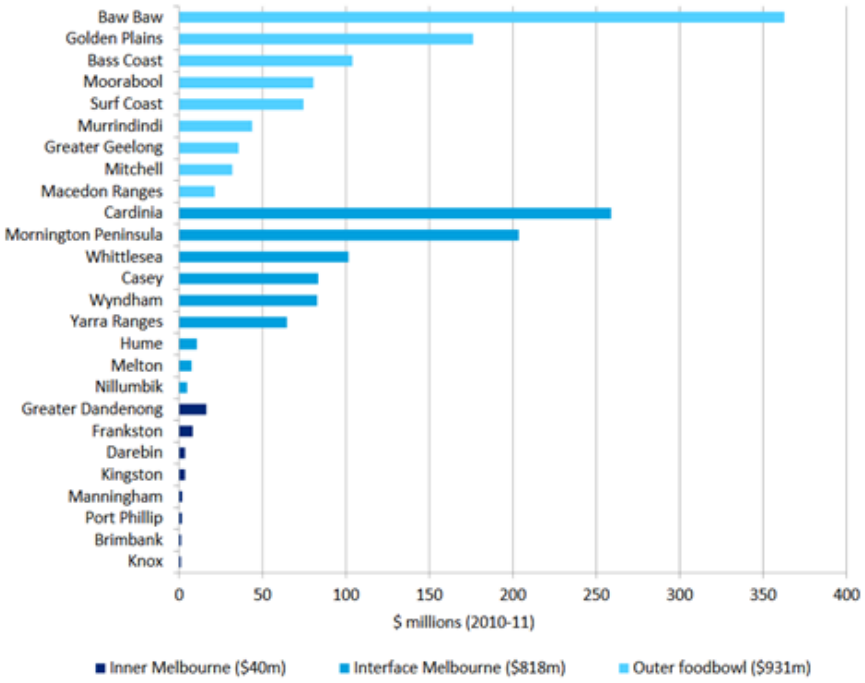

Image 1 Agricultural value by LGA in Melbourne's food bowl[53]

[50] DELWP 2017, Port Phillip Bay Environmental Management Plan, Mebourne, p.20.

[51] DELWP 2017, Port Phillip Bay Environmental Management Plan, Mebourne, p.20

[52] Deloitte & Melbourne University 2016, The economic contribution of Melbourne's foodbowl, Melbourne

[53] Deloitte & Melbourne University 2016, The economic contribution of Melbourne's foodbowl, Melbourne, p.4.

Viticulture is an important industry for the Melbourne region, and results in a high value-added product. For example, while the value of grapes in the Yarra Valley Region is $20 million, the value of wine produced on rural properties in the Yarra Valley is $250 million.[54]

Urban development represents a major threat to Melbourne's food bowl, in terms of the land available to agriculture, and the economic contribution of food in this region. Modelling a future population of 7 million people, combined with loss of land, agricultural output is modelled to fall by $32 million to $111 million. The growing population, combined with the loss of agricultural land, is projected to drive up food prices.[55]

4.12 Renewable Energy Uptake

Across the region there are an estimated 658 MW of solar installed on dwellings. This is a 13% coverage across the region. It is estimated that 84.8% are on households, the rest being commercial installs (using smaller than 10kw systems as a proxy for household rather than commercial installs). Growth areas have a much higher density of solar - 17.7% than inner-middle areas, and a higher proportion of household solar, at 87.8% of total solar in the growth areas[56]. *Appendix H* has the breakdown of solar density, capacity and total number by LGA.

[54] Regional Development Australia 2012, A Regional Plan for Melbourne's East, Australian Government. p. 39.
[55] Deloitte & Melbourne University 2016, The economic contribution of Melbourne's foodbowl, Melbourne.
[56] Australian PV Institute (APVI) http://pv-map.apvi.org.au/historical#4/-26.67/134.12 Retrieved 15/01/17

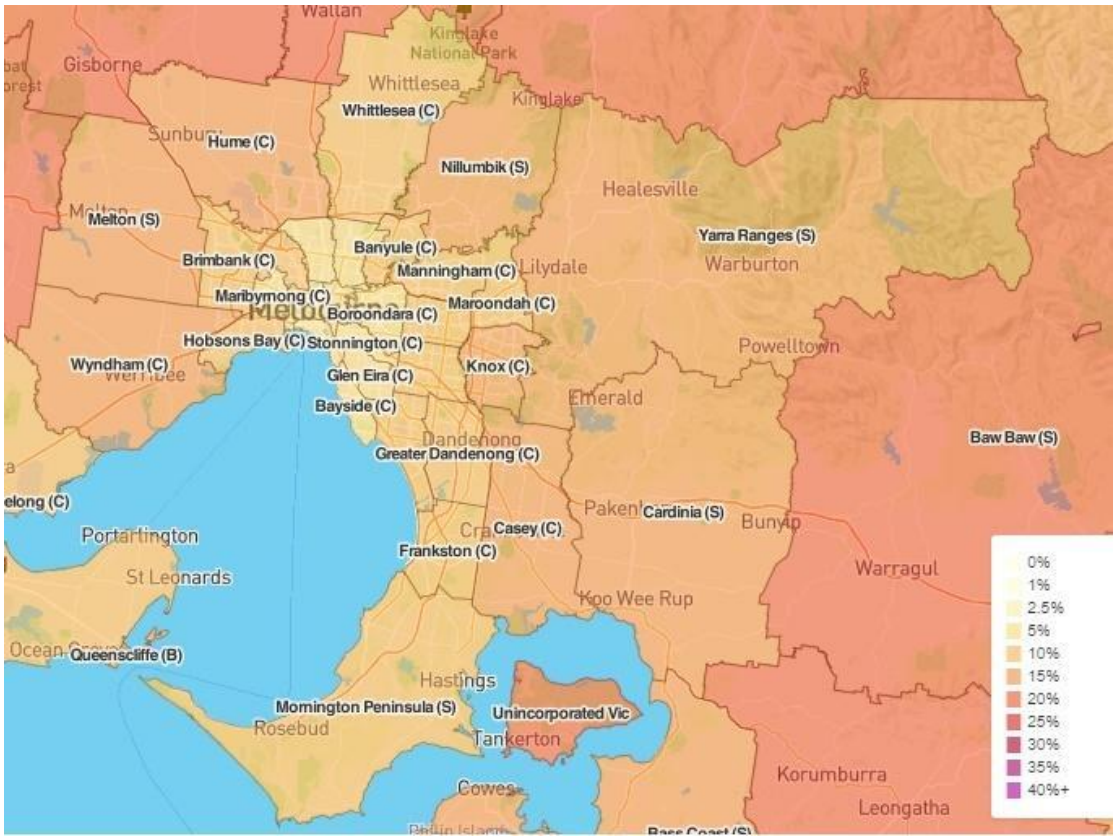

Image 2 Solar PV estimates by density[57]

5. Stakeholder Analysis

The *Stakeholder Analysis* is delivered through desktop research combined with interviews with greenhouse alliances staff to identify key stakeholders that play a role in adaptation.

5.1 Key Stakeholders

An analysis of stakeholders was undertaken, identifying stakeholders involved in adaptation. *Appendix I* lists stakeholders, their contact details where available, and information about their relevance to adaptation. Where it has been able to provide information on the sectors they are involved in, this has been provided.

- Stakeholders for adaptation, including contact details, were identified at different levels of Government; within statutory authorities; and working within academia.

[57] Australian PV Institute (APVI) Mapping Australian Photovoltaic Installations http://pv-map.apvi.org.au/historical#9/-37.9594/145.1047 Retrieved 20.12.17

- The identification of, and contact details for adaptation stakeholders was either mixed or limited for: private sector and industry bodies; and community groups.

- The identification of stakeholders and contact details for adaptation was limited, when looking at individual leaders and Aboriginal and Traditional Owner groups.

- It should also be noted that while contacts were identified for community and health sectors, some gaps remain. No specific contact was identified through engagement with Executive Officers or further stakeholders for mental health services in relation to climate change adaptation.

- Direct contacts for emergency management was also a gap in this analysis, indicating a lack of linkage between emergency management and the work undertaken through the Greenhouse Alliances.

Please see below a summary provided by each Greenhouse Alliance Executive Officer, regarding stakeholders in their region:

WAGA

WAGA is an alliance of the six western Melbourne councils – Brimbank, Hobsons Bay, Maribyrnong, Melton, Moonee Valley and Wyndham – and Greater Geelong and Moorabool. The six Melbourne-based WAGA members also have an economic development partnership, through 'LeadWest', and are members of the more general 'Western Partnership', which includes representatives from Victoria University (VU), City West Water, the Victorian Government and the community as well as these six councils. 'Greening the West' is a further alliance, based in western Melbourne, working on green infrastructure projects, such as the One Million Trees project, funded by the Australian Government to plant trees in public spaces. Members of Greening the West include the six western Melbourne councils, water authorities in the region, the Port Phillip and Westernport Catchment Management Authority and others. WAGA's three coastal councils – Greater Geelong, Hobsons Bay and Wyndham – are also members of the Association of Bayside Municipalities, actively working on coastal adaptation projects.

Apart from local government and their alliances, major stakeholders in the region interested in climate change adaptation include:

- Deakin, Victoria and Federation Universities
- City West Water, Barwon Water and Western Water
- Melbourne Water, particularly through the Western Treatment Plant, based in Wyndham and its research into water and sewage management, biodiversity and renewable energy
- The region's energy distributors, Powercor and Jemena

- Local community groups, such as Friends of Lower Kororoit Creek, also involved in Greening the West, and Geelong Sustainability
- Businesses that act as the region's unofficial 'sustainability champions', including those with large solar arrays on their premises, some of which have been financed through Environmental Upgrade Agreements. Highpoint Shopping Centre (Maribyrnong) and Werribee Plaza/Pacific Werribee (Wyndham) are retail developments with stand-out sustainability features that address waste minimisation and water management as well as renewable energy and energy efficiency.

SECCCA

SECCCA is a collaboration of nine local governments in Melbourne's south east - Bass Coast Shire Council, Baw Baw Shire Council, Bayside City, Cardinia Shire Council, City of Casey, City of Greater Dandenong, City of Kingston, Mornington Peninsula Shire Council and City of Port Phillip. Several of the Metropolitan councils - Cardinia, Casey, Greater Dandenong, Frankston and Mornington Peninsula - form South East Melbourne, a partnership focused on the economic development of the region. South East Melbourne are concerned with improving infrastructure, and developing employment and industry in the area. There are indirect measures to improve community resilience to climate change. South East Melbourne are also concerned with the impact of climate change in the region, and have supported SECCCA in their work in Melbourne's south east. Metropolitan councils who are also members of the Association of Bayside Municipalities (ABM) include Frankston, Kingston, Mornington Peninsula and Port Phillip. The ABM are active in understanding the impacts and adapting to climate change. Other key stakeholders in the south east include:

- South West Water, who have a long-term strategy in relation to water management in the region;
- Monash University, who have strong research links to climate change adaptation, and have conducted projects for the National Climate Change Adaptation Research Facility in relation to social vulnerability to climate change, and the differential impacts of the Urban Heat Island effect across communities;
- Bayside Climate Change Action Group, an active community group concerned with climate change;
- The electricity distributors in the region, United Energy and Ausnet. United Energy partnered with GreenSync to trial demand response in Mornington Peninsula, a demand-side tool to improve grid stability, particularly during peak periods such as heatwaves;
- Enliven Health are a primary care network, engaging with the impact of climate change on their service delivery;
- The Port of Melbourne and the Port of Hastings.

EAGA

EAGA is a formal Alliance of eight Councils in Melbourne's East, committed to delivering mitigation and adaptation projects and advocating for initiatives that support sustainable, low carbon

communities. Members include: Boroondara, Glen Eira, Knox, Maroondah, Monash, Stonnington, Whitehorse, Yarra Ranges. EAGA leads councils engagement with the region's key distribution networks - AusNet Services and United Energy - and is actively working with both distributors on cross sector initiatives aim to enhance the resilience of the regions distribution network, increase energy security and decrease emissions. Other key stakeholders in the regions include:

- Monash university - currently partnering with councils on community survey around energy security and renewables and microgrids
- Swinburne University - actively working with councils on Greening the Greyfields, incorporating adaptation into planning process
- Yarra Valley Water - working with councils in the integration of WSUD
- Eastern Transport Coalition - seven EAGA councils, plus Greater Dandenong, advocate for sustainable and integrated transport services that reduce car dependency
- Eastern health
- Eastern Metropolitan Partnership (https://www.suburbandevelopment.vic.gov.au/partnerships/metropolitan-partnerships/eastern-partnership)
- Owners and managers of the regions retail centres, including Chadstone

NAGA

NAGA is a network of nine northern metropolitan Melbourne councils, jointly serving 1.1 million people, and the Moreland Energy Foundation, working to achieve significant emissions abatement and energy cost savings by delivering effective programs and leveraging local government, community and business action. Our members include: Melbourne, Yarra, Manningham, Banyule, Darebin, Moreland, Hume, Whittlesea and Nillumbik. NAGA shares information, coordinates emission reduction and adaptation activities, and cooperates on the research and development of innovative regional projects.

The other major stakeholders based in the region interested in climate change adaptation include:

- NorthLINK, a business association that has established a long-term vision for economic development in the region;
- Universities, in particular RMIT and the University of Melbourne;
- North Western Melbourne Primary Health Network;
- Resilient Melbourne, covers entire metropolitan area but based at City of Melbourne;
- Energy Distribution companies
- Northern and Inner Metropolitan Partnerships
- Melbourne Airport

From the interviews with the Greenhouse Alliance Executive Officers, several key stakeholders emerged, either due to the significance of their work in adaptation, or their role within the region. These stakeholders are able to provide further contacts in their sectors. A discussion of these key contacts is provided below.

Craig Rowley
E: Craig.Rowley@leadwest.com.au
Craig Rowley is the CEO for LeadWest, a collaboration of six local councils in Melbourne's Inner West. LeadWest has important linkages with industry, and have also demonstrated their commitment to action on climate change, through their partnership with the Western Alliance for Greenhouse Action in Low Carbon West. Craig has provided further contacts for healthcare and social assistance, retail, and several large manufacturers.

Daniel Voronoff
E: daniel.voronoff@dhhs.vic.gov.au
Daniel Voronoff has been involved in stakeholder mapping for the community sector, for the DHHS. This mapping relates to the climate resilience of community organisations. Daniel is well-placed to provide further contacts for stakeholders from the community sector, and also has an understanding of current climate adaptation efforts, as well as gaps in climate adaptation across the sector.

Martin Hartigan
E: martin.hartigan@tnc.org
Martin Hartigan is coordinating the Resilient Melbourne Urban Forestry Strategy, and has further contacts for stakeholders in biodiversity for the Port Phillip Region.

Nigel Tapper
E: Nigel.Tapper@monash.edu
Nigel Tapper is an academic at Monash University with a longstanding interest in human vulnerability to climate change, and adaptation. He is currently working on a project with the IPCC and the UNFCCC to develop an index to measure adaptation, combining features such as investment data and infrastructure data. This index should allow for a geographical indication of adaptation and vulnerability to the impacts of climate change. He has previously engaged with several other stakeholders in the Melbourne Metropolitan region.

Lauren Rickards
E: Lauren.rickards@rmit.edu.au
A senior lecturer at RMIT University, with a strong interest in climate change and adaptation. Lauren Rickards is particularly interested in the human impacts of climate change. She has worked on many projects in adaptation, and can provide further contacts.

5.2 Limitations of analysis

Desktop-based based research further identified organisations that are stakeholders in adaptation to climate change, yet no specific contact was able to be identified. Where this is the case, the stakeholder but no contact has been listed.

Interviews with Greenhouse Alliance executive officers also identified important stakeholders in the region, who they have not engaged with in relation to climate change. For example, the South East Melbourne Manufacturing Alliance (SEMMA) is a peak body for over 200 manufacturers in the region. Given the important role manufacturing plays in many local economies, it is important the manufacturing industry adapt well to climate change.

Where stakeholders have been listed, but their internal engagement with climate change adaptation is unknown (as with SEMMA) this has been noted in Appendix I, through the use of a 'sector,' as opposed to 'adaptation' label.

6. Climate Change Impact Assessment

The *Climate Change Impact Assessment* comprised desktop-based research on key expected impacts.

6.1 Overview

The future impacts of climate change are developed through the use of climate models. These models are the result of decades of work, and are based on observed and past patterns, and also incorporate the physical processes predicted as a result of climate change, which will change these historical trends.[58] Representative concentration pathways, (RCPs) are used to model plausible future climates. These projections describe a lower emissions future (using RCP4.5) and a high emissions future (using RCP8.5). Many projections are highly dependent on future actions taken to limit greenhouse gas emissions, as illustrated in the graphs below:

[58] CSIRO & BOM 2016, 'Climate Models,' *Climate Change in Australia: Projections for Australia's NRM Regions*, viewed 19.10.17, https://www.climatechangeinaustralia.gov.au/en/climate-campus/modelling-and-projections/climate-models

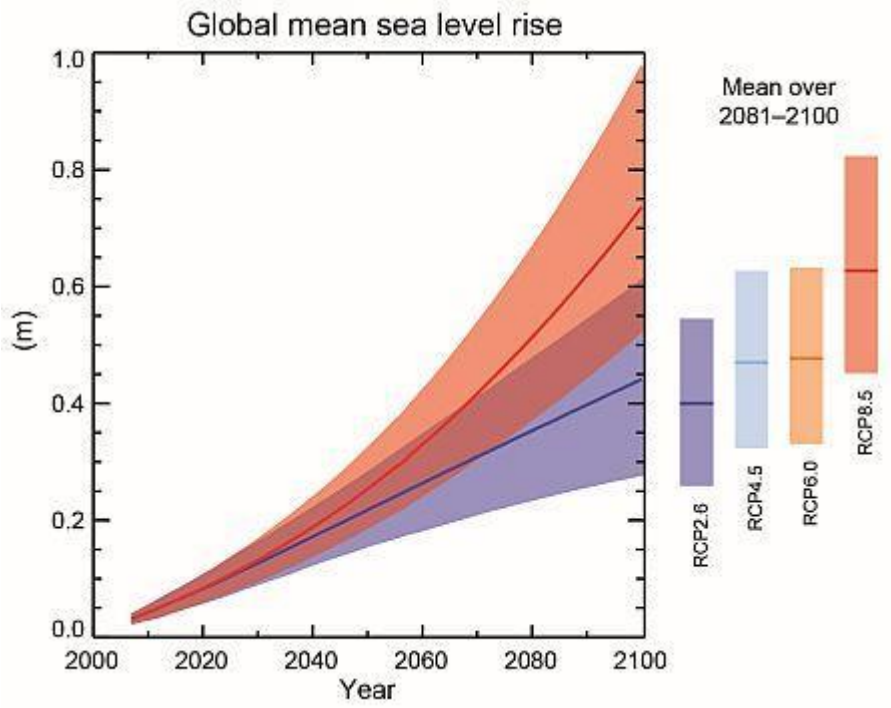

Image 4 CMIP5 multi-model simulated time series from 1950 to 2100 for change in global annual mean sea level rise relative to 1986–2005[59]

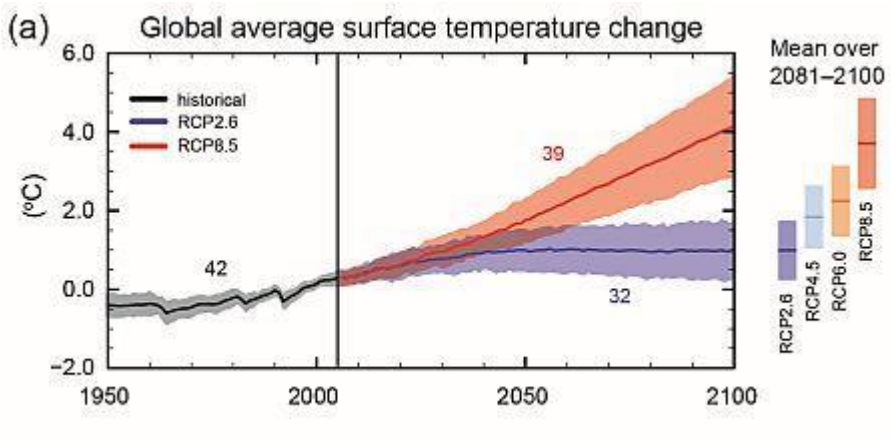

Image 3 CMIP5 multi-model simulated time series from 1950 to 2100 for change in global annual mean surface temperature relative to 1986–2005[60]

[59] Intergovernmental Panel on Climate Change (IPCC) 2013 http://www.ipcc.ch/report/ar5/wg1
[60] Intergovernmental Panel on Climate Change (IPCC) 2013 http://www.ipcc.ch/report/ar5/wg1

Given the different impacts of different concentration pathways, projections are provided for the Port Phillip Region under both higher and lower emissions scenarios.

The higher emissions future represents the current, or business-as-usual, scenario. Climate modelling indicates that the Port Phillip Region will see

- increases in both average temperatures and extreme heat events, impacting bushfire risk;
- an increase in storm surges, and an increase in the height and potential damage of these surges;
- ocean acidification and warming, affecting marine ecosystems and biodiversity;
- changes in rainfall events, including heavy rainfall events and associated flooding, and drought events
- changes to wind speed, impacting storm events and storm surges

Some uncertainty exists within climate modelling, particularly for smaller scale areas. Because of this level of uncertainty, confidence levels are given to indicate the certainty of projections. This is based on the quality and completeness of knowledge, which informs the climate models used for projection[61].

Table 11 provides an overview of various impacts.

	2030 Lower	2030 Higher	2070 Lower	2070 Higher	Source
Average temperature (°C)	0.82 (0.45 to 1.03)	0.94 (0.63 to 1.29)	1.54 (1.17 to 1.88)	2.57 (2.05 to 3.13)	Climate Ready Victoria: Greater Melbourne (2015)
Average rainfall (%)	–0.92 (–10.50 to 4.17)	–1.66 (–12.23 to 3.01)	–3.05 (–16.17 to 4.56)	–4.68 (–23.38 to 4.48)	Climate Ready Victoria: Greater Melbourne (2015)
Evaporation (%)	2.83 (1.70 to 4.56)	4.30 (2.56 to 6.80)	6.31 (3.70 to 9.22)	10.87 (6.41 to 14.48)	Climate Ready Victoria: Greater Melbourne (2015)

[61] CSIRO & BOM 2016, 'Uncertainty and Confidence in Projections,' *Climate Change in Australia: Projections for Australia's NRM Regions,* viewed 19.10.17, https://www.climatechangeinaustralia.gov.au/en/climate-campus/modelling-and-projections/projecting-future-climate/uncertainty-and-confidence/

Wind speed (%)	–0.56 (–4.92 to 1.09)	0.86 (–2.10 to 2.86)	–0.52 (–6.39 to 1.98)	–0.24 (–5.32 to 3.01)	Climate Ready Victoria: Greater Melbourne (2015)
Relative humidity (% absolute)	–0.74 (–1.64 to 0.21)	–1.04 (–2.45 to –0.13)	–1.32 (–3.76 to –0.33)	–2.50 (–5.17 to –0.65)	Climate Ready Victoria: Greater Melbourne (2015)
Solar radiation (%)	1.45 (0.42 to 2.87)	2.09 (0.42 to 3.64)	2.42 (0.69 to 4.89)	4.09 (1.37 to 6.91)	Climate Ready Victoria: Greater Melbourne (2015)
Soil moisture (%)	–1.77 (–4.36 to –0.31)	–3.68 (–5.36 to 0.63)	–3.26 (–7.98 to –0.17)	–5.99 (–9.61 to –2.73)	Climate Ready Victoria: Greater Melbourne (2015)
Sea level (m) (range shows 5th to 95th percentile)					
Williamstown	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.17)	0.32 (0.20 to 0.45)	0.39 (0.25 to 0.54)	Climate Ready Victoria: Greater Melbourne (2015)
Stony Point	0.11 (0.07 to 0.16)	0.12 (0.08 to 0.17)	0.32 (0.20 to 0.45)	0.39 (0.25 to 0.54)	Climate Ready Victoria: Greater Melbourne (2015)
Sea surface temperature (°C)					
Stony Point	0.51 (0.39 to 0.66)	0.55 (0.31 to 0.89)	0.89 (0.77 to 1.41)	1.57 (1.31 to 2.48)	Climate Ready Victoria: Greater Melbourne (2015)
Ocean acidification (pH)					
Stony Point	–0.07 (–0.08 to –0.07)	–0.08 (–0.09 to –0.08)	–0.15 (–0.15 to –0.14)	–0.24 (–0.25 to –0.23)	Climate Ready Victoria: Greater Melbourne (2015)
Fire Range					

Increase in FFDI (%)	7	10		30	Southern Slopes Cluster Report (2015)
Number of days with a 'severe' fire danger rating	20	40		100	Southern Slopes Cluster Report (2015)

Table 11 Projected impacts of climate change for the Port Phillip Region

6.2 Temperature Increases[62]

Projections for increases to both annual and seasonal surface air temperature, for minimum, maximum and mean measurements are given with *very high confidence.*

Under a lower emissions scenario, temperature is expected to rise above the climate of 1986-2005 by 0.82 (0.45 to 1.03) C in 2030; 1.54 (1.17 to 1.88) C in 2070; and 1.5 (1.1 to 1.9) in 2090.

Under a higher emissions scenario, temperature is expected to rise above the climate of 1986-2005 by (0.94) 0.63-1.29 C in 2030; 2.57 (2.05 to 3.13) C in 2070; 3 (2.4 to 3.8) in 2090.
Hot days and extreme heat days are also projected to increase. In 2015, the average annual days in Melbourne exceeding:

- 35 C is 11
- 40 C is 1.6
- Below 2 C (Frost Risk) is 0.9

The annual number of days in Melbourne projected to exceed 35 C in 2030 under a lower emission scenario is 13 (12-15), and by 2090 is 16 (15-20). Under a higher emissions scenario, this number in 2090 is 24 (19-32).

The annual number of days in Melbourne projected to exceed 40 C in 2030 under a lower emission scenario is 2.4 (2.1-3.0), and by 2090 is 3.6 (2.8-4.9). Under a higher emissions scenario, this number in 2090 is 6.8 (4.6-11).

[62] Discussion based on based on Department of Environment, Land Water & Planning. 2015, *Climate Ready Victoria: Greater Melbourne*, Melbourne, Australia; and Webb, L.B. and Hennessy, K. 2015, *Projections for selected Australian cities*, CSIRO and Bureau of Meteorology, Australia, p.11. While the information in Webb & Hennessy relates to projections for Melbourne CBD, the results are "average results for the cluster or sub-cluster in which the cities are located... Projected changes presented here will be applicable to all other cities and sites in the cluster and sub-clusters."

The annual number of days in Melbourne projected to be below 2 C in 2030 under a lower emission scenario is 0.6 (0.8 to 0.4), and by 2090 is 0.2 (0.3 to 0.1). Under a higher emissions scenario, this number in 2090 is 0.0 (0.0 to 0.0).

6.3 Urban Heat Island Effect[63]

Urban heat island is a term used to describe the higher temperatures and trapped heat that can occur in urbanised areas. This is particularly problematic in the context of climate change, as it will exacerbate instances of extreme heat and heatwaves. Given the growing population of Melbourne, close attention should be paid to infill and urban sprawl, as a loss of vegetation and the cooling ecosystem services it provides could worsen this effect. Vulnerability to heat is impacted by several factors, including age, socio-economic status, housing and infrastructure. Vulnerability to heat in Metropolitan Melbourne is mapped in Image 5.

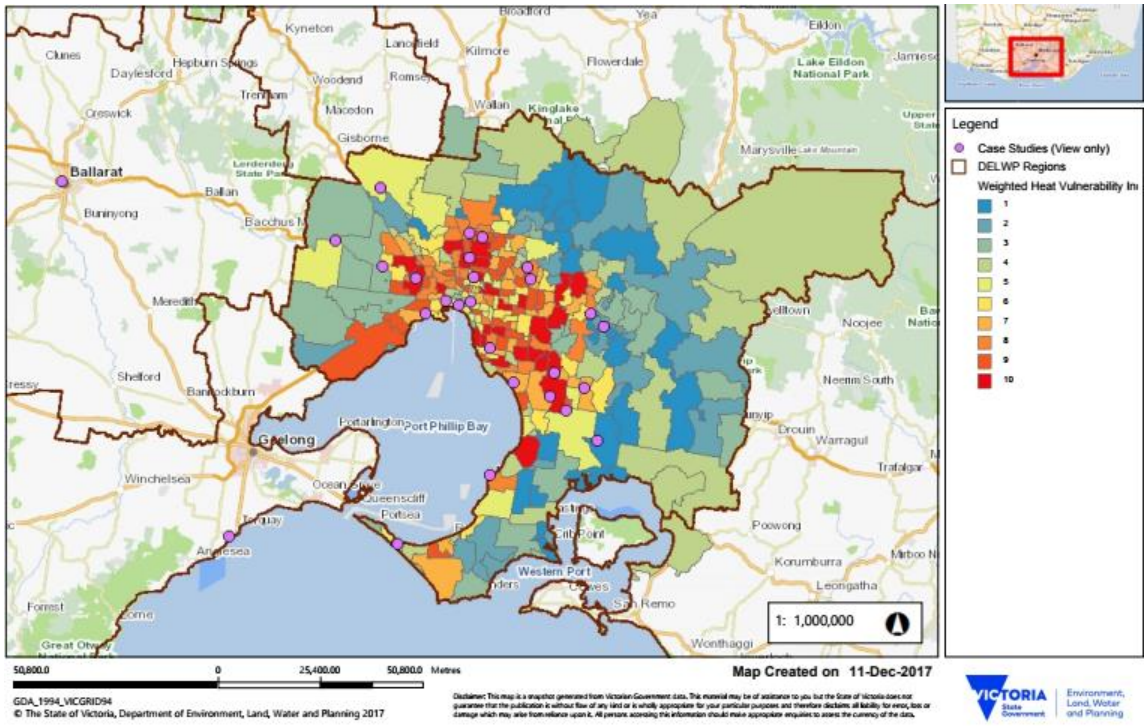

Image 5 Heat vulnerability map for the Port Phillip Region.[64]

63 Hunter Block, A, Livesly, SJ, Williams, NSG 2012, Responding to the Urban Heat Island: A Review of the Potential of Green Infrastructure, Victorian Climate Change Adaptation Research Facility, Melbourne.

64 Loughnan, ME, Tapper, NJ, Phan, T, Lynch, K, McInnes, JA 2013, A spatial vulnerability analysis of urban populations during extreme heat events in Australian capital cities, National Climate Change Adaptation Research Facility, Gold Coast, 128 pp.

6.4 Sea level rise[65]

Continued rises in sea levels for Melbourne are given with *very high confidence*.

By 2030, the projected range of sea level rise for Melbourne is 0.07 to 0.19 m above 1986–2005.

By 2090, the projected range of sea level rise increases to 0.27 to 0.66 m under the lower emissions scenario, and 0.39 to 0.89 m for the higher emissions scenario. These ranges are considered *likely*.

Given that many of Metropolitan Melbourne's LGAs are on the Port Phillip Bay, and others are on the Westernport Bay, sea level rise will have a significant impact on current and future infrastructure, residential dwellings, amenity, industry and health and wellbeing. Planning should provide allowances for projected sea level rise. A recent study recommends the allowances in Table 12.

Stony Point	2050 Projection		2090 Projection	
	Sea Level Rise (m)	Allowance (m)	Sea Level Rise (m)	Allowance (m)
Lower Emissions Scenario (2050)	0.20 (0.12-0.28)	0.22	0.45 (0.27-0.63)	0.51
Higher Emissions Scenario	0.24 (0.15-0.32)	0.25	0.59 (0.38-0.81)	0.70

Table 12 Recommended allowances for sea level rise[66]

6.5 Coastal Erosion[67]

Coastal erosion is storm induced, and coastal recession is driven by progressive erosion. High tides, high wave and storm surges all contribute. It is projected that with increased wave height and

[65] Grose, M. et al., 2015, Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia, p.29.
[66] McInnes et al. 2015, Information for Australian Impact and Adaptation Planning in response to Sea-Level Rise, *Australian Meteorological and Oceanographic Journal*, 65: 127-149. P. 134.
[67] Department of Sustainability and Environment 2012, Victorian Coastal Hazard Guide, Victorian Government, Melbourne. p.40.

frequency of storm surges resulting from climate change will drive accelerated coastal erosion and recession in the future. The extent of this erosion and recession is highly dependent on the shoreline type. Image 6 gives an indication of coastal vulnerabilities to typical coastal climate change impacts, depending on the shoreline type.

			Landform					
	Driver	Location	Hard rock coasts	Soft rock coasts	Sandy shores	Sandy shores (generally tide-dominated)	Other soft sediment shores	Engineered coasts
Climate change driver	Sea level	Open	L	M	L–H	–	–	L–M
		Re-entrant	L	M	–	H	H	L–M
	Storm surge	Open	L	M	H	–	–	L–M
		Re-entrant	L	M	–	H	H	L
	Wave height	Open	L–H	M	H	–	–	L–M
		Re-entrant	L–H	M–H	–	L–M	H	L–M
	Wave direction	Open	L	M	L–H	–	–	L–M
		Re-entrant	L	M	–	M	H	L
	Rainfall	Open	L	L	L–M	–	–	L
		Re-entrant	L	L	–	L	L–M	L

L = Low, M = Medium, H = High
Sea level = sensitivity to accelerations in sea level rise
Storm surge = sensitivity to changes in the frequency or/and intensity of storm surge
Wave height = sensitivity to changes in wave height generated by storms
Wave direction = sensitivity to changes in wave direction (e.g. changes in sediment transport patterns)
Rainfall = sensitivity to changes in the pattern and/or intensity of rainfall

Image 6 Coastal vulnerabilities[68]

6.6 Ocean Acidification and Warming[69]

Ocean acidification and warming will have a significant impact on marine ecosystems, and the ecosystem services they provide.[70] This is significant for Metropolitan Melbourne LGAs on the Port Phillip and Westernport Bays.

[68] Ibid

[69] Department of Environment, Land Water & Planning. 2015, *Climate Ready Victoria: Greater Melbourne*, Melbourne, Australia.

[70] McInnes et al. 2015, Information for Australian Impact and Adaptation Planning in response to Sea-Level Rise, *Australian Meteorological and Oceanographic Journal*, 65: 127-149.

The range of sea surface temperature increases under a low emissions scenario to 2030 is 0.39-0.66 C, and to 2070 is 0.77 to 1.41 C.

The range of sea surface temperature increases under a high emissions scenario to 2030 is 0.31 to 0.89 C, and to 2070 is 1.31 to 2.48 C.

Ocean acidification (pH) to 2090 differs significantly under a low emissions scenario –0.15 (–0.15 to –0.14), when compared to a high emissions scenario –0.24 (–0.25 to –0.23).

6.7 Storm surges (Storm Height Return Levels)

Storm surges are set to become more frequent in the future as a result of climate change. Storm surges along the Victorian coast are driven by west-to-east travelling cold fronts, which occur all year, though with greater frequency and intensity during winter[71]. Modelled alongside astronomical tides, projections are available for 1-in100 year storm tide heights.

Storm height return levels are driven by several factors, and are here projected according to sea level rise and wind-speed, both of which will be impacted by climate change, and both of which will impact storm surge heights.

Within the Metropolitan Melbourne region, under late-20th century climate conditions the worst impacts will be in Western Port Bay, with storm height return levels of over 2m. Port Phillip Bay will see more moderate storm height return levels of 1.0-1.2m, due to attenuation of tides across the entrance of the bay.

Under high emissions scenarios for sea level rise, contemporary instances of 1-in-100 year flood events will become much more frequent[72].

6.8 Increase in fire range

Fire weather (lower rainfall combined with higher temperatures results in a higher drought factor and fire weather risk in this region) is projected to increase in 2030 and 2090. This is driven by several factors which interact with fire weather, and are set to change with a changing climate.

Modelling of future fire weather is largely dependent upon rainfall - both annual and seasonal, and projections are subject to variability. Therefore, there is *high confidence* that climate change will

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[71] McInnes et al. 2013, An assessment of current and future vulnerability to coastal inundation due to sea-level extremes in Victoria, southeast Australia, *International Journal of Climatology*, 33: p.34

[72] Hunter J (2012) A simple technique for estimating an allowance for uncertain sea-level rise. Climatic Change, 113: 239–252.

drive harsher fire weather in the future, though there is *low confidence* in the magnitude of this change[73]. Using two triggers from the McArthur Forest Fire Danger Index (FFDI), the sum of which over a year indicate general fire weather risk.[74]

Under a low emissions scenario, this index increases by roughly 7% by 2030 and 10% by 2090; with the number of days with a 'severe' fire danger rating increasing by 20% by 2030, and 40% by 2090.

Under a high emissions scenario, this index increases by roughly 30% by 2090; with the number of days with a 'severe' fire danger rating increasing by 100% by 2090.

6.9 Increase in extreme weather events (drought & storms)

Drought

Droughts are expected to increase, with the duration and frequency of extreme droughts seeing the largest change (particularly under a high emissions scenario to 2090). Given the influence of rainfall on drought, projections for the direction of change are given with a *medium confidence*, and projections for magnitude are given with *low confidence*[75]. There is also emerging evidence that droughts influence extreme hot weather events, and wind from inland Australia reaching Melbourne after extended drought periods could drive temperatures up[76].

Storms

Climate change will have an impact upon the occurrence of severe thunderstorms. Under a high emissions scenario by the end of the 20th century, severe thunderstorm days for Melbourne could increase by 22%[77].

Extra-tropical cyclones (also mid-latitude or frontal cyclones) occur over the Southern Ocean, and impact the Victorian coast. Extra-tropical cyclones rotate in a clockwise direction around centres of

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[73] Grose, M. et al., 2015, Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia, p.36.

[74] While the FFDI may be replaced in the near future, due to no longer being able to cope with fire extremes wrought by climate change (http://www.abc.net.au/news/2017-12-13/bushfire-danger-rating-system-trialled-summer/9203446) it is used here to calculate the change in fore range.

[75] Grose, M. et al., 2015, Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia. p.29.

[76] Nicholls, N. & Larsen, S. (2011) Impact of drought on temperature extremes in Melbourne, Australia. Australian Meteorological and Oceanographic Journal, 61: 113-116.

[77] Allen JT, Karoly DJ and Walsh KJ (2014) Future Australian severe thunderstorm environments Part B: The influence of a strongly warming climate on convective environments. Journal of Climate, 27: 3848–3868.

low atmospheric pressure[78]. They are typically less intense than tropical cyclones. The impact of climate change on extra-tropical cyclones is not well understood, however a recent study suggests that these events over Southeastern Australia could become less frequent but more intense[79].

Coastal low pressure systems can develop along the east coast of Australia through a variety of weather systems, causing heavy rain, strong winds and large waves. The impact of climate change on coastal low pressure systems still carries uncertainty, however studies suggest East Coast Lows will become less frequent, though the wind hazard associated with intense events may increase[80].

It is *highly likely* that there will be an increase in heavy rainfall events, and associated flooding in the future. However, the magnitude of change cannot be reliably predicted, and therefore the "time when any change may be evident against natural fluctuations, cannot be reliably predicted."[81] It is estimated that stormwater currently washes 37,000 tonnes of sediment and 1,400 tonnes of nutrients (such as nitrogen from fertiliser) into the Yarra River each year, as well as litter, heavy metals and pathogens[82].

6.10 Soil Moisture[83]

Soil moisture in Victoria is projected to decline with climate change as a result of a number of interacting factors such as rainfall, evaporation and temperature. This has implications for land use. Agriculture and viticulture in particular amongst natural and built environments are vulnerable to declining soil moisture. A decrease in soil moisture also has the potential to increase fire risk, and it is important to attend to how this will impact urban development in bushfire prone areas.

7. Next steps

Part two and three of the project will deliver vulnerability mapping and existing adaptation responses, respectively.

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78 Department of Sustainability and Environment 2012, Victorian Coastal Hazard Guide, Victorian Government, Melbourne.p.23.

79 Grieger J, Leckebusch G, Donat M, Schuster M, Ulbrich U (2014) Southern Hemisphere winter cyclone activity under recent and future climate conditions in multi-model AOGCM simulations. Int J Climatol 34:3400–3416

80 Walsh, K, White, CJ, McInnes, K, Holmes, J, Schuster, S, Richter H, Evans, JP, Di Luca A, Warren, RA, 2016, Natural Hazards in Australia: storms, wind and hail, *Climatic Change*, 139: 55-67.

81 Grose, M. et al., 2015, Southern Slopes Cluster Report, Climate Change in Australia Projections for Australia's Natural Resource Management Regions: Cluster Reports, eds. Ekström, M. et al., CSIRO and Bureau of Meteorology, Australia. p.29.

82 Plan Melbourne pg 121

83 Buxton, M, Osman-Schlegel, NY, Lopes, D 2016, Soil moisture change and land use in Victoria, Australia, Australasian Journal of Environmental Management, 23:3, 265-280.

Vulnerability Mapping will bring together the outcomes from the *Regional Snapshot* and the *Climate Change Impact Assessment*, to identify populations and assets that are particularly vulnerable to climate change. This will be in the form of desktop analysis drawing on the data gathered in the previous sections and based upon the approach to vulnerability assessment mapping used by NAGA in its regional adaptation strategy, *Adaptation in the North*. This will be delivered by 19 January 2018.

Finally, the project will capture *Existing Adaptation Responses* through interviews with greenhouse alliance officers, through a survey of stakeholders identified in the *Stakeholder Analysis* and through desktop research of funded projects. This will include current and recently completed projects and identified needs for future support. This will be delivered by 2 February 2018.

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