YARRA
ENERGY
FOUNDATION

Final Summary Report

Building Vulnerability Assessment of Potential Refuge Buildings in Melbourne's West

Title	→	Final Summary Report
Purpose	→	Overview of building vulnerability assessments in Melbourne's west

Final Summary Report

1. Introduction

In this project titled "Building Vulnerability Assessment of Potential Refuge Buildings in Melbourne's West", the Yarra Energy Foundation (YEF) assessed heat related risks and vulnerabilities for 40 council and community buildings in the Melbourne's Western Alliance for Greenhouse Action (WAGA) region. The buildings were nominated by councils in consultation with the WAGA, Department of Environment, Land, Water and Planning (DELWP) and Yarra Energy Foundation.

The project's objectives were to

- assess the vulnerability of selected buildings to extreme hotter temperatures
- identify opportunities to improve building resilience and estimate cost of upgrades
- share knowledge and build capacity of council staff attending the site assessments so that they are better informed, better prepared and more knowledgeable about the role of heat refuges in the context of heatwaves

Buildings were assessed using a customised Building Vulnerability Assessment (BVA) framework where specific building components were analysed to understand their exposure[1] and sensitivity[2] to extreme hotter temperatures. On-site assessments were conducted based on best available information and reasonable assumptions were made where data were unavailable.

This report is an overview of the whole project and presents the types of buildings selected, geographic distribution of sites, methodology adopted for the assessments, general findings across the 40 site assessments, observations from capacity building of council staff and recommendations to inform future building upgrades.

Specific findings and recommendations for each individual building have been reported to DELWP and WAGA in separate reports.

[1] In the context of the BVA framework, exposure is the degree to which a system experiences stress from different climate events
[2] In the context of BVA framework, sensitivity is the degree to which a system is harmed or affected by the exposure

2. Types of buildings nominated by councils

As part of the project, different types of buildings have been nominated by councils for assessments (shown in Figure 1). As a general observation, local government areas with newer buildings such as Wyndham and Melton have higher proportion of buildings that are built to latest standards and are less vulnerable to impacts of extreme heat. In older council buildings, there tended to be existing adaptation measures in place to cope with hotter temperatures, such as higher proportion of surrounding trees and shading elements for windows, doors and the building facade.

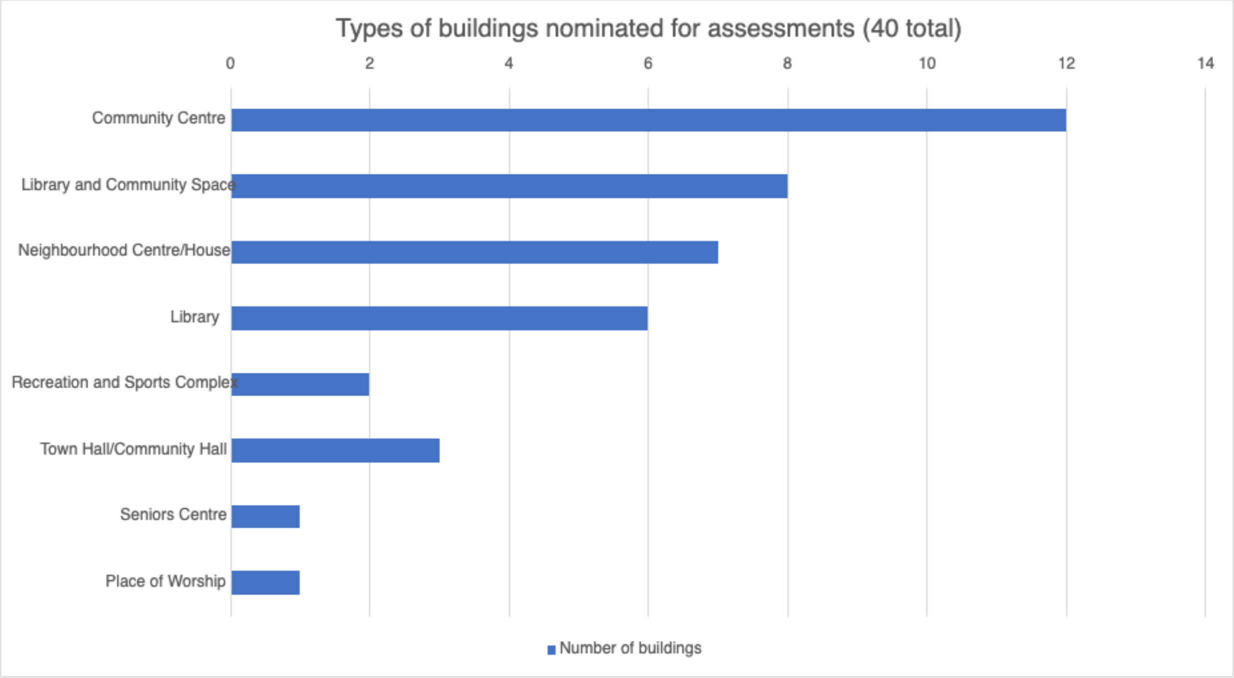

Figure 1: Bar chart showing types of buildings nominated by councils for building vulnerability assessments

3. Site locations and spatial distribution

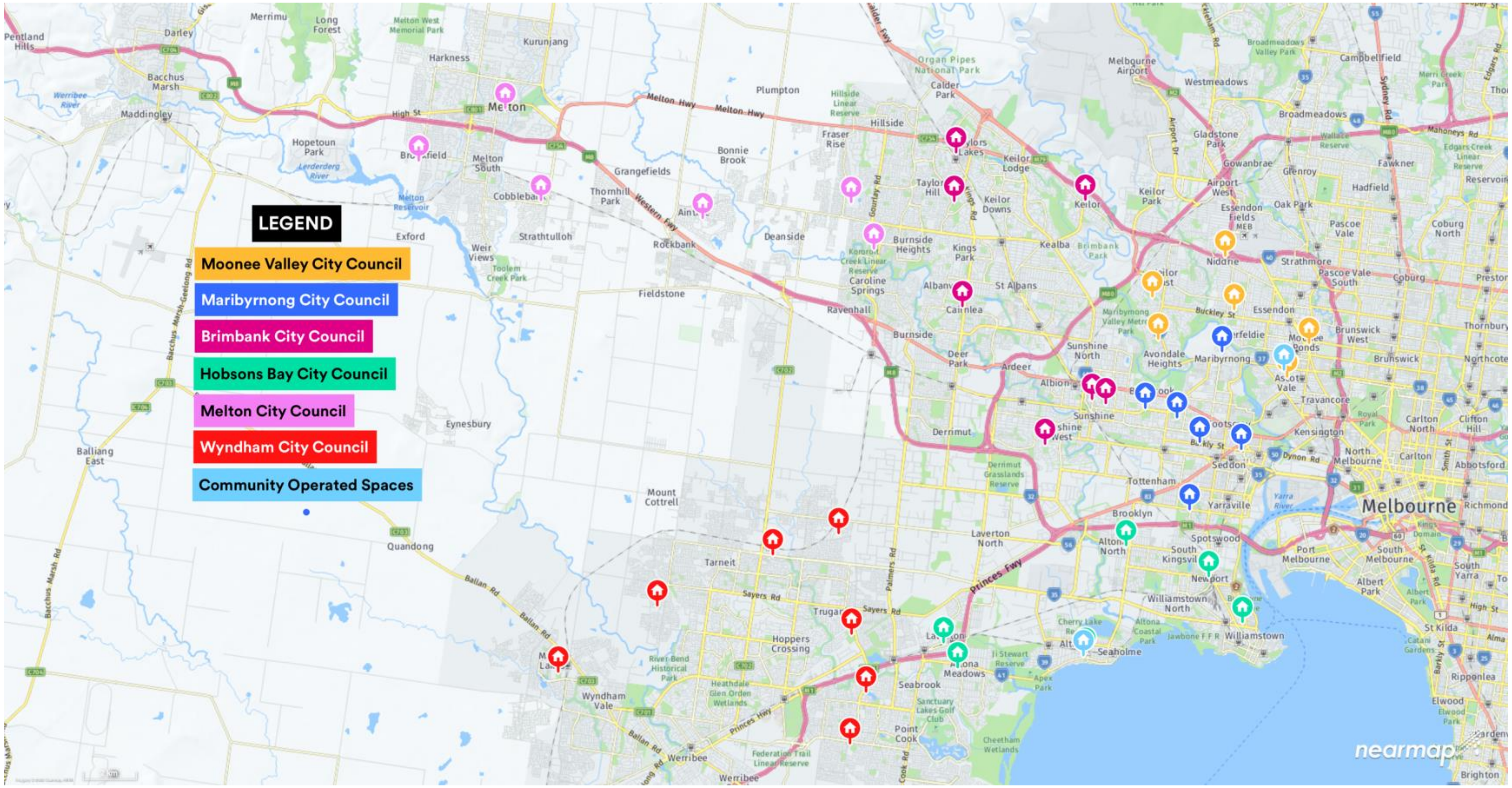

Figure 2: A map showing the location and spatial distribution of sites nominated by councils (40 total)

4. Assessment methodology

The approach and methodology for the assessment is based on Building Vulnerability Assessment Framework developed by Arup[3]. The framework was customised by YEF to understand potential vulnerabilities of buildings specific to extreme hotter temperatures. Building components that were prioritised for assessment are outlined in Appendix 1. At each site, these components were assessed to determine their exposure and sensitivity to extreme heat. The results were then used to determine a 'potential impact rating' which was combined with 'importance of function to building use' rating to obtain a vulnerability rating (the assessment process is summarised in Figure 3).

The 'importance of function to building use' ratings were adjusted as appropriate for heat safe spaces (HSS) as shown in Table 1.

Table 1: Importance of function to building use when operated as a heat safe space

Building Use	Importance of function to building use						
	Thermal comfort	Air quality	Power	Access (lifts)	Structural performance	Weather resistance	Fire resistance
Heat safe space	High	Medium	High	High	Medium	High	Not applicable

A step-by-step process for the assessment is outlined below.

- At each site, building components were assessed to determine their 'exposure' and 'sensitivity' to extreme heat.
- The results were used to determine a 'potential impact rating' which was then combined with the 'importance of function to building use' rating to obtain a vulnerability rating.
- The building vulnerability ratings were analysed for both normal and emergency use cases.
- 'Very high' and 'high' vulnerability ratings when used as a heat safe space (HSS) are identified as most significant.

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[3] Arup Pty Ltd (2015) EAGA & NAGA Building Vulnerability Assessments. Assessment Sheets

- Recommended upgrades to manage these high and very high vulnerabilities/risks were identified along with indicative cost of upgrades.

Note that the assessment methodology always captures highest vulnerabilities of a particular building component but not the vulnerabilities of similar components with lower vulnerabilities. Therefore, the ratings and risks will need to be calibrated and interpreted accordingly from a building perspective.

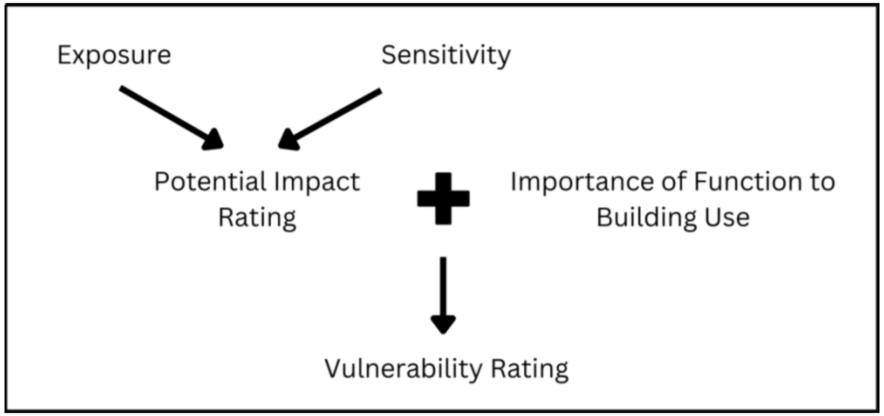

Figure 3: Building Vulnerability Assessment Framework process for each building component

5. Key building vulnerability findings and recommended adaptation measures

The key findings from across the 40 site assessments highlight the vulnerabilities and risks facing the buildings during extreme hot temperatures. These are detailed in Table 2 and visually displayed using a bar chart in Figure 4.

Table 2: Building components with the highest vulnerabilities to extreme hotter temperatures and recommended adaptation measures

Functional Requirement	Ref.[4]	Building component	Vulnerability description	Risks	Adaptation measures	Number of buildings with vulnerability (out of 40)
Power	P1	Electricity – grid & building	Electricity grid failure/outage due to extreme weather	Loss of electricity to the building. Safety compromised (no lighting, air conditioning, lifts, IT services, communications). Access to the building may be lost or restricted	Determine electrical needs of the building and if required add a permanent backup power source such as a battery, generator, plug-in point for emergency power supply or connection to a neighbourhood battery	40
Thermal comfort	TC1, TC3	Cooling equipment	Outdoor cooling equipment is in direct sun, air intake located near hot microclimate - overheating of internal spaces	Mechanical cooling equipment may reduce in cooling capacity in hotter weather. On extreme days, this could lead to insufficient cooling being available, or in worst case, being not available at all	Relocate the cooling equipment and fresh air intake in a well ventilated and shaded area during peak cooling demand periods Introduce shading structures to protect the cooling equipment from direct sun as a cost-effective action	37
			Outdoor cooling equipment in direct sun & building envelope allows heat transfer - impact from	Increased wear and tear, higher running costs, high greenhouse gas emissions,		

[4] Refer to Building Vulnerability Assessment Framework from Arup

<table>
<tr><td></td><td></td><td></td><td>extreme heat/ more frequent higher temperatures on cooling equipment</td><td>inability to achieve safe indoor temperature</td><td></td><td></td></tr>
<tr><td rowspan="3"></td><td>TC8, TC11</td><td>Roof</td><td rowspan="3">Higher outdoor temperatures being transferred into the building via conduction and/or infiltration</td><td rowspan="3">Inability to achieve safe indoor temperatures. Occupant comfort and health can be a concern during heatwave periods</td><td rowspan="3">Determine heat transfer through radiation/conduction from the roof, windows and doors and external walls. Manage and upgrade the building to meet the latest National Construction Code requirements, especially:
insulation
ventilation
energy efficiency
windows and doors, their thermal efficiency and energy transfer
Strategically plant new trees and vegetation around the building to improve shading, evapotranspiration and wind channelling</td><td>29</td></tr>
<tr><td>TC9, TC12</td><td>Exterior walls</td><td>26</td></tr>
<tr><td>TC10, TC13</td><td>Windows and doors</td><td>32</td></tr>
<tr><td rowspan="2">Structural Performance</td><td>SP13</td><td>Exterior walls</td><td rowspan="2">Higher outdoor temperatures lead to expansion of materials</td><td rowspan="2">Structural failure, compromised safety, function and service continuity</td><td rowspan="2">Check the structural condition of exterior walls, windows and doors against the latest NCC standards & identify actions, feasibility and costs and bring them up to the current standard requirements</td><td>2</td></tr>
<tr><td>SP14</td><td>Windows and doors</td><td>15</td></tr>
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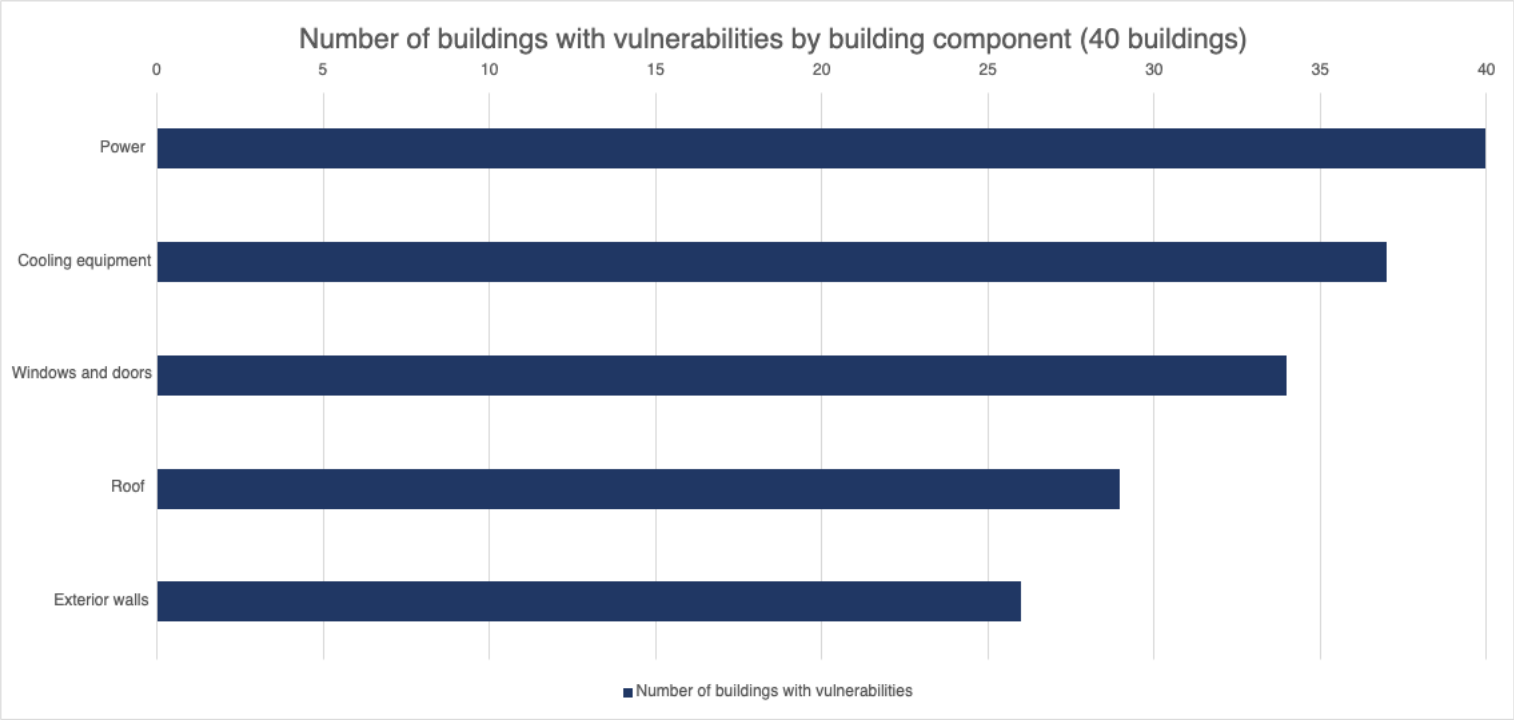

Figure 4: Bar chart showing number of buildings with vulnerabilities by building component

6. Observations on council staff participation and capacity building

As part of the project, council asset managers and other relevant council staff were invited to attend and participate in the site assessments. This exercise encouraged participation from different council departments and sought to build capacity amongst participants about the assessment process and the role of heat refuges in the context of heatwaves. YEF saw notable interest from council staff to participate in the assessments and at times council staff from different teams participated in the assessments including sustainability, emergency management, facilities, centre staff and library departments.

At most sites YEF staff were accompanied by a council staff officer who provided input on the local context and building specifications. Only few council staff were able to complete the full comprehensive assessment alongside YEF staff due to time and capacity constraints. A majority of site assessments involved seeking input from council staff officer in the first 15 to 30 minutes of the scheduled appointment and completing a mini assessment which informed the comprehensive assessment.

From general observations and conservations with council staff, YEF found that in many cases council staff have found the assessment process informative and that it sparked thinking on their role in an emergency heatwave scenario. At times, council staff observed vulnerabilities of their buildings during the assessment and made notes to repair and/or upgrade certain components. YEF observed also that council staff at times appeared uninterested in the assessment framework and the data collection using the tool, which itself was repetitive and tedious by nature. Overall however, it was observed that council staff officers were positive about the project and keen to understand the vulnerability of spaces they operate and where improvements could be made to make the spaces more comfortable for the community.

6. Prioritising upgrades and recommendations

The results of the building assessments highlighted that across all 40 buildings assessed, the majority had at least some aspect of vulnerability to extreme heat events, the most common of which are exposure of cooling equipment to direct sun, no options for back-up power in case of outages and potential heat transfer through the building envelope. Councils that conduct the priority building upgrades will contribute to service continuity and likely lead to safer, more comfortable, more affordable and lower greenhouse gas intensive operations, in addition to improving the building's use as a refuge during extreme heat events.

YEF has provided 40 individual site-specific reports which include details of the highest priority vulnerabilities and recommendations on possible actions that can be taken to address them. However, the following recommendations can be applied broadly to all councils based on common observations of all sites in this project.

General recommendations:

- Results of the building vulnerability assessments and proposed adaptation measures should be critically reviewed by the assets team in collaboration with sustainability and emergency management teams to identify what steps can be taken to improve building quality
- Obtain detailed quotations for proposed adaptation measures to more accurately understand the likely cost of upgrades
- Implement upgrades that are the most cost-effective with clear and ideally multiple benefits, both for heat vulnerability and also the building's main function
    - For example, the first stage of upgrades might include improving draught sealing, installing double glazed windows and doors and measures to reduce heat transfer into the building through radiation, conduction or infiltration
    - For example, latter stages might include more capital intensive and complex upgrades such as relocation of heat rejection equipment and improving structural condition of the building to adapt to extreme heat
- Identify and secure funding for upgrades through existing council asset renewal budgets and/or pursue additional sources of funding such as in council financial year budget cycles and grant funding sources

Other recommendations:

- Integrate building vulnerability assessment methods into existing asset condition assessments and track the progress in reducing vulnerability of buildings over time
- Train relevant council staff to conduct assessments and adopt the building vulnerability assessment framework to suit local context and requirements

7. Appendix

7.1 Appendix 1: Building components prioritised for assessments from the BVA framework

Functional Requirement	Ref.	Building component	Climate disturbance	Impact pathway
Thermal comfort	TC1	Cooling equipment	Extreme temperature (i.e., Hotter maximum temperatures)	• Overheating of internal spaces • Higher maximum outside temperatures are likely to increase the heat load on the cooling system. This could occur due to heat transfer through the building envelope and due to outside air that may be supplied by the air conditioning system. A second issue is that mechanical cooling may reduce in cooling capacity in hotter weather up to a maximum operating temperature. On extreme days, this could lead to insufficient cooling being available, or in worst case, being not available at all.
	TC2	Cooling by natural ventilation	High temperature and higher night time temperatures.	• Overheating of internal spaces • During periods of extreme high temperature, naturally ventilated spaces tend to rely on thermal mass (e.g., exposed concrete or brick) and flushing with cool night air to remain cool during the day. If night time temperatures are high, it becomes very difficult to cool the thermal mass. If this happens for successive days, the internal temperature will rise.
	TC3	Cooling equipment	More frequent high temperatures	• Increased wear and tear, higher running costs, high carbon emissions • More frequent high temperature is likely to mean that mechanical cooling equipment is running at capacity or near capacity for more hours per year. This may increase the wear and tear on the equipment, and is likely also lead to higher running costs and carbon emissions.
	TC8	Roof	Extreme temperature + Warmer temperatures	• Direct heat + heat transfer • Heat transfer occurs through the roof system from hot to cool spaces. Hot weather on the outside of the building can enter the building via conduction through materials;

				materials that are highly conductive, such as metals, will transfer heat to the interior of buildings more quickly than timber. A thermal barrier, such as insulation, mitigates such heat transfer. This can affect the ability of building services (mechanical equipment) to cool interior spaces. Occupant comfort & health can be a concern during hit periods.
	TC9	Exterior walls	Extreme temperature + Warmer temperatures	• Direct heat + heat transfer • Heat transfer occurs through the walls from hot to cool spaces. Hot weather on the outside of the building can enter the building via conduction through materials; materials that are highly conductive, such as metals, will transfer heat to the interior of buildings more quickly than timber. A thermal barrier, such as insulation, mitigates such heat transfer. This can affect the ability of building services (mechanical equipment) to cool interior spaces. Occupant comfort & health can be a concern during hit periods.
	TC10	Windows and doors	Extreme temperature + Warmer temperatures	• Direct heat + heat transfer • Heat transfer occurs through windows and doors from hot to cool spaces. Hot weather on the outside of the building can enter the building via conduction through materials; materials that are highly conductive, such as aluminium frames, will transfer heat to the interior of buildings more quickly than timber. A thermal barrier, such as insulation, mitigates such heat transfer. This can affect the ability of building services (mechanical equipment) to cool interior spaces. Occupants and services adjacent to the façade will experience increased temperatures of the internal ambient air. Proper seals mitigate infiltration occurrences.
	TC11	Roof	Extreme temperature + Warmer temperatures	• Infiltration of hot air to the interior • Air infiltration occurs between hot (high pressure) to cool (low pressure) spaces. Hot weather on the outside of the building can enter through holes and/or gaps in the façade. This can affect the ability of the building services (mechanical equipment) to cool interior spaces. Occupants and services adjacent to the façade will experience increased temperatures of the internal ambient air. Proper seals mitigate infiltration occurrences. The term penetration includes pipes, vents, mechanical equipment, windows and doors. Seals references the material between roof and the penetration element.

	TC12	Exterior walls	Extreme temperature + Warmer temperatures	• Air infiltration occurs between hot (high pressure) to cool (low pressure) spaces. Hot weather on the outside of the building can enter through holes and/or gaps in the façade. This can affect the ability of the building services (mechanical equipment) to cool interior spaces. Occupants and services adjacent to the façade will experience increased temperatures of the internal ambient air. Proper seals mitigate infiltration occurrences.
	TC13	Windows and doors	Extreme temperature + Warmer temperatures	• Infiltration of hot air to the interior • Air infiltration occurs between hot (high pressure) to cool (low pressure) spaces. Hot weather on the outside of the building can enter through holes and/or gaps in the façade. This can affect the ability of the building services (mechanical equipment) to cool interior spaces. Occupants and services adjacent to the façade will experience increased temperatures of the internal ambient air. Proper seals mitigate infiltration occurrences.
Power	P1	Electricity - grid	Electricity grid outage due to extreme weather (wind, rain, temperature etc)	• Loss of electricity to the building • An increasing frequency of extreme events could increase the risk of power outages. While electricity utilities have a responsibility to meet their reliability targets, Councils have no control over how successfully utilities do this. As such, Councils should determine which buildings and council services are vulnerable to power outage.
	P3	Electricity – building	Extreme high temperature	• Loss of electricity to the building, damage to building, fire risk • Electrical systems are designed to operate in specified ambient temperatures. In the current version of A3000, the Australian wiring rules, the nominated temperature is 40 deg C. At higher temperatures, the electrical resistance in metals increases, meaning that cables become less efficient at carrying electricity (i.e. more energy is dissipated as heat). In extreme situations, the combination of high ambient temperature and increased heat losses could damage the cable insulation. Electrical cabling and infrastructure that is in naturally ventilated locations could be vulnerable on days of extreme high temperature.
Lifts	L1	Lift	Extreme temperature	• Overheating of lift motors, leading to failure • Electric motors are designed to work up to a recommended ambient temperature, which is typically 40 deg C. At higher temperatures, the electrical resistance of metals increases, meaning that cables become less

				efficient at carrying electricity (i.e. more energy dissipated as heat). In extreme situations, the combination of high temperature and increased heat losses could damage the cable insulation. Electrical cabling and infrastructure that is in naturally ventilated locations could be vulnerable on days of extreme high temperature.
Structural performance	SP13	Exterior walls	Extreme temperature + Warmer temperatures	• Damage or failure of cladding materials • Physical damage to walls can occur during high temperatures when materials expand and contract adjacent systems possibly dislodging or damaging the materials. Damage is depending on the conductive properties of the materials. Extreme conditions may result in safety concern with the integrity/stability of the system. Expansion or control joints within the wall or between elements can accommodate such expansions
	SP14	Windows and doors	Extreme temperature + Warmer temperatures	• Damage or failure of cladding materials • Physical damage to windows or doors can occur during high temperatures when materials expand and contract adjacent systems possibly dislodging or damaging the materials. Damage is depending on the conductive properties of the materials. Extreme conditions may result in safety concern with the integrity/stability of the system. Expansion or control joints within the wall or between elements can accommodate such expansions

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