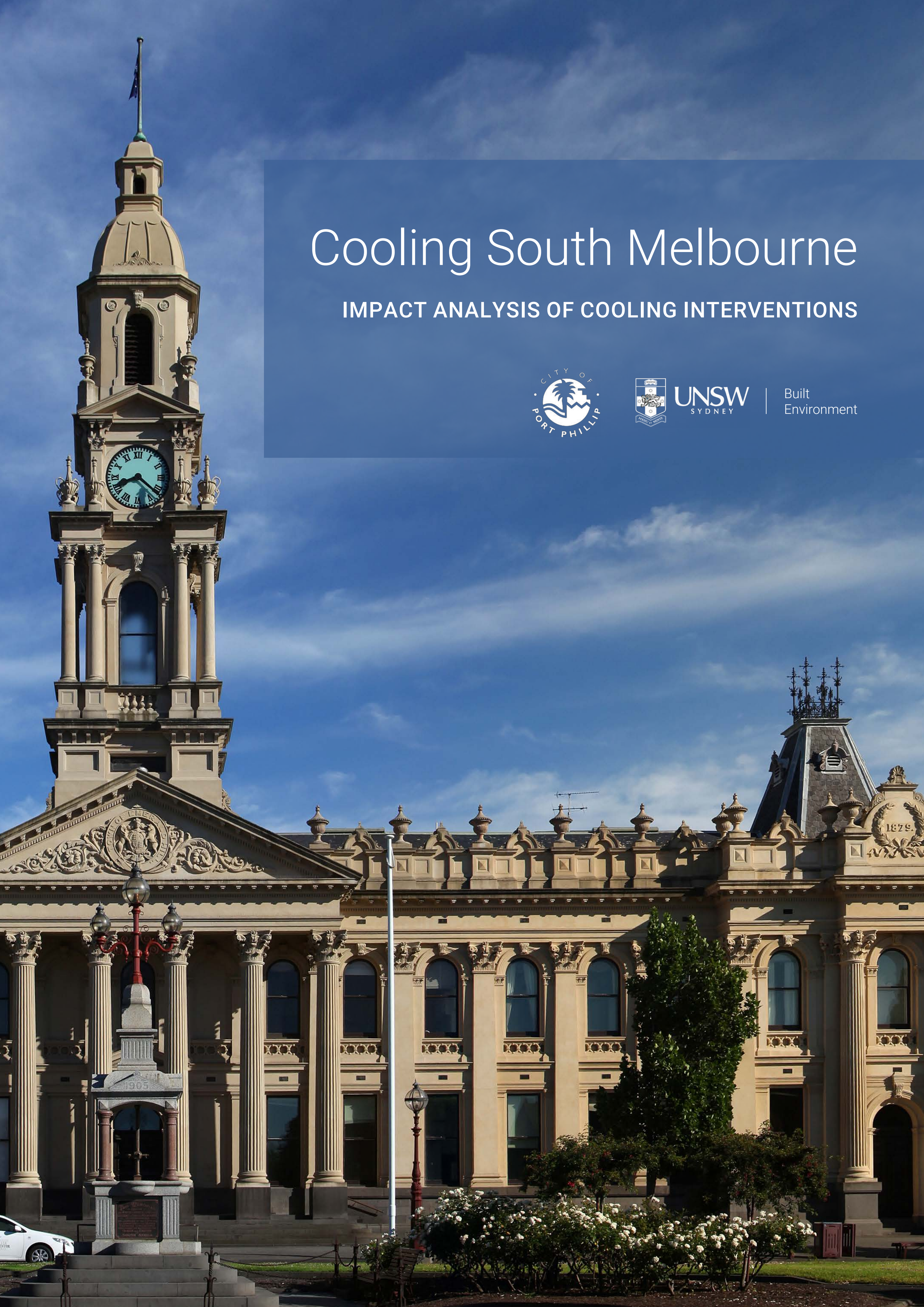
Cooling South Melbourne

IMPACT ANALYSIS OF COOLING INTERVENTIONS

CITY OF PORT PHILLIP

UNSW SYDNEY | Built Environment



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Above: Outdoor Summer Event at the South Melbourne Market
Photo: City of Port Phillip

Cover & Back: South Melbourne Town Hall
Photo: Donaldytong / Wikimedia / CC BY-SA 3.0

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Executive Summary

Climate change is the defining challenge of our time. Just last year, 2019 was the second warmest year and ended the warmest decade (2010- 2019) ever recorded (WMO, 2020). The City of Port Phillip has identified the need to reduce the urban heat island (UHI) effect – increased ambient temperature in high-density urban areas compared to surrounding suburban or rural areas – as a key priority in developing a greener, cooler and more liveable city that is resilient and can adapt to climate change (City of Port Phillip, 2018). Many of the City of Port Phillip's local strategies, guidelines, plans and policies for future planning therefore prioritise the need to minimise the impacts of increased urban overheating.

The South Melbourne Study Area has been highlighted as an area that, due to its land use, demographics and ambient temperature, is considered by Council to be a heat vulnerability hot spot. Additionally, the area is expected to undergo change in the coming years with a new structure plan slated for development in the coming 12 months. A key challenge for the City of Port Phillip is to manage this future growth and redevelopment in South Melbourne in a way that does not limit its ability to mitigate and adapt to urban heat.

The primary purpose for this report is to gather information in response to this challenge, which includes information that could influence the design of both the public realm (surface types, material use, plant species selection and planting density) and private realm building design (form, structure, materials and green infrastructure), as well as identifying suitable locations for cooling interventions. Its purpose is also to model this information so that it can be used in the development and testing of built form and public realm interventions that will inform and provide supporting strategic justification for updating the South Melbourne Structure Plan (2007).

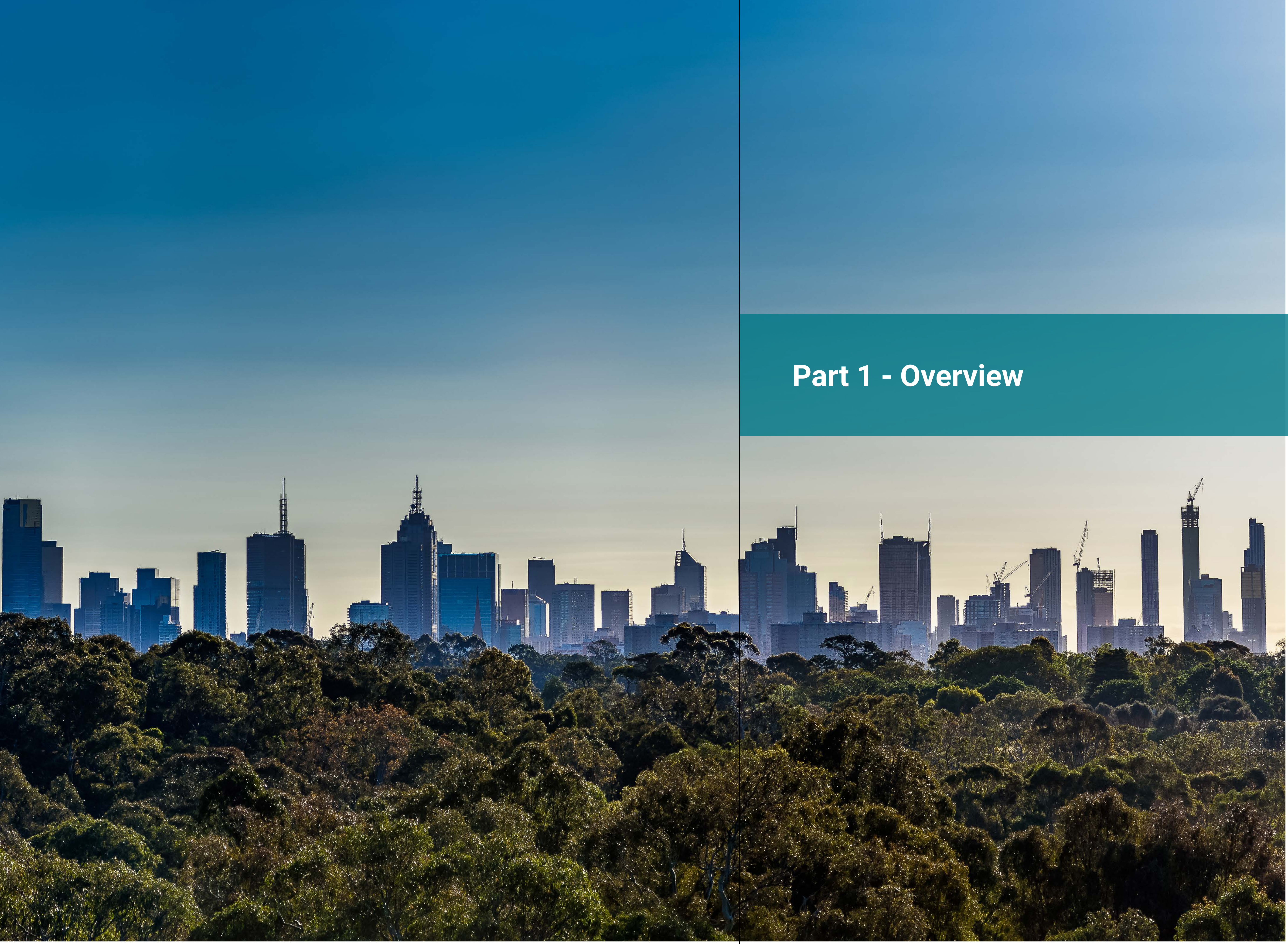
To ensure the development of a greener, cooler and more liveable city in the future, this report identifies key urban overheating challenges for both Greater Melbourne and the South Melbourne Study Area and proposes urban overheating mitigation strategies to address them. These mitigation strategies include increasing public and private urban greenery, water misting, changes to street, footpath and roof materials, as well as a combination of these, and are consolidated into nine cooling intervention scenarios for the South Melbourne Study Area. These intervention scenarios are informed by a cooling impact analysis of Greater Melbourne using the Weather Research & Forecasting (WRF) model and are tailored specifically to the urban context of South Melbourne and the Structure Plan controls.

3D model data for the study area, including typologies of new buildings and private green coverage scenarios, was provided by the City of Port Phillip which enabled the nine cooling intervention scenarios in the microscale level to be modelled using ENVI-met, a computation fluid dynamics (CFD) model. This impact analysis highlights the maximum possible cooling potential for the South Melbourne Study Area under both current climate conditions in 2020 and future conditions in 2050. These nine scenarios and their cooling potential have also been integrated into the online and interactive Microclimate and Urban Heat Island Mitigation Decision-Support (UHI-DS) Tool.

The results of this impact analysis show that all nine cooling intervention scenarios can effectively reduce street level air and surface temperatures throughout the South Melbourne Study Area under current and future climate conditions. Increasing urban greenery in the public realm and the addition of cool materials for all streets, footpaths and private hard surfaces was highly effective at reducing street level air and surface temperatures, especially in business and retail precincts that have wider, unshaded streets. Moderate green infrastructure for private green coverage demonstrated an effective scenario for new buildings. While the impact of cool roofs is less than cool materials for hard urban surfaces, it is important to note, given the extent of existing buildings with aging roof materials in the study area, that cool roofs can lead to significant reductions in roof surface temperatures. This can potentially improve indoor thermal comfort, reduce energy and air conditioning use and thereby limit potential heating effects from the waste heat of air conditioning. The most effective intervention scenario was the combination of all mitigation strategies including water misting sprays, which had a significant localised cooling impact on street level air and surface temperatures. The combination of all cooling interventions was able to respond to the diversity of land use and urban typologies throughout the study area.

One of the redevelopment scenarios involved the increasing of building heights within the key redevelopment precincts of the study area beyond the maximum permissible planning controls. This scenario resulted from a careful consideration of transitional building scale, integration with public and private green infrastructure, material properties, and prevailing wind flows through the study area. It was shown that if planning controls effectively address these factors, an increase in future density in the study area does not have to mean the impacts of the UHI effect are exacerbated.

Developed from the outcomes of the impact analysis of cooling intervention scenarios, a set of recommendations are provided to inform future planning of South Melbourne towards 2050.



Part 1 - Overview

Left: Melbourne CBD skyline
Photo: Adam Calaitzis / Adobe Stock

Climate Conditions in Melbourne

Greater Melbourne is characterised by a temperate oceanic climate and is well known for its highly variable weather conditions. These temperature swings are due to its geographic location that is subject to both cold air masses from the south and hot and dry air masses from the desert. This means that while Melbourne is typically slightly cooler than most other Australian cities in summer, it still experiences unpredictable temperature spikes and heatwaves, with record temperatures exceeding 45˚C (BOM, 2020a).

Temperatures will continue to increase across Greater Melbourne in the future, but the severity of these increases depends on global greenhouse gas emissions over the coming decades (Clarke JM et al., 2019). CSIRO's recent Greater Melbourne Climate Projections 2019 suggests that maximum annual temperatures could increase by up to 1.6˚C by the 2030s and up to 2.7˚C by the 2050s under a high greenhouse gas emissions scenario. Also under a high emissions scenario, the frequency of extreme heat days (>35˚C) is projected to increase from 8.3 days up to 20.4 days by the 2050s (Table 1). Similarly, the frequency of hot nights (minimum temperature >20˚C) is projected to increase from 5.8 days up to 18.4 days by the 2050s (Clarke JM et al., 2019) (Table 1).

To put this into perspective, CSIRO suggest that if urgent action isn't taken to reduce global greenhouse gas emissions, Melbourne's climate in the 2050s could be more like Wangaratta's current climate – a regional city over 200km inland from Melbourne (Clarke JM et al., 2019).

Table 1: Number of extreme heat days and hot nights projected for Greater Melbourne under a high greenhouse gas emissions scenario (Clarke JM et al., 2019)

Extreme Heat Days (Days/Year with a Maximum Temperature >35˚C)	
1981-2010	**2040-2059**
8.3 days	13.1 to 20.4 days

Hot Nights (Days/Year with a Minimum Temperature >20˚C)	
1981-2010	**2040-2059**
5.8 days	13.3 to 18.4 days

Urban Development Characteristics

For the last two decades, Melbourne has been experiencing a significant demographic change that is driving a population boom in the inner-city and outer-suburban developments. While Melbourne's transport system has good foundations, including the largest tram network in the world, the more the city sprawls in response to this growing population, the more likely it is to "become an unsustainable city divided by disadvantage and inequality" (Victorian Government, 2017a). In addition to creating an urban growth boundary and developing a city of 20-minute neighbourhoods, the Victorian Government emphasises urban renewal as a key strategy to ensuring Melbourne grows sustainably (Victorian Government, 2017a).

Managing this growth through higher density urban areas is therefore a key challenge for the City of Port Phillip, which is already Victoria's most densely populated municipality (City of Port Phillip, 2018). If not planned well, increasing density in urban areas can have significant environmental impacts and exacerbate the UHI effect. The South Melbourne Study Area (Figure 1) in this report is a key development area for increasing density within the City of Port Phillip municipality. An overview of its existing and proposed urban development characteristics is given below.

Figure 1: South Melbourne Study Area within the City of Port Phillip municipality
Photo: NearMap, 2020

Existing Urban Conditions

The South Melbourne Study Area has five broader land uses – the South Melbourne Activity Centre, the surrounding business precincts, mixed-use precincts, the Emerald Hill Civic, Cultural and Community Hub and the heritage residential areas. There is a diverse mix of building types such as the Victorian era shopfronts of Clarendon Street, the contemporary commercial and retail development along Kings Way, the heritage residential areas dating back to the 1800s and social housing from the 1960s. There is a substantial portion of the study area protected by the City of Port Phillip's heritage policy which discourages the demolition of any significant and contributory buildings (City of Port Phillip & David Lock Associates, 2007).

Buildings within the South Melbourne Study Area generally range from two to four storeys with some exceptions such as the South Melbourne Town Hall Spire and Park Towers, as well as more recent mixed use developments in the north west and approved but yet to be build office developments in the north east. There is a transitional scale throughout the study area from the low-scale residential development to the south to the increased height towards the Kings Way boundary and an abrupt transition to the high-rise towers of Southbank and Docklands. This is known as the 'bowl of South Melbourne Central' (City of Port Phillip & David Lock Associates, 2007).

Within the commercial, retail and industrial areas, buildings are constructed with a zero setback to create a hard street edge. This means that there is limited public open space in these areas but there are still a few public open spaces within and surrounding the study area (e.g. small parks in residential areas, St Vincent Gardens to the west, Albert Park to the south - see Figure 2) (City of Port Phillip & David Lock Associates, 2007). The existing street canopy coverage of South Melbourne (17%) is above the municipal average but the park canopy coverage is below (City of Port Phillip, 2019).

Below: Park Towers
Photo: Mattinbgn / Wikimedia / CC BY-SA 3.0

Left: Fishley Street Terraces

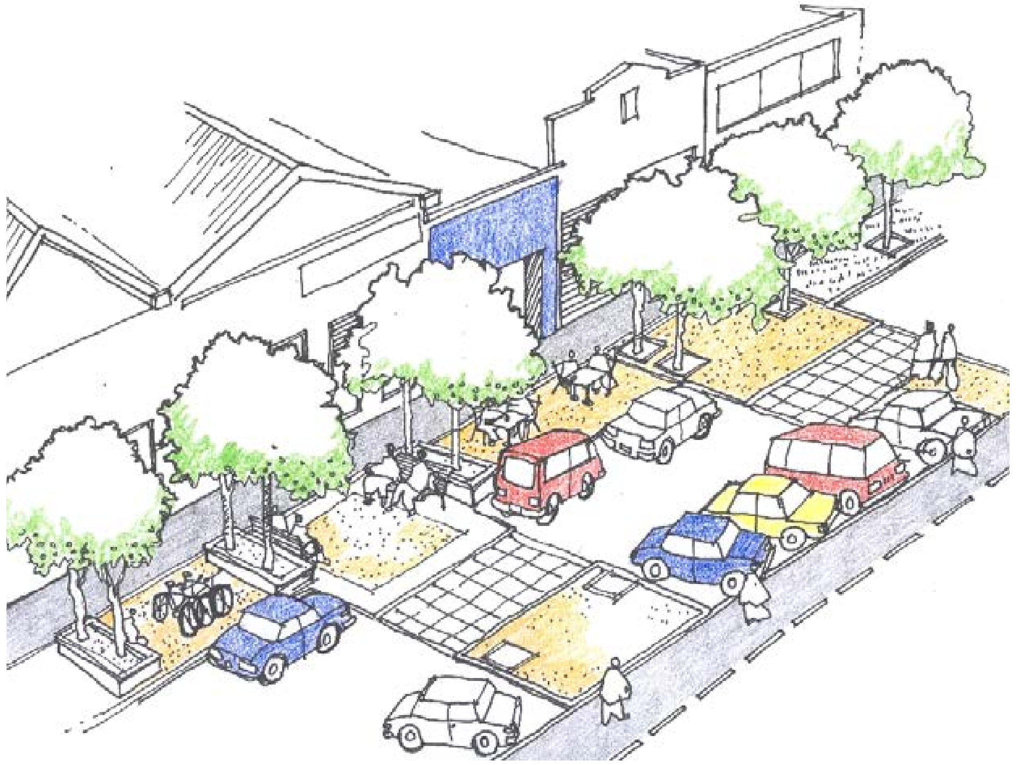
Future Redevelopment

In 2007, the City of Port Phillip adopted the South Melbourne Central Structure Plan that outlined the vision for any development at that time. This document divides South Melbourne into 13 distinct precincts (adapted to 14 for this report – see Figure 2) that have similarities in land use patterns and urban character. The existing development controls for the South Melbourne Study Area are based on this Structure Plan. The South Melbourne Central Urban Design Framework builds upon the strategic directions of the Structure Plan and sets out the specific urban design principles, objectives and built form guidelines to achieve this vision. It focuses on the areas that have the most development potential, which are the business and mixed-use areas as well as key individual development sites (City of Port Phillip, 2007; City of Port Phillip & David Lock Associates, 2007).

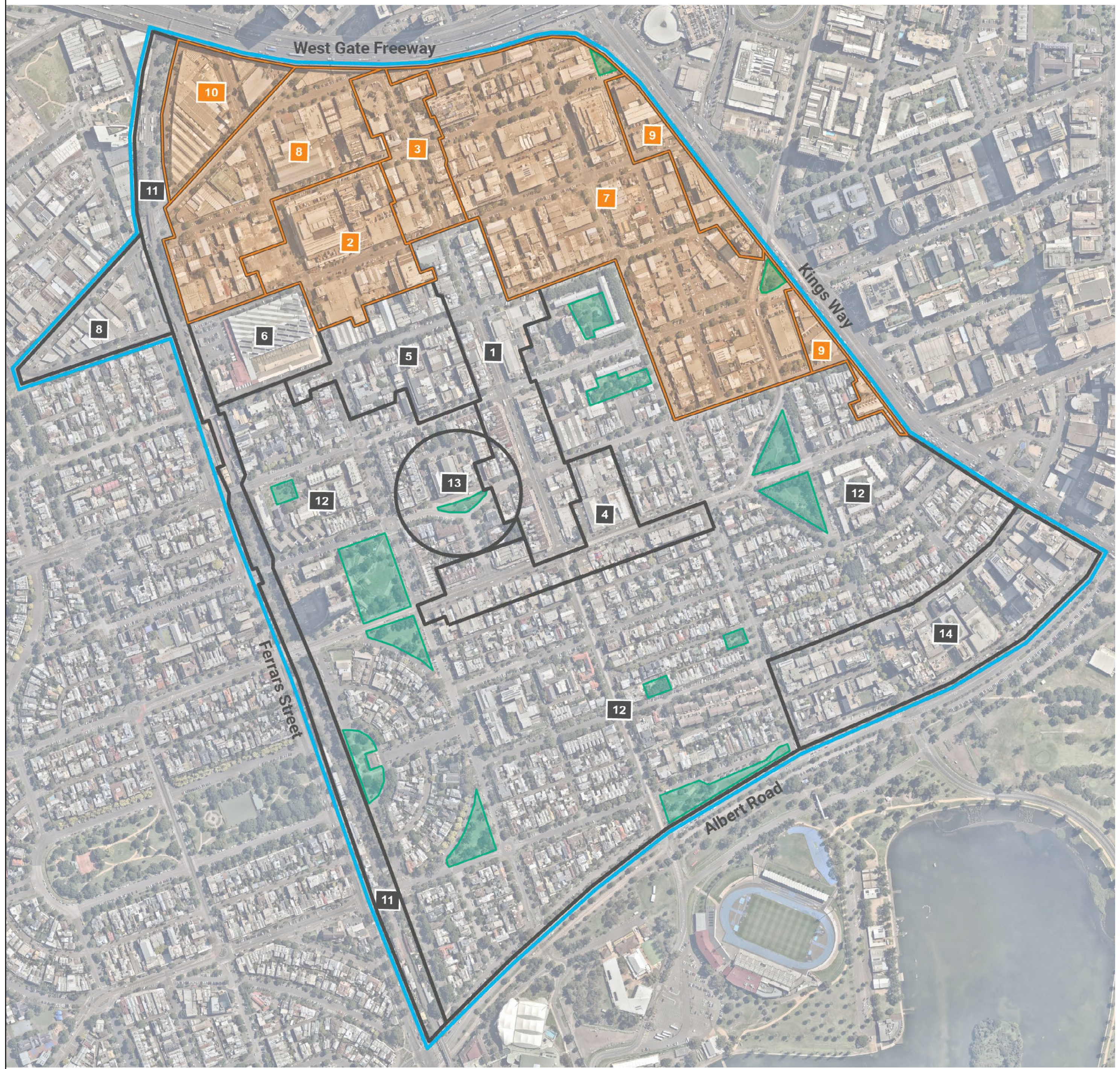
New development with a range of different building types, scales and functions are encouraged within these areas provided they align with the strategic intent of the Structure Plan. Land use changes are proposed to enable South Melbourne to evolve as a unique mixed-use precinct that supports residential, business and retail activities, including a creative industries cluster. New buildings in these key development areas are permitted an increase in height, typically to a maximum of six storeys, but must ensure that the streetscape character is maintained and that street level interaction is encouraged. New development in these areas also offers an opportunity to improve the public domain by maximising public open space where possible and prioritising sustainable modes of transport (City of Port Phillip, 2007; City of Port Phillip & David Lock Associates, 2007).

A more detailed description of the existing and proposed urban development characteristics for the 14 precincts is provided in Table 2.

It is important to note that a thorough review of this Structure Plan from 2007 is considered necessary, and the City of Port Phillip has commenced preparation of a new South Melbourne Structure Plan. This process will likely result in new built form controls for South Melbourne, meaning that the current controls will have limited influence on future redevelopment in South Melbourne. This review presents an opportunity for new development controls and public realm initiatives to mitigate urban heat island impacts, and there is a timely opportunity to update existing planning controls to embed the recommendations developed from this study.



Left: Sketch showing the potential to maximise public open space and encourage sustainable modes of transport (City of Port Phillip & David Lock Associates, 2007)



South Melbourne Study Area Precincts:

1. Clarendon Street Core Local Shopping Strip
2. Emerging Activity Precinct
3. Northern Mixed Activity Edge
4. Southern Mixed Activity Edge
5. Coventry Street Specialty Shopping Precinct
6. South Melbourne Market
7. Eastern Business Precinct
8. Western Business Precinct
9. Kings Way Mixed Use Corridor
10. City Road Wedge
11. Ferrars Street Light Rail Corridor
12. Heritage Overlay Residential Areas
13. Emerald Hill Civic, Cultural and Community Hub
14. Southern Business Precinct

South Melbourne Study Area Boundary

South Melbourne Study Area Precinct Boundaries

Precincts That Have Significant Redevelopment Potential

Green Open Space

Figure 2: South Melbourne Study Area showing the 14 precincts and key redevelopment areas Photo: NearMap, 2020

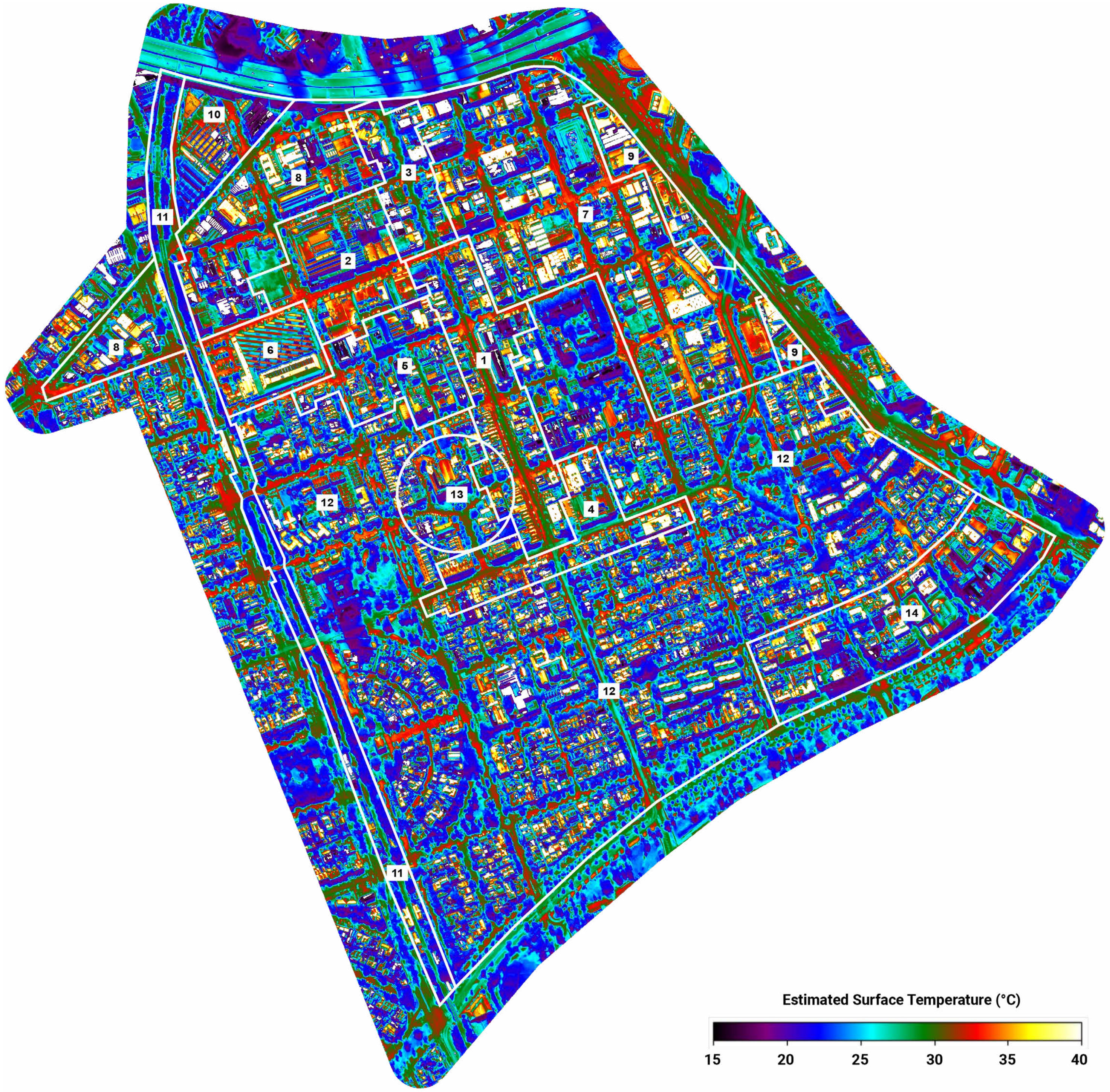
Urban Overheating Challenges

As the population, ambient temperature and the frequency of extreme heat events increases, the challenge of urban overheating grows. While this is a global challenge, many of the impacts of urban overheating are experienced at a local level. It is well documented that higher ambient temperatures in urban areas can have a direct and serious impact on the health, wellbeing and safety of citizens and the overall environmental quality of a city (Santamouris, 2015). More specifically, urban overheating can cause increases in cooling energy consumption, peak electricity demand, citizen vulnerability, heat related mortality and morbidity and levels of harmful pollutants (Santamouris, 2020), as well as cause significant loss of income for local businesses (Sweeney Research & City of Melbourne, 2014). A key challenge for the City of Port Phillip is to manage this future growth and redevelopment in South Melbourne in a way that does not limit its ability to mitigate and adapt to urban heat.

To help understand the existing urban overheating challenges facing South Melbourne, Figure 3 shows the surface temperature distribution across the study area in April 2020. The significant variations in surface temperature are influenced by differences in the physical urban environment (built form, scale, density, materials, etc.) and land cover (paved, vegetated, water, etc.). Areas of lower surface temperatures (shown in purple, blue and green) are predominantly seen in the heritage residential areas to the south and the social housing areas where there is a higher street canopy coverage. Within these residential areas, a significant number of dwellings have higher roof surface temperatures which can often be attributed to darker or lower performing materials of heritage buildings. Areas of higher overall surface temperatures (shown in red, yellow and white) are predominantly the business, retail and industrial areas of the South Melbourne Study Area. Factors that contribute to these higher surface temperatures are the wide unshaded streets, the compact urban context and the large exposed roof surfaces. More specific urban overheating challenges for the 14 precincts is provided in Table 2.

Importantly, the areas of higher overall surface temperatures are the key redevelopment areas within the South Melbourne Study Area. Therefore, it is crucial that the redevelopment of these hot spots effectively mitigates the impacts of urban overheating.

Below: Large exposed roofs of the business, retail and industrial areas of the South Melbourne Study Area
Photo: Bob Tan / Wikimedia / CC BY-SA 4.0



South Melbourne Study Area Precincts:

1. Clarendon Street Core Local Shopping Strip
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3. Northern Mixed Activity Edge
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5. Coventry Street Specialty Shopping Precinct
6. South Melbourne Market
7. Eastern Business Precinct
8. Western Business Precinct
9. Kings Way Mixed Use Corridor
10. City Road Wedge
11. Ferrars Street Light Rail Corridor
12. Heritage Overlay Residential Areas
13. Emerald Hill Civic, Cultural and Community Hub
14. Southern Business Precinct

Figure 3: Airborne thermal imagery of the South Melbourne Study Area taken at approximately 13:00 on April 14, 2020

Table 2: Urban development characteristics and overheating challenges in the South Melbourne Study Area

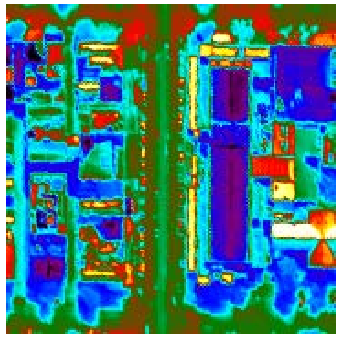
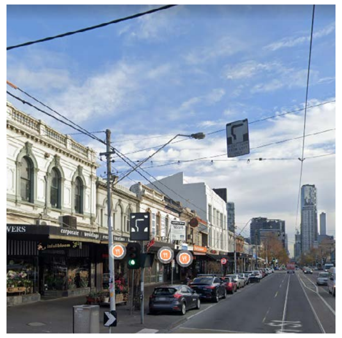
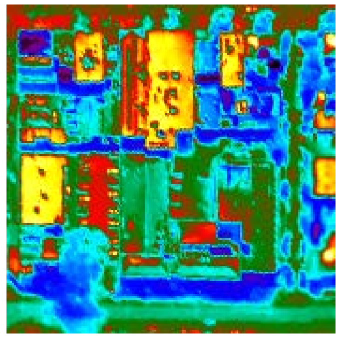
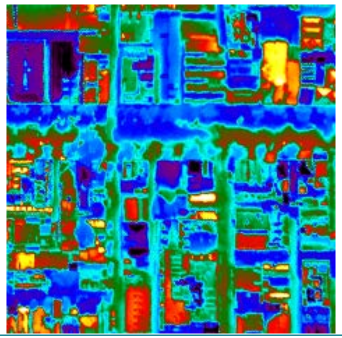
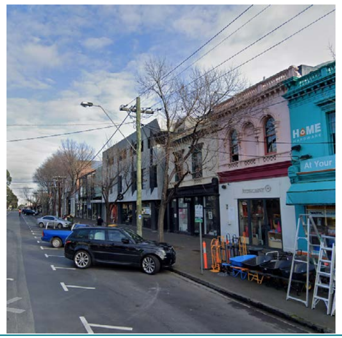
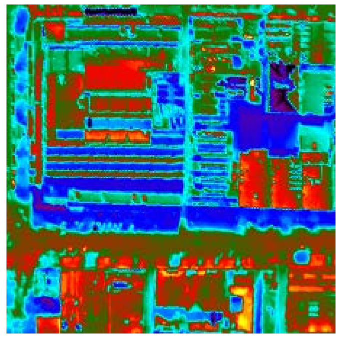
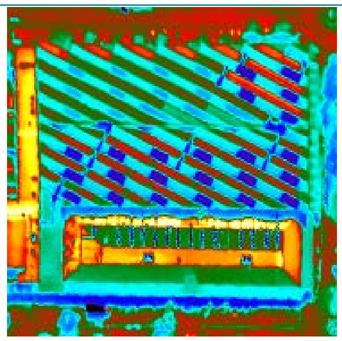
PRECINCTS & URBAN TYPOLOGIES		THERMAL IMAGERY	AERIAL IMAGERY	STREETSCAPE	URBAN DEVELOPMENT CHARACTERISTICS	URBAN OVERHEATING CHALLENGES
1 **Clarendon Street Core Local Shopping Strip**	COMPACT LOW-RISE (Retail)				**Existing:** » A dense mix of low-rise buildings (1-3 storeys) that have predominantly retail functions and are heritage protected » Low tree canopy coverage along streets » Predominantly paved surfaces in public and private areas » Surrounded by wide streets (>28m) with moderate volumes of street and on-site parking **Potential New Development:** » New development in these precincts is quite limited due to heritage restrictions with a few isolated exceptions (e.g. between Bank St and Park St, east of Clarendon St) » Medium-rise (3-9 storeys) mixed-use development encouraged with ground level retail with commercial or residential above	» Some darker roof materials (especially in areas of heritage buildings) which could result in indoor thermal discomfort during high temperature days » Large areas of unshaded impervious ground cover - wide streets (e.g. Clarendon St, Coventry St, Park St) » Contested urban space (e.g. tram line, retail functions) limits opportunities for urban vegetation in public areas » Compact urban context limits opportunities for urban vegetation in private areas » Any new development must be carefully considered so it does not exacerbate the impacts of urban overheating (e.g. urban greenery, material selection, etc.)
4 **Southern Mixed Activity Edge**						
5 **Coventry Street Specialty Shopping Precinct**						
2 **Emerging Activity Precinct**	COMPACT MEDIUM-RISE				**Existing:** » A dense mix of medium-rise buildings (3-9 storeys) » Low tree canopy coverage along streets » Predominantly paved surfaces in public and private areas » Surrounded by wide streets (>28m) with moderate/high volumes of street and on-site parking **Potential New Development:** » New development is limited due to recent developments and heritage restrictions with a few isolated exceptions (e.g. south of York St) » Medium-rise (3-9 storeys) mixed-use development with primarily retail and business functions	» Abundant urban surface materials that absorb and store large amounts of heat » Large areas of unshaded impervious ground cover - wide streets (e.g. York St, Cecil St) » Compact urban context limits opportunities for urban vegetation in private areas » Any new development must be carefully considered so it does not exacerbate the impacts of urban overheating (e.g. urban greenery, material selection, etc.)
6 **South Melbourne Market**	LARGE LOW-RISE				**Existing:** » Open arrangements of large footprint low-rise buildings (1-3 storeys) » Low tree canopy coverage along streets » Predominantly paved surfaces in public and private areas » Surrounded by wide streets (>28m) with high volumes of street and on-site parking **Potential New Development:** » Potential to redevelop at grade car park with a medium-rise (3-9 storeys) mixed-use development that could include parking, commercial, residential and community uses	» Large roof areas exposed to direct solar radiation (extensive rooftop solar contributes to higher surface temperatures in certain areas) » Large areas of unshaded impervious ground cover (e.g. wide streets and on-site carparking) » Limited opportunities for urban vegetation in private areas » Limited shading in pedestrian areas for special events (surrounding roads used as pedestrian areas with temporary shading) » Any new development must be carefully considered so it does not exacerbate the impacts of urban overheating (e.g. urban greenery, material selection, etc.)

Table 2 (continued): Urban development characteristics and overheating challenges in the South Melbourne Study Area

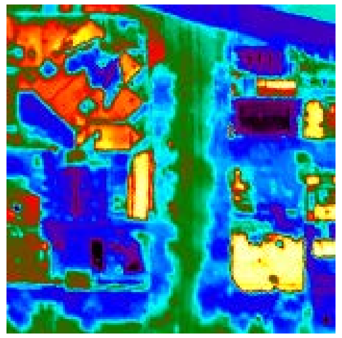
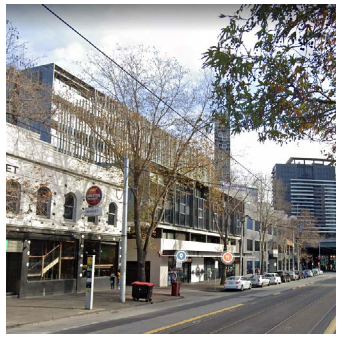
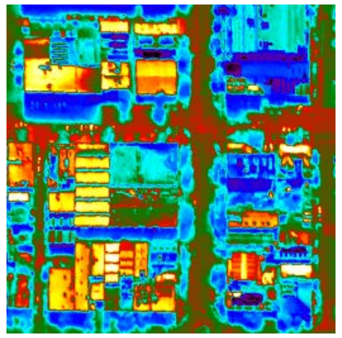
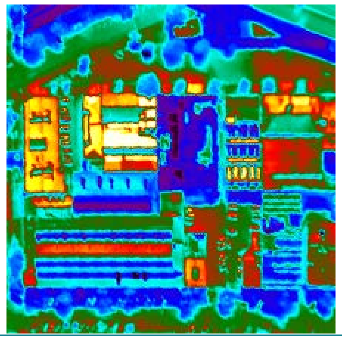
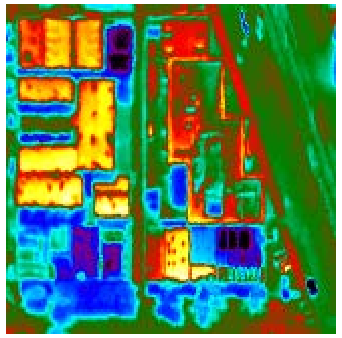
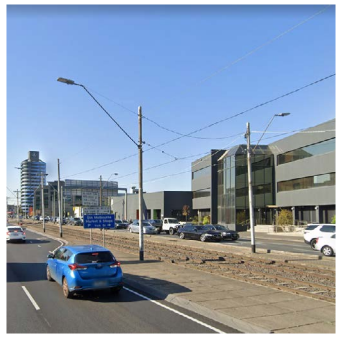
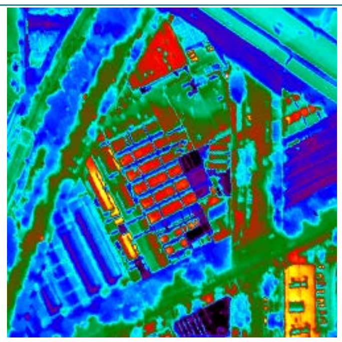
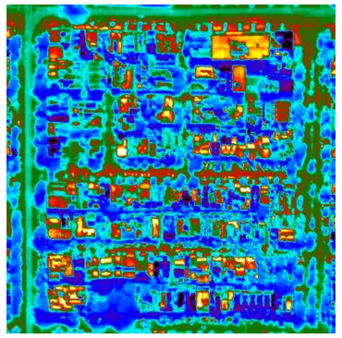
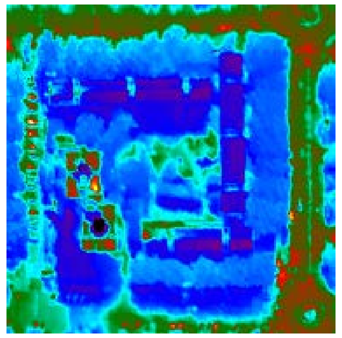
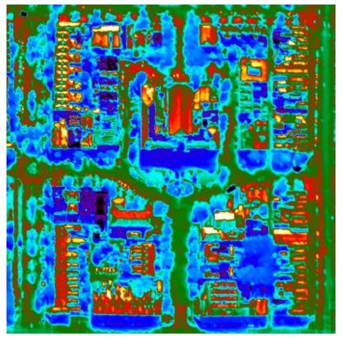
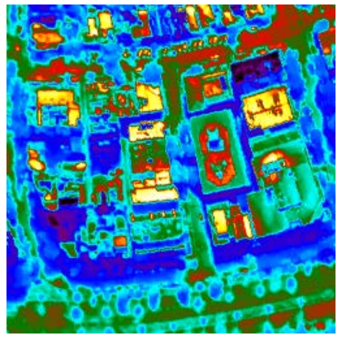
PRECINCTS & URBAN TYPOLOGIES		THERMAL IMAGERY	AERIAL IMAGERY	STREETSCAPE	URBAN DEVELOPMENT CHARACTERISTICS	URBAN OVERHEATING CHALLENGES
3 **Northern Mixed Activity Edge**	COMPACT LOW/MEDIUM-RISE				**Existing:** » A dense mix of low-rise (1-3 storeys) and medium-rise buildings (3-9 storeys) that have predominantly commercial functions » Moderate tree canopy coverage along streets » Predominantly paved surfaces in public and private areas » A mix of wide (>28m), medium (12-28m) and narrow (<12m) streets with moderate volumes of street and on-site parking **Potential New Development:** » These three precincts offer the greatest potential for new medium-rise (3-9 storeys) development that have primarily retail, business and industrial uses	» Abundant urban surface materials that absorb and store large amounts of heat » Increased roof surface temperature and surrounding air temperature from darker roof materials which could also result in indoor thermal discomfort during high temperature days » Large areas of unshaded impervious ground cover - wide streets (e.g. Tope St, York St, Eastern Rd, Cecil St) » Compact urban context limits opportunities for urban vegetation in private areas » Any new development must be carefully considered so it does not exacerbate the impacts of urban overheating (e.g. urban greenery, material selection, etc.)
7 **Eastern Business Precinct**	COMPACT LOW/MEDIUM-RISE					
8 **Western Business Precinct**	COMPACT LOW/MEDIUM-RISE					
9 **Kings Way Mixed Use Corridor**	COMPACT LOW/ MEDIUM/HIGH-RISE				**Existing:** » A dense mix of low-rise (1-3 storeys), medium-rise (3-9 storeys) and high-rise buildings (>9 storeys) » Low tree canopy coverage along streets » Predominantly paved surfaces in public and private areas » Surrounded by wide streets (>28m) with low volumes of street and on-site parking **Potential New Development:** » Potential for new medium-rise (3-9 storeys) and high-rise (>9 storeys) mixed-use buildings that integrate street level retail, residential and office uses	» Abundant urban surface materials that absorb and store large amounts of heat » Increased roof surface temperature and surrounding air temperature from darker roof materials which could also result in indoor thermal discomfort during high temperature days » Large areas of unshaded impervious ground cover - wide streets (e.g. Kings Way, York St, Coventry St) » Compact urban context limits opportunities for urban vegetation in private areas » Any new development must be carefully considered so it does not exacerbate the impacts of urban overheating (e.g. urban greenery, material selection, etc.)
10 **City Road Wedge**	COMPACT LOW-RISE (Industrial)				**Existing:** » A dense mix of low-rise (1-3 storeys) commercial and industrial buildings that are predominantly heritage protected » Low/moderate tree canopy coverage along streets » Predominantly paved surfaces in public and private areas » Surrounded by wide streets (>28m) with low volumes of street and on-site parking **Potential New Development:** » Potential for a new high-rise (>9 storeys) residential building to act as a transitional scale between South Melbourne Central and the Southbank high-rise	» Large roof areas exposed to direct solar radiation » Large areas of unshaded impervious ground cover - wide streets (e.g. City Rd, Cecil St, Whiteman St) » Compact urban context limits opportunities for urban vegetation in private areas » Any new development must be carefully considered so it does not exacerbate the impacts of urban overheating (e.g. urban greenery, material selection, etc.)

Table 2 (continued): Urban development characteristics and overheating challenges in the South Melbourne Study Area

PRECINCTS & URBAN TYPOLOGIES		THERMAL IMAGERY	AERIAL IMAGERY	STREETSCAPE	URBAN DEVELOPMENT CHARACTERISTICS	URBAN OVERHEATING CHALLENGES
12 **Heritage Overlay Residential Areas**	COMPACT LOW-RISE (Residential)				» A dense mix of low-rise (1-3 storeys) semi-detached residential buildings that are predominantly heritage protected » Limited permeable ground cover in private areas » Moderate/high tree canopy coverage along streets with some vegetated street verges and public green spaces » A mix of wide (>28m), medium (12-28m) and narrow (<12m) streets with moderate volumes of street parking	» Increased roof surface temperature and surrounding air temperature from darker roof materials which could also result in indoor thermal discomfort during high temperature days » Limited opportunities for private garden spaces » Large areas of unshaded impervious ground cover - the wider streets (e.g. James Service Pl, Napier St, Stead St, Cecil St)
	OPEN MEDIUM/ HIGH-RISE				» Open arrangements of medium-rise (3-9 storeys) and high-rise buildings (>9 storeys) » Abundance of permeable (vegetated) land cover in public and private areas » High tree canopy coverage along streets with vegetated street verges » Surrounded by wide streets (>28m) with moderate/high volumes of street and on-site parking » Typically social/affordable housing within urban areas	» Large building envelopes exposed to direct solar radiation due to the open built form arrangements » Urban heat vulnerability - some inhabitants in social housing areas may be unable to maintain a thermally comfortable indoor environment
13 **Emerald Hill Civic, Cultural and Community Hub**	COMPACT LOW-RISE (Civic Centre)				» A dense mix of low-rise (1-3 storeys) semi-detached buildings and key public services (e.g. Town Hall, Library, Police Station) that are heritage protected » A mix of permeable (vegetated) and impervious (paved) ground cover in public and private areas » Moderate tree canopy coverage along streets » Surrounded by wide streets (>28m) with moderate volumes of street parking	» Increased roof surface temperature and surrounding air temperature from darker roof materials which could also result in indoor thermal discomfort during high temperature days » Large areas of unshaded impervious ground cover - wide streets (e.g. Perrins St, Bank St, Clarendon St) » Heritage elements may limit cooling potential (e.g. bluestone paving, roof materials, etc.)
14 **Southern Business Precinct**	COMPACT MEDIUM/ HIGH-RISE				» A dense mix of medium-rise (3-9 storeys) and high-rise buildings (>9 storeys) » Moderate tree canopy coverage along streets with some vegetated street verges » Urban surfaces shaded by surrounding tall buildings » A mix of predominantly wide (>28m) and medium (12-28m) streets with low/moderate volumes of street and on-site parking	» Abundant urban surface materials that absorb and store large amounts of heat » Increased roof surface temperature and surrounding air temperature from darker roof materials which could also result in indoor thermal discomfort during high temperature days » Compact urban context limits opportunities for urban vegetation in private areas

Estimated Surface Temperature (°C)

15 20 25 30 35 40

Aerial Images: NearMap, 2020

Streetscape Images: Google Streetview, 2020

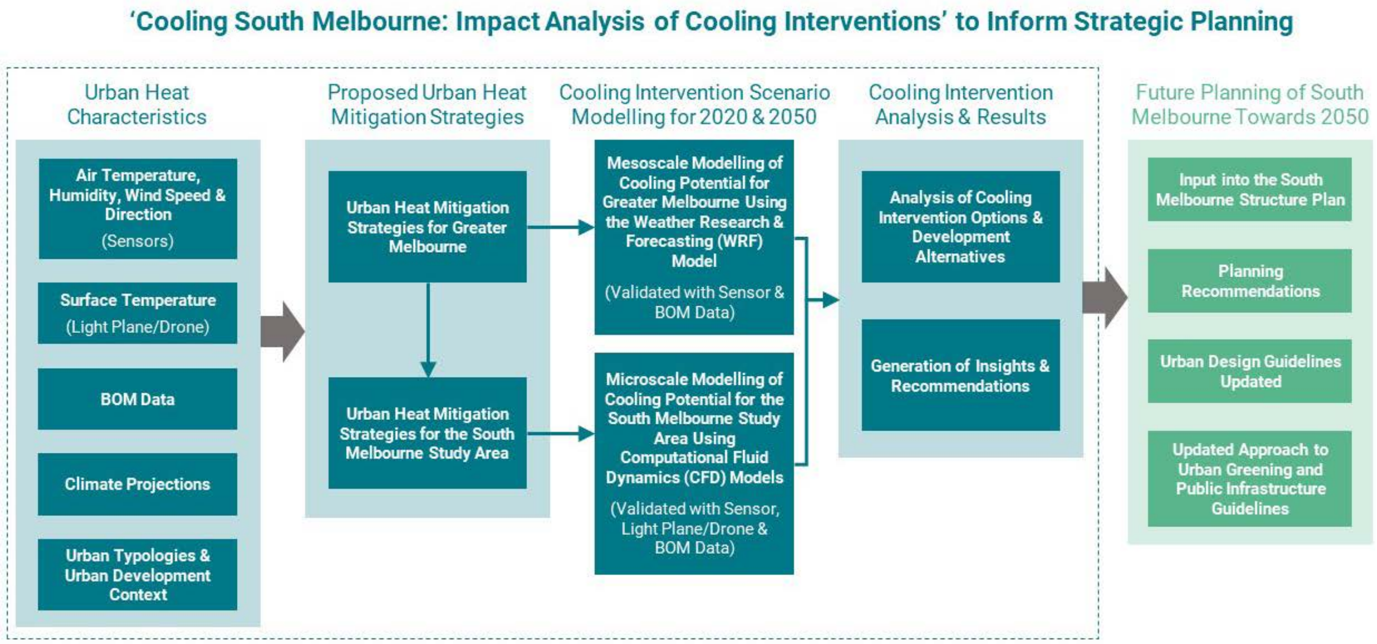
Part 2 - Urban Overheating Mitigation Strategies to Inform Strategic Planning

Left: View of South Melbourne looking north towards the CBD
Photo: Michael Evans / Adobe Stock

The Need for Urban Heat Mitigation in Planning Processes

Tackling urban overheating challenges requires multi-sector collaboration as well as leadership in urban policy and strategic planning processes to incorporate climate change adaptation and mitigation strategies. The Victorian Government has developed an Implementation Plan for Plan Melbourne 2017-2050 that includes the improvement of climate change strategies in the Victoria Planning Provisions and all planning schemes, and will ensure these provisions are based on scientific outcomes (Victorian Government, 2017b). This report demonstrates an urban planning and development approach to mitigating urban overheating and minimising the impact of climate extremes on the outdoor thermal environment, urban amenity and human health. It investigates what mitigation strategies are appropriate for Greater Melbourne and a South Melbourne Study Area, and determines to what extent various cooling intervention options involving built form, urban greenery and cool materials can help in mitigating urban overheating and keeping our streetscapes and cities cool. Computer fluid dynamics models and simulations are employed to provide scientific outcomes and establish evidence to inform future provisions and planning schemes at a local level for the City of Port Phillip. An overview of the key processes carried out for this Cooling South Melbourne report is shown in Figure 4.

Figure 4: Overview of the key processes carried out for this report



Proposed Urban Overheating Mitigation Strategies

Greater Melbourne

The Guide to Urban Cooling Strategies recommends increased tree canopy, cool materials, permeable paving and evaporative cooling as effective strategies for cooling Greater Melbourne. Melbourne CBD's high urban density settings results in 12.9% of canopy cover (Jacobs et al., 2014). Therefore, increasing tree canopy cover is an appropriate strategy to reduce air temperature and improve amenity and thermal comfort at street level. To address Melbourne's high solar radiation intensity and UV level in summer, high albedo and high emittance[1] materials for urban surfaces such as cool pavements and roofs are effective in radiating the urban heat away, which can significantly reduce surface and air temperatures. Melbourne's relatively low rainfall during summer means that permeable paving and water irrigation strategies will also be effective for cooling Greater Melbourne (Osmond & Sharifi, 2017).

The cooling impact analysis of high albedo materials, water irrigation, increased urban greenery and combination of these cooling interventions for Greater Melbourne will be presented in Part 3. The outcomes of this impact analysis will inform the cooling intervention options for the South Melbourne Study Area.

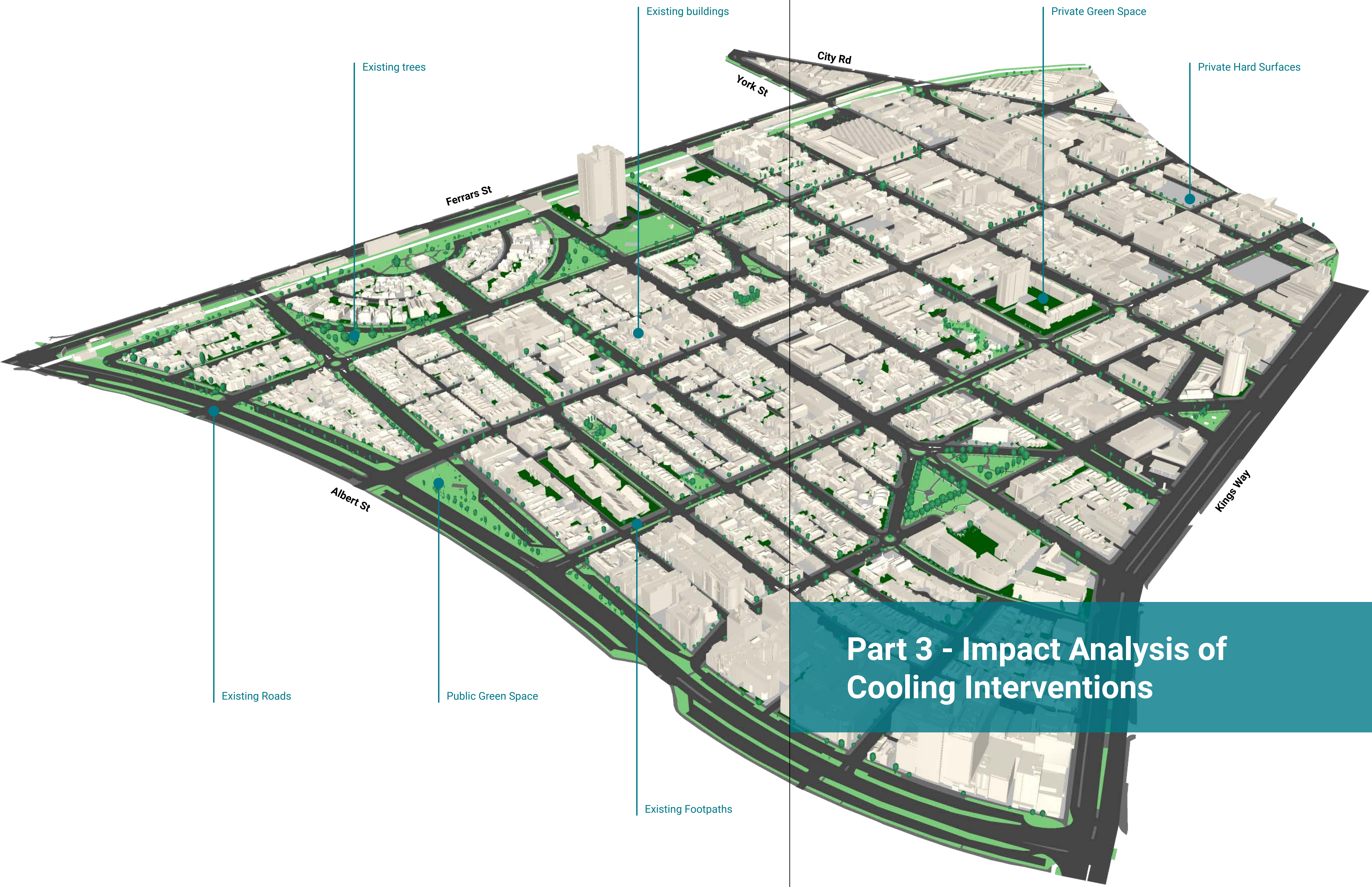
South Melbourne Study Area

The South Melbourne Study Area, an inner-city area just south of the CBD, has distinctive urban characteristics and urban overheating challenges (Table 2). The proposed urban overheating mitigation strategies for this study area are aligned with the strategies for Greater Melbourne but are tailored to its specific urban context.

The South Melbourne Study Area, despite having 17% of street canopy coverage from existing trees (City of Port Phillip, 2019), still offers opportunities to increase urban greenery in the public realm through additional trees and rain gardens along restricted streets (see Scenario 2). Increases in urban greenery can also be achieved in private areas through three green infrastructure scenarios defined by the development of the City of Melbourne's Green Factor Tool (Ashley, 2020). The addition of new buildings in the northern and eastern redevelopment areas offers a unique opportunity to explore the cooling impact of these three private green coverage scenarios (BAU, Moderate and Optimised), as well as cool materials for public and private hard surfaces and cool roofs. Due to Melbourne's hot and dry summers, water misting sprays are also investigated as a cooling intervention to reduce air temperatures across the study area.

Part 3 conducts a cooling impact analysis of these cooling interventions for the current climate in 2020 and the future climate of 2050. The outcomes of this analysis show the maximum cooling potential for the South Melbourne Study Area and can be used to inform the City of Port Phillip's planning of South Melbourne towards 2050.

[1] Albedo refers to the proportion of incident light reflected from a surface; its reflectivity. Emittance refers to the amount of heat radiated from a material at a given temperature compared to a theoretical 'black body' (Osmond & Sharifi, 2017). As most urban surfaces already have high emittance and albedo is easier to modify, the focus will be on changing the albedo of urban surfaces



Part 3 - Impact Analysis of Cooling Interventions

Left: 3D model of the existing conditions (base case) of the South Melbourne Study Area

Cooling Potential for Greater Melbourne in 2020 and 2050

The cooling potential for Greater Melbourne in 2020 and 2050 was modelled using the Weather Research and Forecasting (WRF) model. Four two-way nested domains (Figure 5) were simulated with a horizontal resolution increasing from 13.5 km in the largest domain (d01) to 0.5 km in the innermost domain (d04) (Table 3).

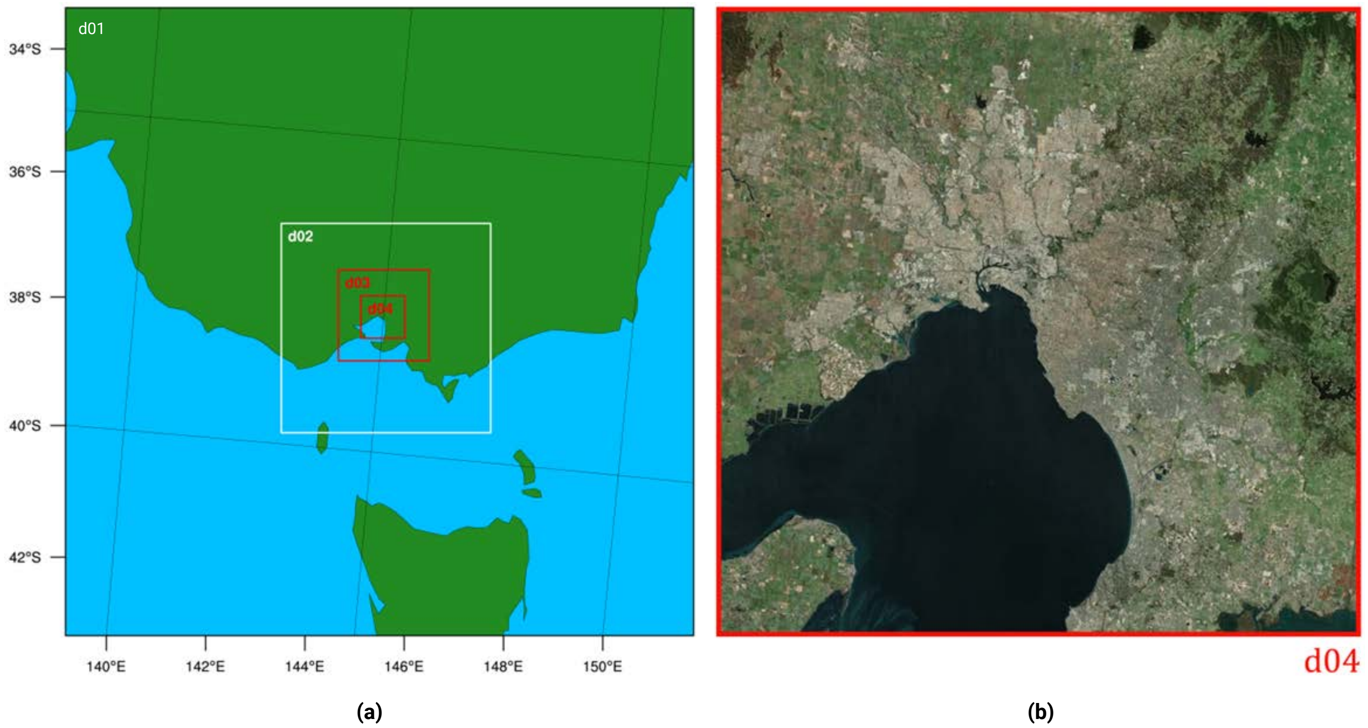
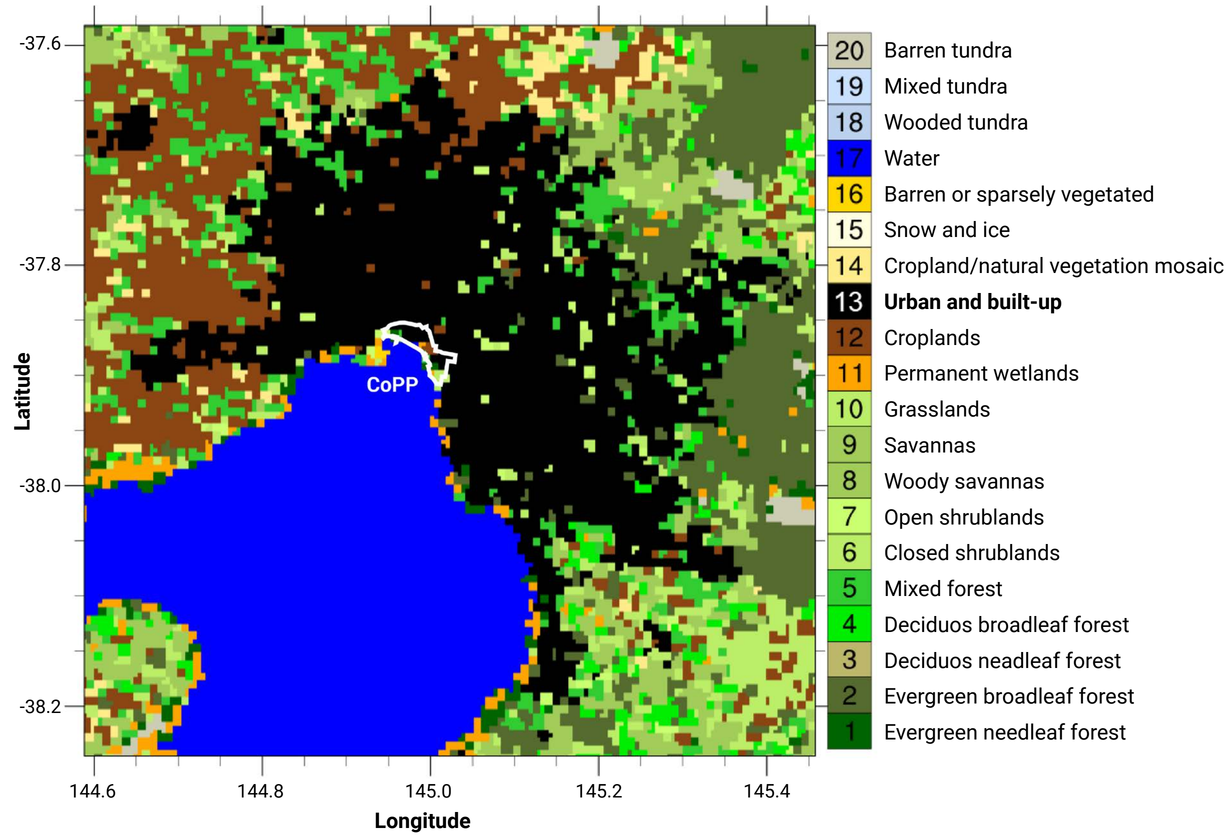


Figure 5: (a) The four two-way nested WRF domains across Greater Melbourne (d01, d02, d03, d04); **(b)** Satellite image of the innermost domain (d04)

Table 3: The four simulation domains in the WRF model

Domain	Resolution (km)	n. cells (longitude x latitude)
d01	13.5	100 x 100
d02	4.5	100 x 100
d03	1.5	130 x 130
d04	0.5	187 x 181



Cooling intervention scenarios were defined and applied to the urban and built-up areas across Greater Melbourne (refer to 13 in Figure 6) to understand its cooling potential and to inform the South Melbourne Study Area. Simulations of cooling intervention scenarios were conducted for the whole of February in 2020 and 2050. Simulation results show that without any direct action or cooling interventions, Greater Melbourne's urban and built-up areas could experience ambient temperature increases of 2.1°C - 3.7°C in February 2050 in comparison to February 2020 (Figure 7). However, through a combination of carefully considered cooling interventions, the simulation results show that maximum ambient temperature reductions of 4.7°C and 6.3°C can be achieved in 2020 and 2050 respectively for a representative summer's day (February 10) (Figure 8).

Figure 6: Land use classification in Greater Melbourne (d04) (NASA, MODIS database). The City of Port Phillip municipal boundary shown in white.

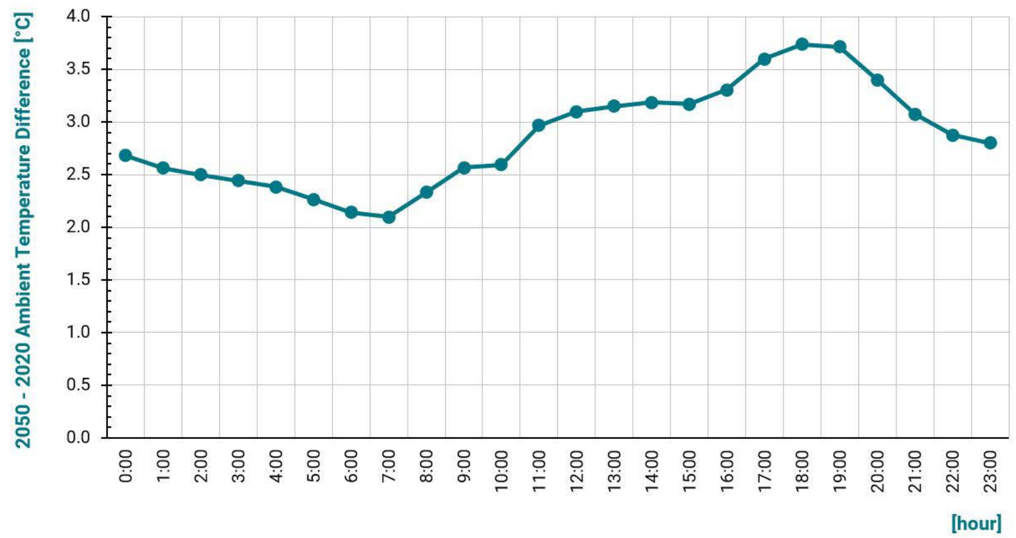


Figure 7: Projected hourly ambient temperature increase for February 2050 in comparison to February 2020 (temperature difference is averaged across the whole month of February)

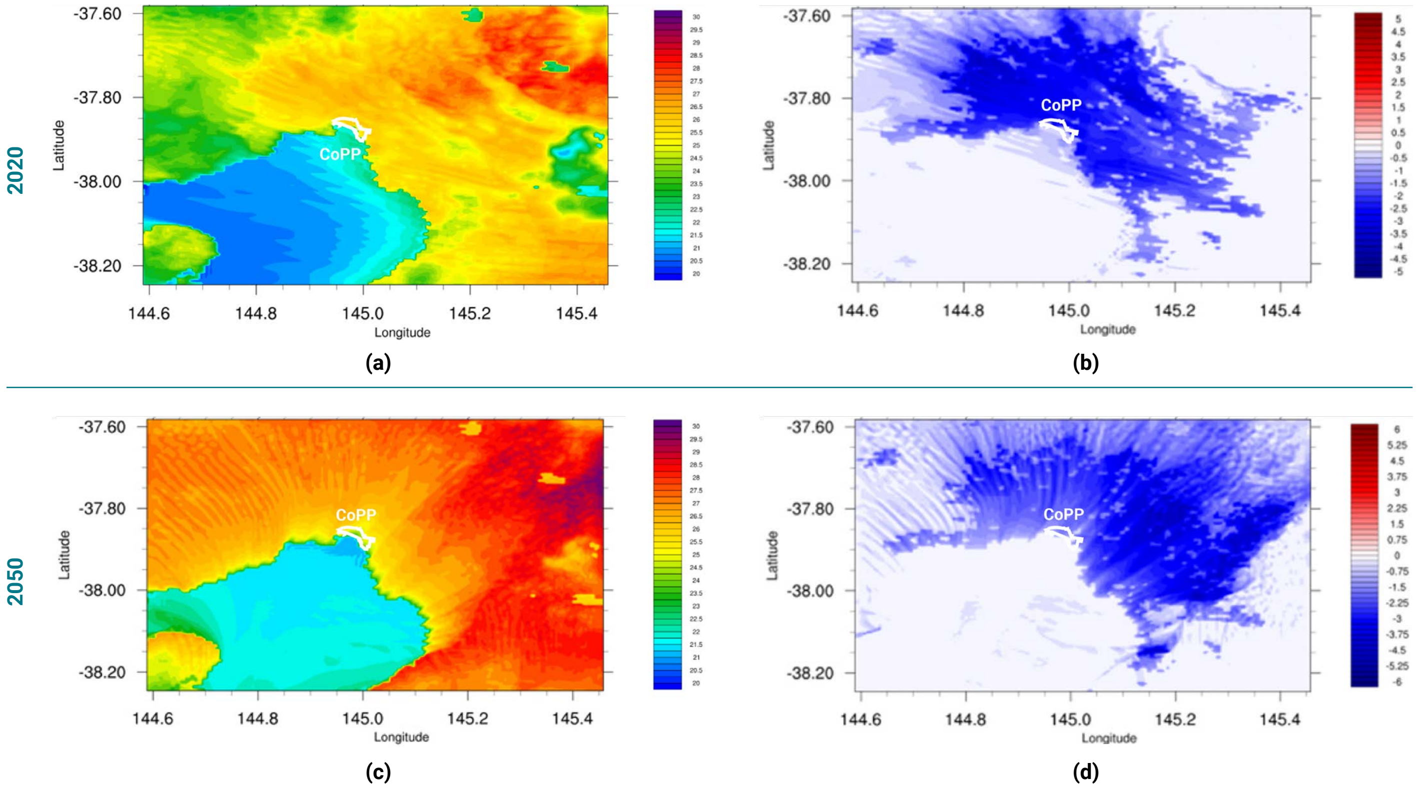


Figure 8: Projected ambient temperature scenarios for Greater Melbourne on February 10, 2020 and 2050 at 14:00 at 2m height. **(a)** Ambient temperature in 2020 (base case); **(b)** Ambient temperature reduction in 2020 through a combination of defined cooling interventions in comparison to the base case; **(c)** Ambient temperature in 2050 (base case); **(d)** Ambient temperature reduction in 2050 through a combination of defined cooling interventions in comparison to the base case. The City of Port Phillip municipal boundary shown in white.

The defined individual and combination of cooling interventions are described below, followed by the comparative impact analysis of cooling interventions for Greater Melbourne:

» **Base case:** the base case scenario was defined with an albedo value of 0.2 for urban surfaces (e.g. roofs, walls, streets) The base case scenario does not include irrigation but waste heat from cars and people (anthropogenic heat) was included for both 2020 and 2050.

» **High albedo materials:** this scenario includes an increased albedo value of 0.6 for urban surfaces (e.g. roofs, walls, streets).

» **Urban greenery:** this scenario includes an increase of 20% in greenery for the urban areas.

» **Irrigation:** this scenario includes the irrigation of vegetation. Evapotranspiration of vegetation is doubled in the urban areas for this scenario.

» **Combination of interventions:** this scenario is a combination of high albedo materials, irrigation and increasing urban greenery.

High Albedo for Urban Surfaces

Simulation results show that high albedo materials for urban surfaces (e.g. roofs, walls, streets) are highly effective in reducing both average and maximum surface and ambient temperatures between 9:00 and 19:00 for February 2020 and 2050 (Figures 9 and 10). These high albedo materials are most effective during the middle of the day between 13:00 and 15:00 when urban surfaces receive the most direct solar radiation. During these hours, maximum surface temperature reductions of up to 5.0°C and 5.4°C can be achieved for 2020 and 2050 respectively, which can lead to maximum ambient temperature reductions of up to 1.9°C for both 2020 and 2050 (Figure 9). While its cooling effectiveness reduces overnight, increasing the albedo of urban surfaces is crucial to improving the outdoor thermal comfort of Greater Melbourne in the future, with average ambient temperature reductions of up to 1.3°C possible throughout February in 2050 (Figure 10).

Urban Greenery

Urban greenery also plays a crucial role in improving the outdoor thermal comfort of our cities. Figures 9 and 10 show that an increase of 20% in urban greenery is highly effective for urban areas at reducing maximum and average ambient temperatures during the early hours of the morning (1:00 - 7:00). During these hours, an increase of urban greenery in the urban and built-up areas of Greater Melbourne can provide maximum ambient temperature reductions of up to 1.5°C and 1.8°C in 2020 and 2050 respectively (Figure 9), as well as provide average ambient temperature reductions of up to 1.0°C throughout February in 2050 (Figure 10).

Water Irrigation

Although increasing the evapotranspiration of urban greenery is the least effective individual cooling intervention strategy, it plays an important role in reducing both ambient and surface temperatures throughout the day (Figures 9 and 10). The simulation results show that well irrigated vegetation across the urban and built-up areas of Greater Melbourne can lead to surface and ambient temperature reductions of up to 1.4°C and 0.5°C respectively for 2020, and up to 1.3°C and 0.5°C respectively for 2050 (Figure 9).

Combination of Cooling Interventions

The combination of cooling interventions leads to significant reductions in both maximum and average surface and ambient temperatures for 2020 and 2050. Figures 9 and 10 show that considerable maximum and average surface temperature reductions are possible between 9:00 and 19:00, primarily due to the effectiveness of increasing the albedo of urban surfaces. During the middle of the day (13:00 - 15:00), the combination of cooling interventions can lead to maximum surface temperature reductions of up to 8.2°C (Figure 9) and average surface temperature reductions of almost 7.0°C throughout February in 2020 and 2050 (Figure 10).

When observing maximum and average ambient temperature reductions, Figures 9 and 10 show that the combination of cooling interventions can provide increased cooling benefits for a greater amount of time. This is due to the effectiveness of high albedo urban surfaces during the day and increased urban greenery at night in reducing ambient temperatures. This sustained cooling potential can lead to maximum ambient temperature reductions of approximately 1.5°C - 3.0°C (Figure 9) and average ambient temperature reductions of approximately 1.0°C - 2.0°C (Figure 10) throughout February in 2020 and 2050.

Figures 11 and 12 show the average ambient temperature reductions of the individual and combination of cooling interventions over a 5-day period (10 - 15 February)[2] for 2020 and 2050 respectively. Despite having different weather conditions, similar trends can be observed with the effectiveness of increased urban greenery at night and high albedo urban surfaces during the day leading to sustained periods of average ambient temperature reductions.

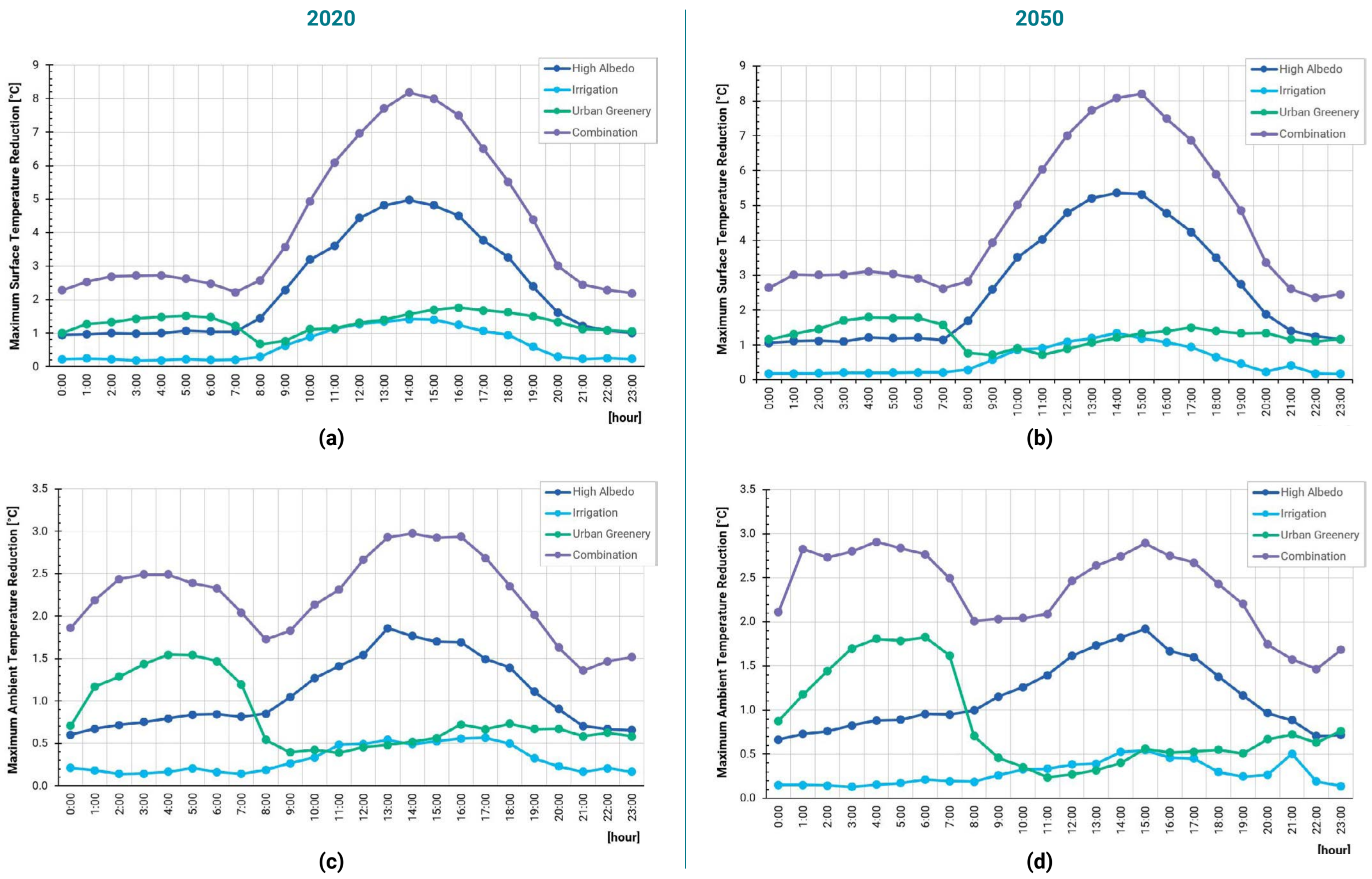


Figure 9: Comparison of the cooling intervention scenarios against the base case showing *maximum* reductions in surface temperatures for **(a)** 2020; and **(b)** 2050; and ambient temperatures for **(c)** 2020; and **(d)** 2050; averaged across February for Greater Melbourne

[2] This was the warmest five-day period for Melbourne's Olympic Park weather station (BOM, 2020b)

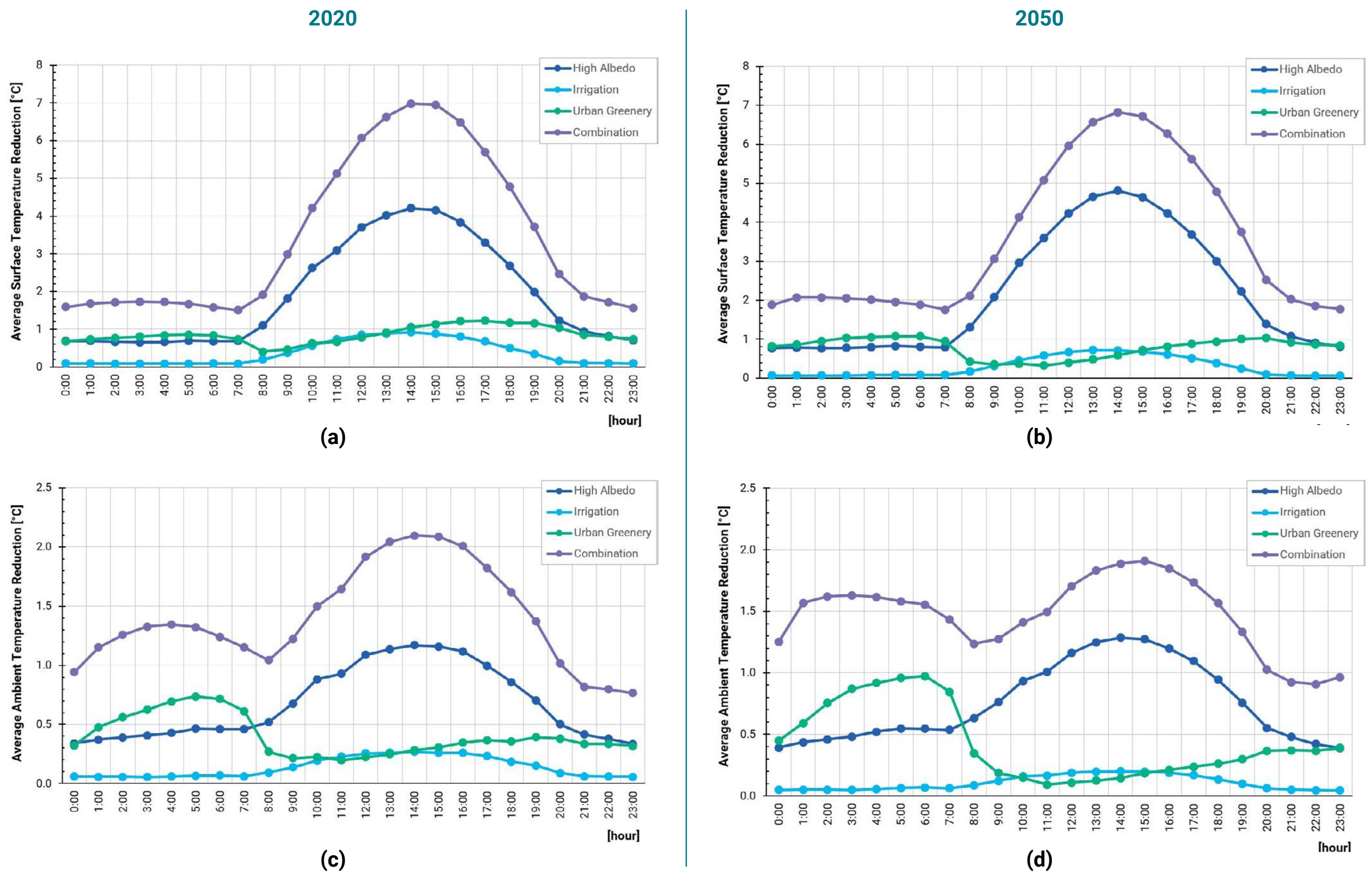


Figure 10: Comparison of the cooling intervention scenarios against the base case showing *average* reductions in surface temperatures for **(a)** 2020; and **(b)** 2050; and ambient temperatures for **(c)** 2020; and **(d)** 2050; averaged across February for Greater Melbourne

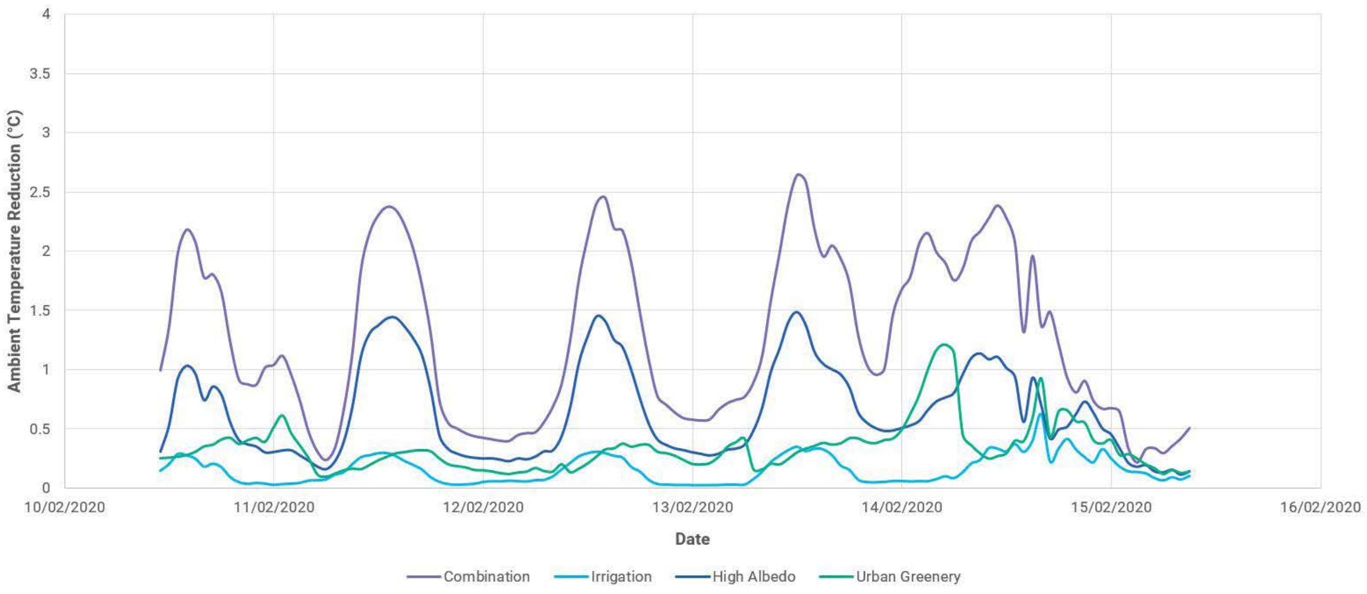


Figure 11: Comparison of average ambient temperature reductions for the individual and combination of cooling interventions across Greater Melbourne between 10 - 15 February 2020

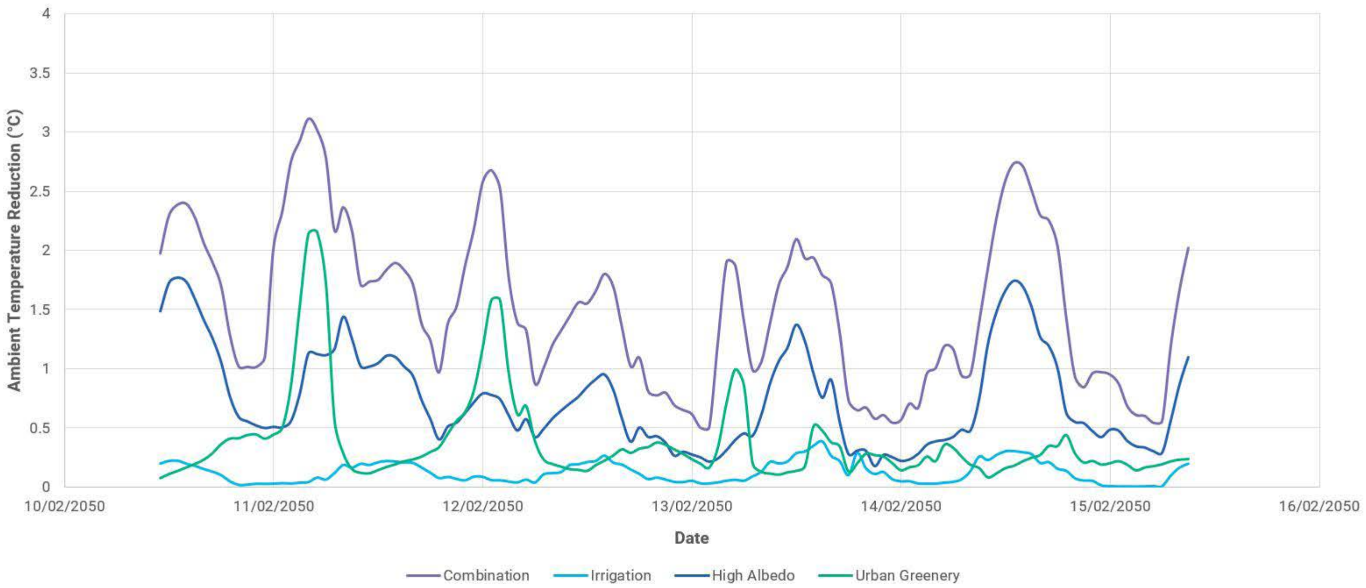


Figure 12: Comparison of average ambient temperature reductions for the individual and combination of cooling interventions across Greater Melbourne between 10 - 15 February 2050

Informing the South Melbourne Study Area

The comparative impact analysis results for Greater Melbourne show that significant reductions in surface and ambient temperatures can be achieved now in 2020 and in the future towards 2050. The simulation results have shown that a carefully considered combination of cooling interventions can achieve the greatest cooling potential for the urban and built-up areas of Greater Melbourne. Individually, an increase of albedo for urban surfaces was the most effective strategy in reducing daytime ambient and surface temperatures, while an increase of urban greenery was the most effective at reducing ambient temperatures across Greater Melbourne.

The results from this impact analysis of Greater Melbourne can inform the selection of appropriate cooling interventions at a local scale for the South Melbourne Study Area. These results can also help to frame the cooling of South Melbourne towards 2050 within the larger objective of cooling Greater Melbourne. The next section will present the impact analysis of a series of cooling interventions tailored to the specific context of the South Melbourne Study Area. It will demonstrate how urban overheating mitigation strategies combined with urban planning and design parameters can impact the local thermal environment, thereby improving outdoor and indoor thermal comfort.

Below: View of the South Melbourne Study Area in the context of Greater Melbourne Photo: nilsversemann / Adobe Stock

Cooling Potential for the South Melbourne Study Area in 2020 and 2050

The impact analysis of cooling interventions for the South Melbourne Study Area was conducted for the current climate of 2020 and the future climate of 2050 using the computational fluid dynamics (CFD) based microclimate model, ENVI-met. The simulation date and time were set for February 14, 2020 and 2050 between 08:00 and 15:00 with a wind speed of 2.5m/s from the north. February 14 2020 was used as it was a hot summer's day in Melbourne with the maximum recorded temperature reaching 33.7°C[3]. Appropriate cooling interventions options were defined and modelled to investigate their potential to mitigate the impacts of urban overheating within the South Melbourne Study Area. The results of these cooling interventions are discussed in this section and are reported from 08:00 - 15:00 for the comparison charts and at 14:00 (typical peak daily temperature) for the surface and air temperature maps. The results from the impact analysis of cooling interventions for Greater Melbourne in the previous section were used to set the boundary climate conditions for the South Melbourne Study Area.

As mentioned in part 1 of this report, the South Melbourne Study Area is divided into 14 distinct precincts, with the business and mixed-use precincts to the north and east having the most significant redevelopment potential (see Figure 2). Therefore, the defined cooling interventions were tailored to the City of Port Phillip's specific planning controls for any redevelopment in these precincts. Namely, the South Melbourne Central Structure and Implementation Plan and its associated Urban Design Framework informed the development of nine cooling intervention scenarios (Table 4) which include proposed new buildings, increasing public and private urban greenery, water misting sprays, and changes to street, footpath and roof materials.

These nine scenarios were developed and analysed to highlight the maximum possible cooling impact for the South Melbourne Study Area. 3D model data for the study area, typologies of new buildings and private green coverage scenarios were provided by the City of Port Phillip which enabled the nine cooling intervention scenarios to be modelled in ENVI-met and the Microclimate and Urban Heat Island Mitigation Decision-Support (UHI-DS) Tool (see Part 5). The parameter settings used to model the cooling intervention scenarios in ENVI-met are outlined in Table 5.

The results of the impact analysis of the cooling intervention scenarios are described in detail in the following sections. It is important to note that this report focuses primarily on improving outdoor thermal comfort for the South Melbourne Study Area. Therefore, the analysis results (heatmaps and charts) show only the cooling potential for outdoor surface and air temperatures at street level (<2m) and exclude the surface temperatures of building elements and any impact on indoor thermal environments. Also, it is important to note that the differences in cooling potential between 2020 and 2050 are primarily due to the different climate conditions for each day (e.g. northerly wind in 2020 and westerly wind in 2050).

[3] Refer to BOM data for Melbourne (Olympic Park) (BOM, 2020b)

Table 4: The nine cooling intervention scenarios for the South Melbourne Study Area

Scenario	Scenario Description
1	**New Buildings with Business as Usual Private Green Coverage:** New buildings (commercial, residential and mixed-use) in the key redevelopment precincts (2, 3, 7, 8, 9 and 10 – see Figure 3) and individual redevelopment sites; and a business as usual (BAU) green infrastructure scenario[4] for private green coverage for these new buildings.
2	**New Buildings with Moderate Private Green Coverage and Additional Public Realm Green Coverage:** New buildings (same as scenario 1); a moderate green infrastructure scenario[4] for private green coverage for these new buildings; and additional street trees and rain gardens.
3	**New Buildings with Optimised Private Green Coverage and Additional Public Realm Green Coverage:** New buildings (same as scenario 1); an optimised green infrastructure scenario[4] for private green coverage for these new buildings; and additional street trees and rain gardens.
4	**New Buildings and Cool Materials for all Streets, Footpaths and Private Hard Surfaces:** Scenario 1 with cool materials for all public and private hard surfaces (e.g. footpaths, carparks, streets, courtyards, etc.).
5	**New Buildings and Cool Roofs for all New and Existing Buildings:** Scenario 1 with cool roofs for all new buildings and existing buildings for the whole study area.
6	**Cool Roofs for all Existing Buildings:** Cool roofs are applied to all existing buildings in the study area.
7	**Combination of all Interventions:** Combination of scenarios 2, 4 and 5.
8	**Combination of all Interventions Including Water Misting:** Combination of scenarios 2, 4 and 5 with additional water misting cooling systems for public open spaces.
9	**New Buildings with Increased Building Height:** Scenario 2 with increased building height that exceed the maximum permissible heights outlined in the City of Port Phillip's planning controls.

Table 5: Input parameters for modelling the cooling intervention scenarios in ENVI-met

Albedo Input Values	
Roads (old asphalt pavements)	0.08
Footpaths, private ground cover, etc. (i.e. concrete pavements)	0.2
Roofs (flat roofs, concrete)	0.2
Roofs (pitched roofs, terracotta tiles)	0.25
Soil	0.15
Façade (concrete)	0.2
Façade (glass curtain walls, assumed 1/3 new buildings)	0.6
Façade (double glazing panel, assumed 2/3 new buildings)	0.32
Cool materials for all streets, footpaths and private hard surfaces	0.6
Cool roofs	0.6
Development Characteristics	
New building height	4 - 10 storeys (16 - 40 m)
Increased building height (Scenario 9)	8 - 24 storeys (32 - 96m)
Business as usual private green coverage	10 - 20%
Moderate private green coverage	40 - 50%
Optimised private green coverage	>60%

[4] BAU, Moderate and Optimised green infrastructure scenarios are from the development of the City of Melbourne's Green Factor Tool (Ashley, 2020)

Scenario 1 - New Buildings with Business as Usual Private Green Coverage

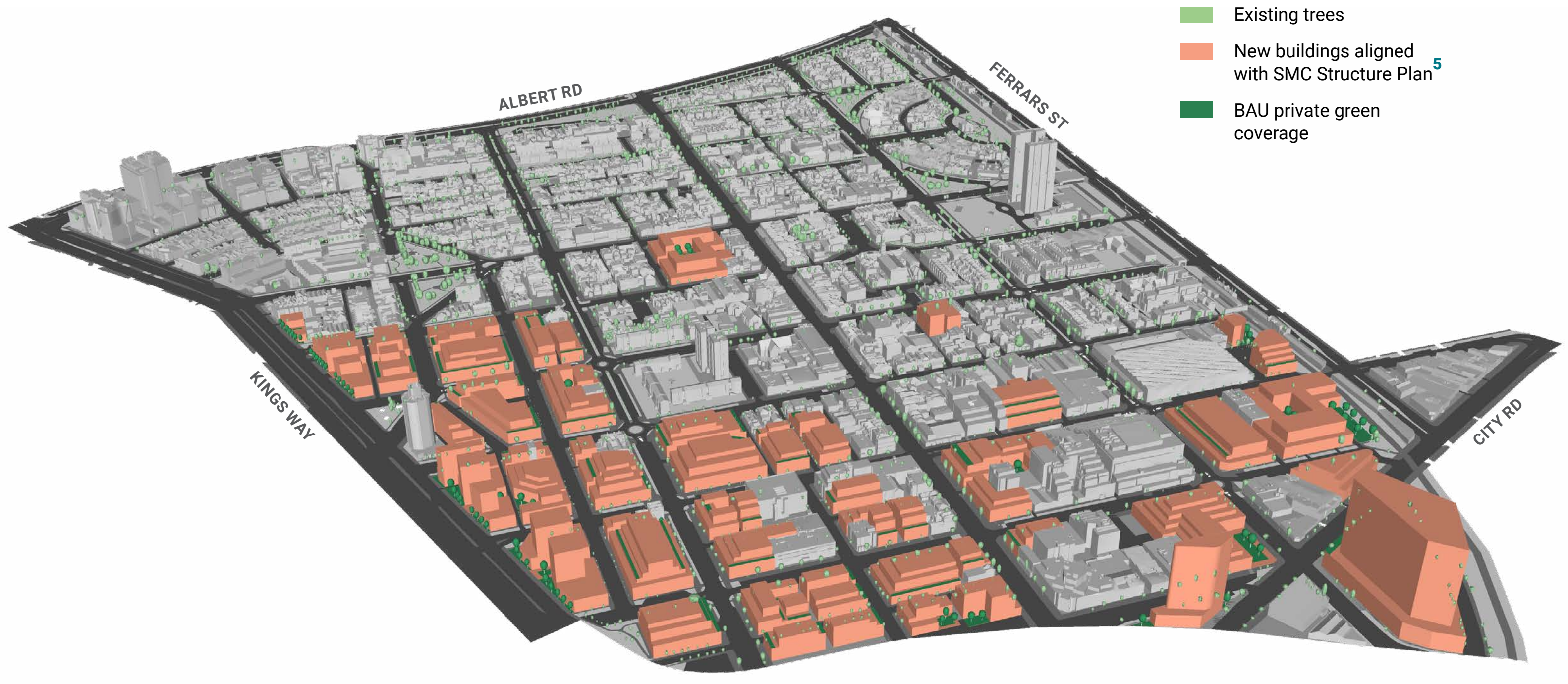


Figure 13: Overview of cooling intervention scenario 1

Description

Scenario 1 involves the impact analysis of a set of proposed new buildings with a business as usual (BAU) green infrastructure scenario for private green coverage (Figure 13). These new buildings are located in the key business and mixed-use redevelopment precincts to the north and east of the South Melbourne Study Area as well as key individual redevelopment sites. The built form (height, setbacks, footprint, materials, etc.) represents the maximum permissible development outlined in the South Melbourne Central (SMC) Structure and Implementation Plan and the SMC Urban Design Framework.

This typically involved maintaining a 2-3 storey (8-12m) street wall with stepped setbacks allowing buildings to reach 5-6 storeys (20-24m), with buildings to the east in the Kings Way Mixed-Use Corridor and to the north in the City Road Wedge allowing increased heights of up to 40m and 90m respectively. This enables any new development to respect the scale of existing heritage buildings and emphasise the 'bowl of South Melbourne Central' (see Part 1).

The new development for Scenario 1 involves a BAU green infrastructure scenario (Ashley, 2020), which equates to 10-20% of the site area as urban greenery (including vertical) for all the new buildings (Figure 14).

[5] New buildings are based on the indicative built form envelopes outlined by the SMC Structure Plan (heights and setbacks)

Figure 14: Example building with BAU private green coverage within the Kings Way Mixed Use Precinct

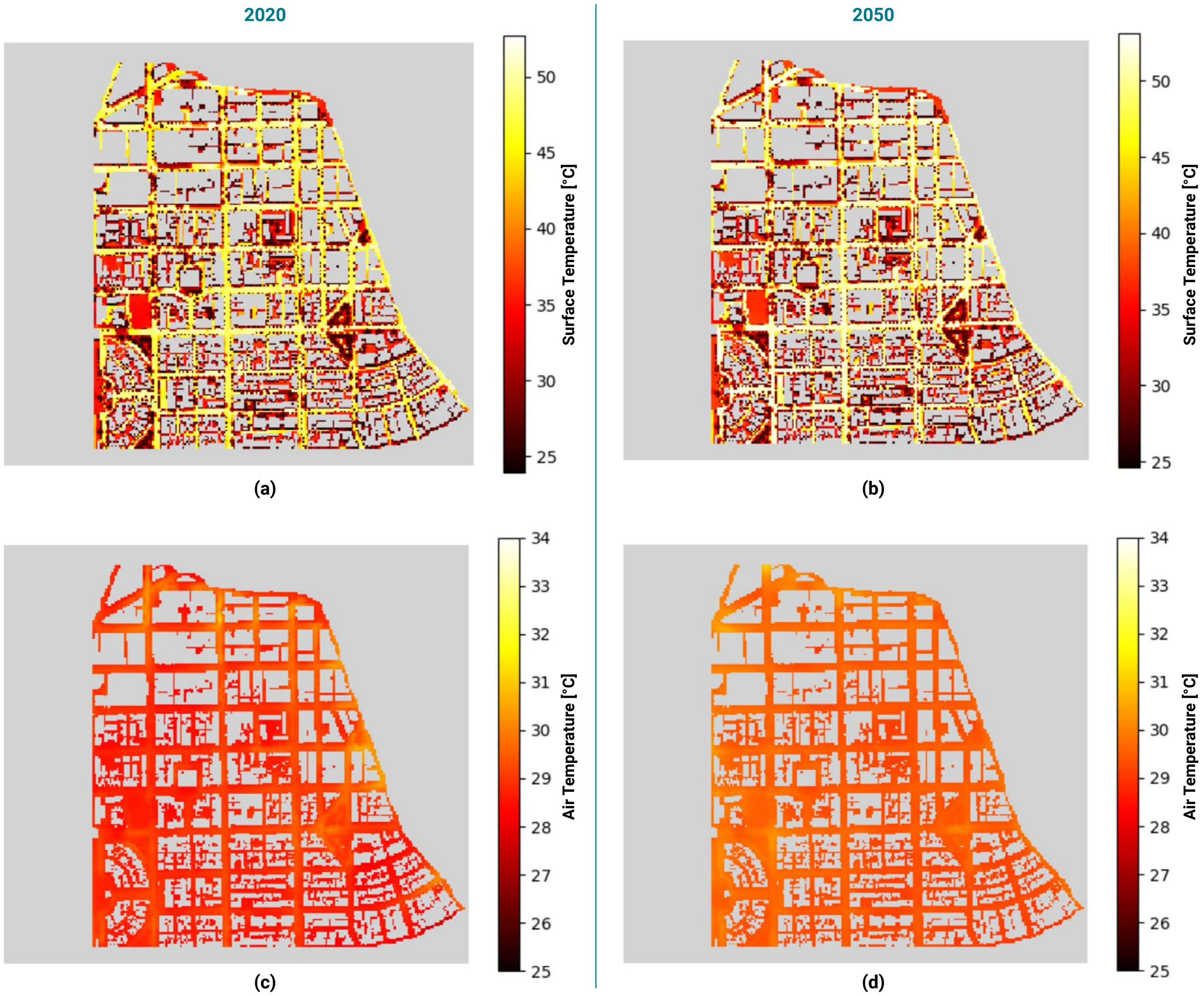


Figure 15: Surface temperature distributions for **(a)** 2020 and **(b)** 2050; and air temperature distributions for **(c)** 2020 and **(d)** 2050; from the change in built form with new buildings and BAU private green coverage (Scenario 1)

Temperature Distribution of the Change in Built Form

The change in built form for Scenario 1 creates some cooler areas that are shaded by the new medium/high-rise buildings (e.g. York St). Figure 15 shows that surface temperatures are hotter for hard surfaces (roads and footpaths), especially for wider roads with less tree canopy (e.g. Cecil St). This results in higher air temperatures near the wider streets and in unshaded public open space (e.g. Dorcas St Reserve and Eastern Reserve) (Figure 15). Similar temperature distribution trends are shown under the projected future climate conditions of 2050 (Figure 15).

The cooling intervention scenarios in this section are discussed in terms of their cooling potential in comparison with Scenario 1 unless stated otherwise. For example, the cooling potential of these new buildings with both moderate and optimised green infrastructure scenarios for private green coverage will be analysed in comparison to BAU in Scenarios 2 and 3 respectively.

Scenario 2 - New Buildings with Moderate Private Green Coverage and Additional Public Realm Green Coverage

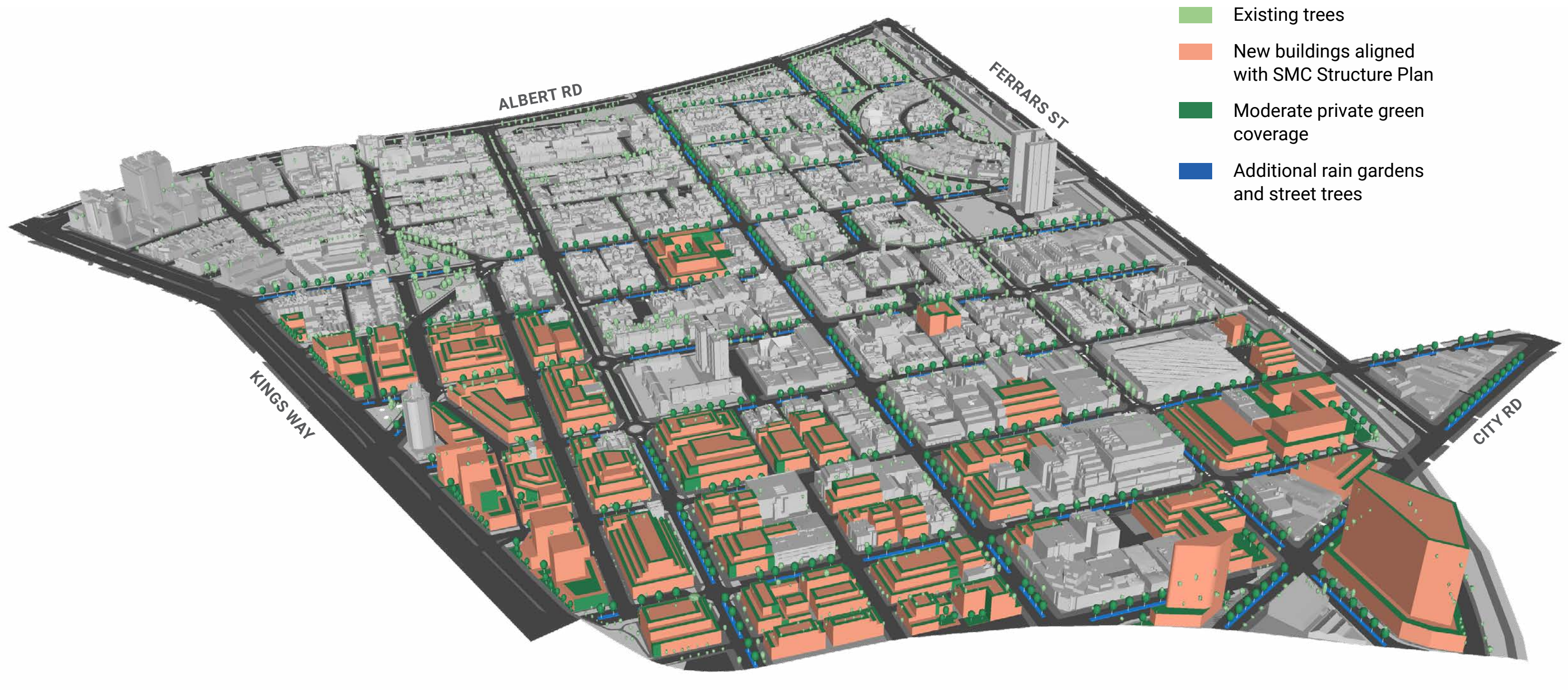


Figure 16: Overview of cooling intervention scenario 2

Description

Scenario 2 involves the same set of new buildings from Scenario 1 but with a moderate green infrastructure scenario for private green coverage to investigate its cooling potential. A moderate green infrastructure scenario equates to 40-50% of the site area as urban greenery (including vertical) (Ashley, 2020) for all the new buildings (Figure 17).

This scenario also includes additional public realm green coverage through additional street trees and rain gardens. Although the existing street tree canopy coverage of the South Melbourne Study Area is above the municipal average (see Part 1), additional greening is proposed to mitigate localised hot spots and to highlight the maximum possible cooling potential. This involved increasing greenery along streets with current restrictions (e.g. tram lines, car parking), which would require changes to future road and pedestrian configurations. An overview of Scenario 2 is shown in Figure 16.

Cooling Potential

An increase of private green coverage from BAU to moderate in the northern and eastern redevelopment precincts, along with additional street trees and rain gardens results in a reduction of street level air temperatures under current and future climate conditions (Figure 18). Reductions are more widespread in these redevelopment areas due to the increase of private green coverage for the new buildings and the density of additional street trees and rain gardens.

Figure 17: Example building with moderate private green coverage within the Eastern Business Precinct

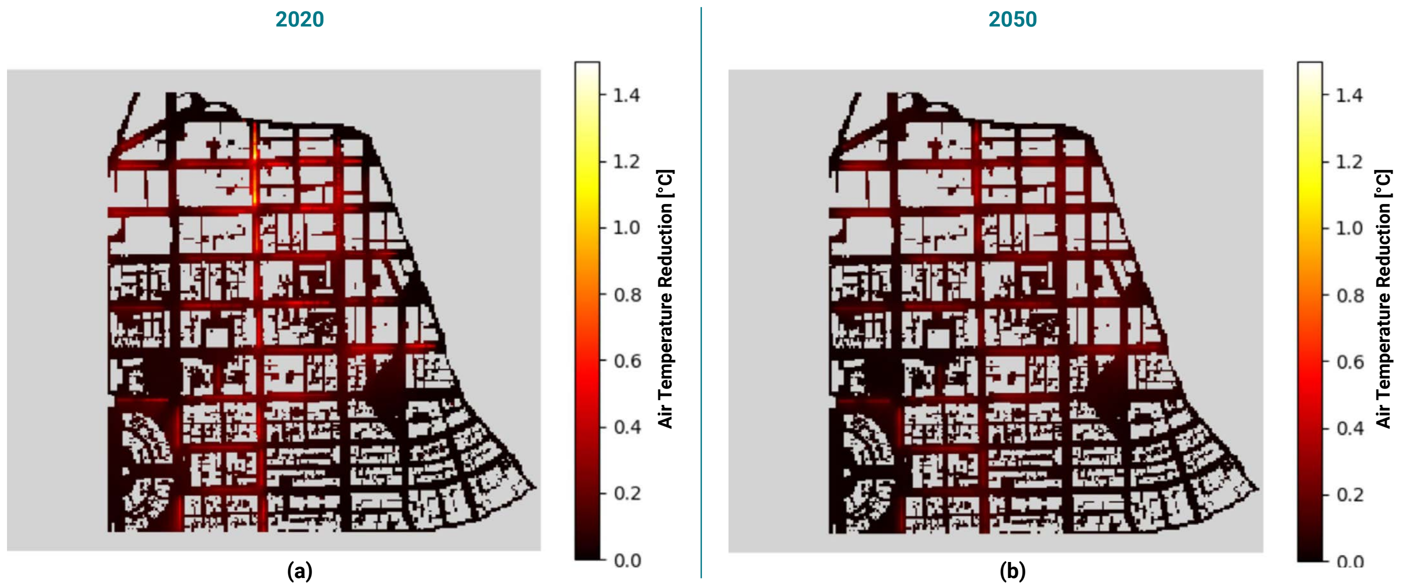


Figure 18: Air temperature reductions[6] of moderate private green coverage for all new buildings (Scenario 2) compared to BAU private green coverage (Scenario 1) for (a) 2020 and (b) 2050

The maximum air temperature reduction resulting from the increase of private green coverage and additional street trees and rain gardens in these key redevelopment areas reaches 0.78°C and 0.82°C in 2020 and 2050 respectively (Figure 19).

[6] Some maximum air and surface temperature results for the cooling intervention scenarios were omitted to increase the reliability of results

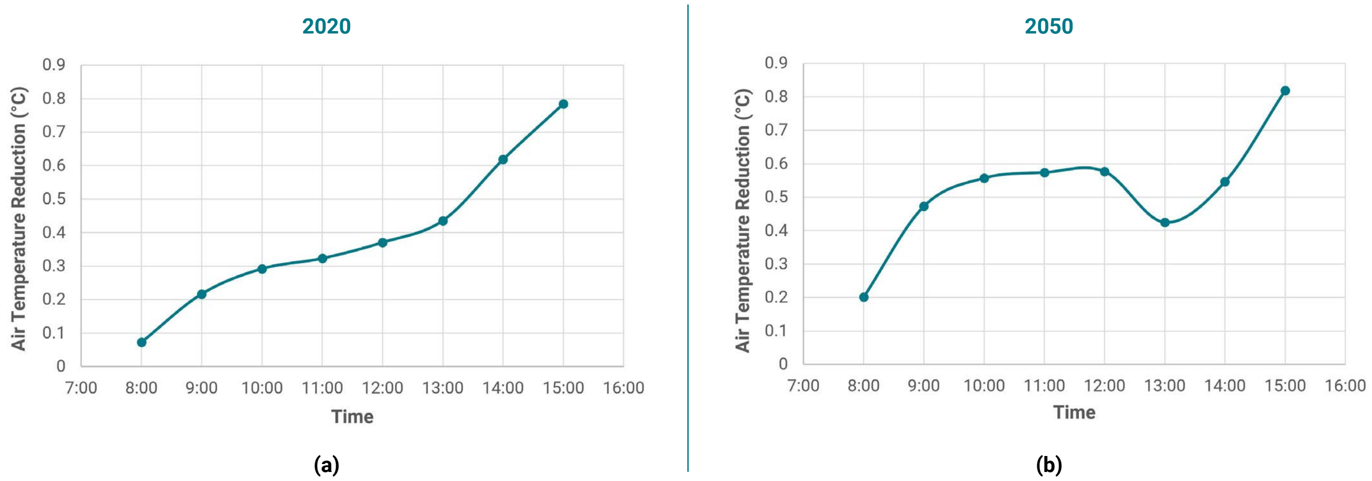


Figure 19: Maximum air temperature reductions of moderate private green coverage for all new buildings (Scenario 2) compared to BAU private green coverage (Scenario 1) for (a) 2020 and (b) 2050

Scenario 3 - New Buildings with Optimised Private Green Coverage and Additional Public Realm Green Coverage

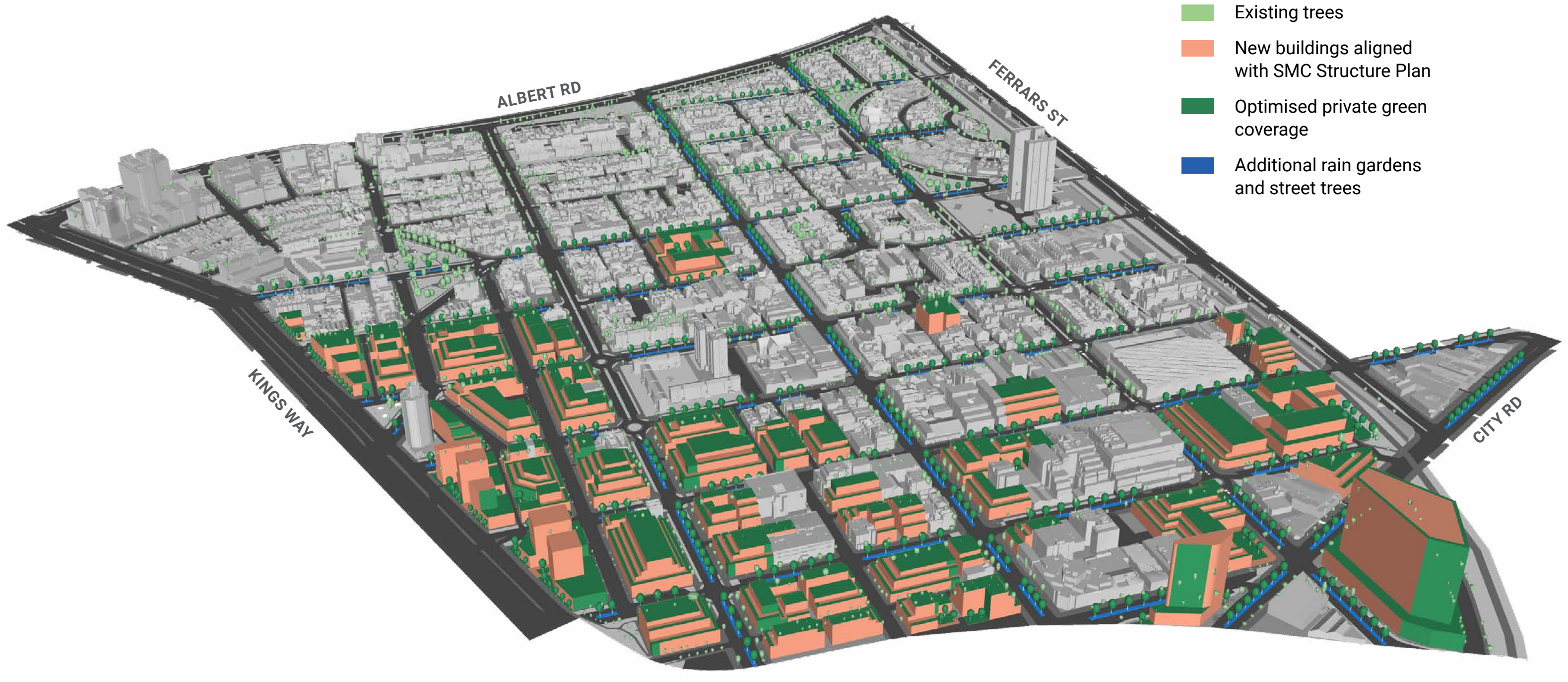


Figure 20: Overview of cooling intervention scenario 3

Description

Scenario 3 involves the same set of new buildings from Scenario 1 but with an optimised green infrastructure scenario for private green coverage to investigate its cooling potential. An optimised green infrastructure scenario equates to >60% of the site area as urban greenery (including vertical) (Ashley, 2020) for all the new buildings (Figure 21). This scenario also includes the additional public realm green coverage outlined in Scenario 2. An overview of Scenario 3 is shown in Figure 20.

Figure 21: Example building with optimised private green coverage within the City Road Wedge

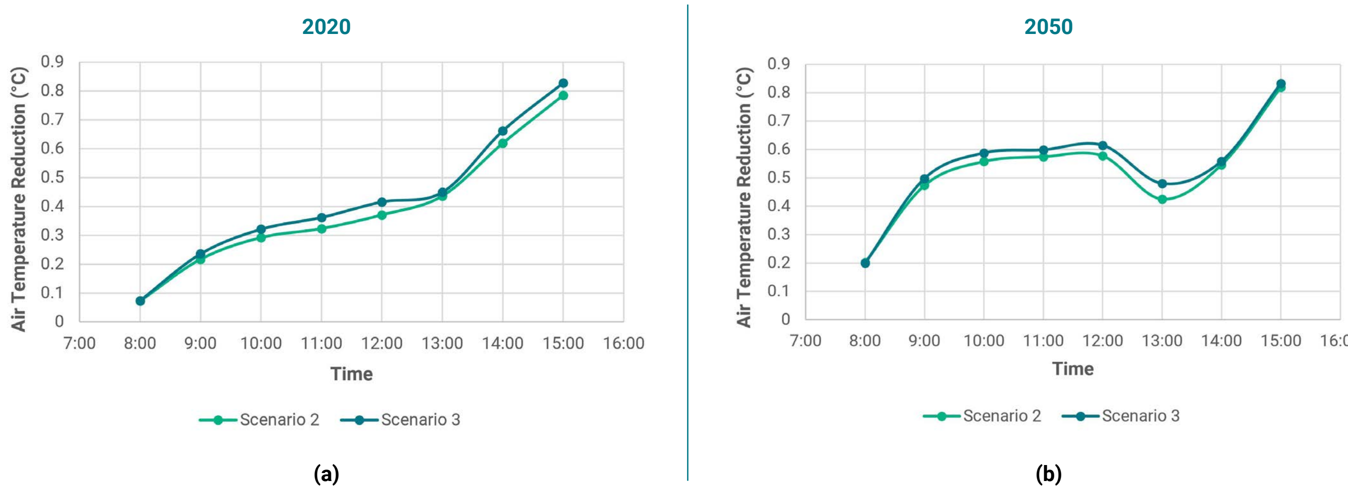


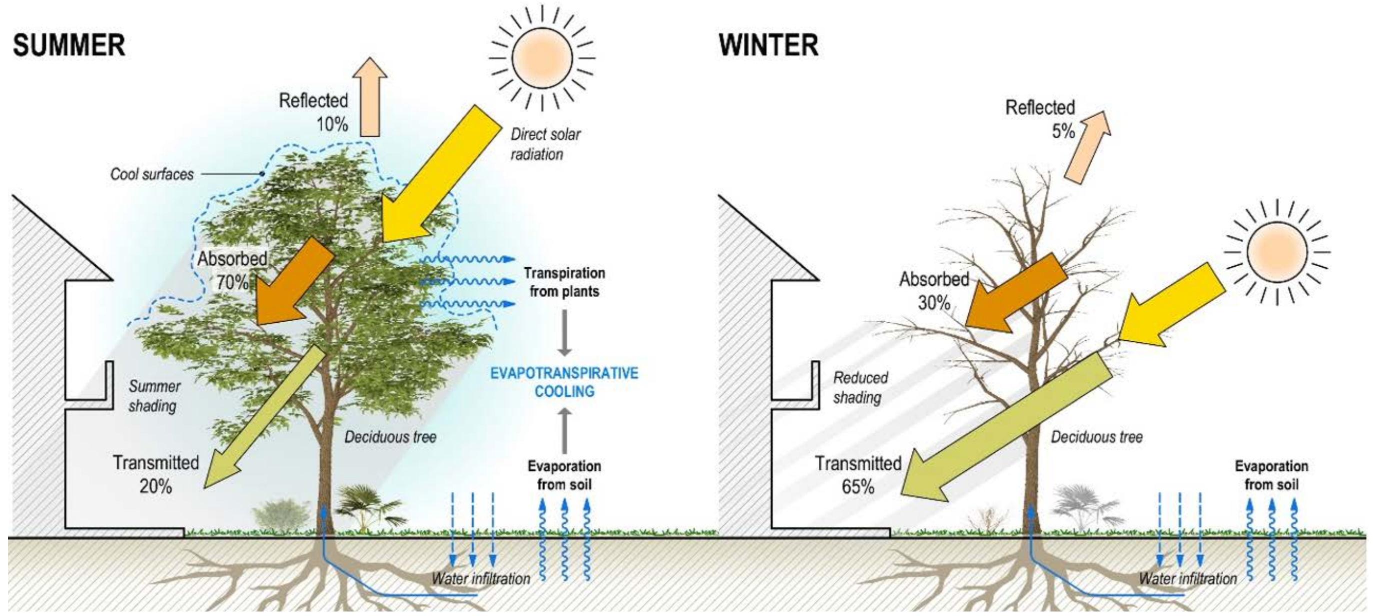
Figure 22: Maximum air temperature reductions of optimised private green coverage for all new buildings (Scenario 3) and moderate private green coverage (Scenario 2) in comparison to BAU private green coverage (Scenario 1) for **(a)** 2020 and **(b)** 2050

Cooling Potential

An increase of private green coverage from a BAU to an optimised scenario in the northern and eastern redevelopment precincts, along with additional street trees and rain gardens also results in a reduction of street level air temperatures under current and future climate conditions.

New buildings with optimised private green coverage, despite having additional benefits outlined by Ashley, 2020 (e.g. biodiverse habitat provision, place value and social cohesion, food supply, etc.), only have a slight improvement in street level cooling potential compared to a moderate green coverage (Scenario 2) when averaged across the whole study area under both current and future climate conditions (Figure 22).

Below: Schematic diagram of the cooling effects of a tree in summer and winter (Bartesaghi-Koc, 2018)



Scenario 4 - New Buildings and Cool Materials for all Streets, Footpaths and Private Hard Surfaces

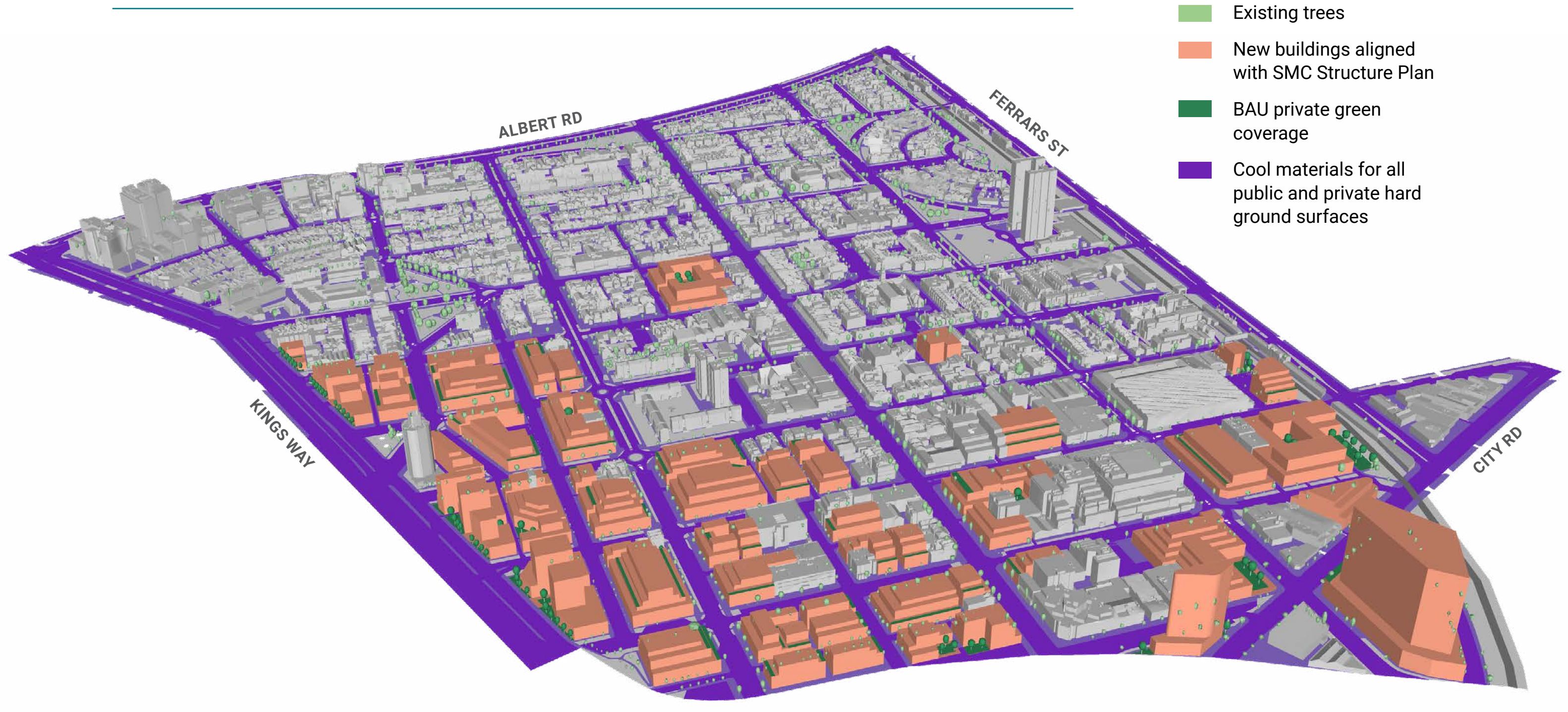


Figure 23: Overview of cooling intervention scenario 4

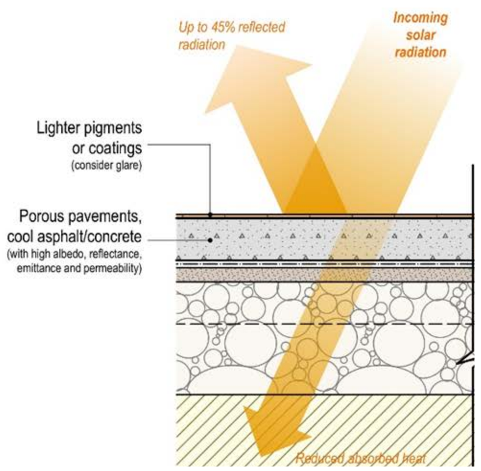
Description

Scenario 4 includes the same parameters as Scenario 1 but with cool materials applied to all streets, footpaths and private hard surfaces in the South Melbourne Study Area to investigate its cooling potential (Figure 23). These cool materials have an increased albedo value of 0.6.

Cooling Potential

The application of cool materials results in a significant cooling effect for the entire study area under current and future climate conditions (Figure 24). Air and surface temperature reductions are most significant in the northern and eastern redevelopment precincts due to the combination of the varying built form from the new buildings and cool materials for all hard surfaces, especially the wide unshaded streets.

In comparison to Scenario 1, the application of cool materials across the whole study area can result in maximum air and surface temperature reductions of up to 1.5°C and 13.4°C respectively under current and future climate conditions (Figure 25).



Left: Cross section through a typical cool pavement (Osmond & Sharifi, 2017)

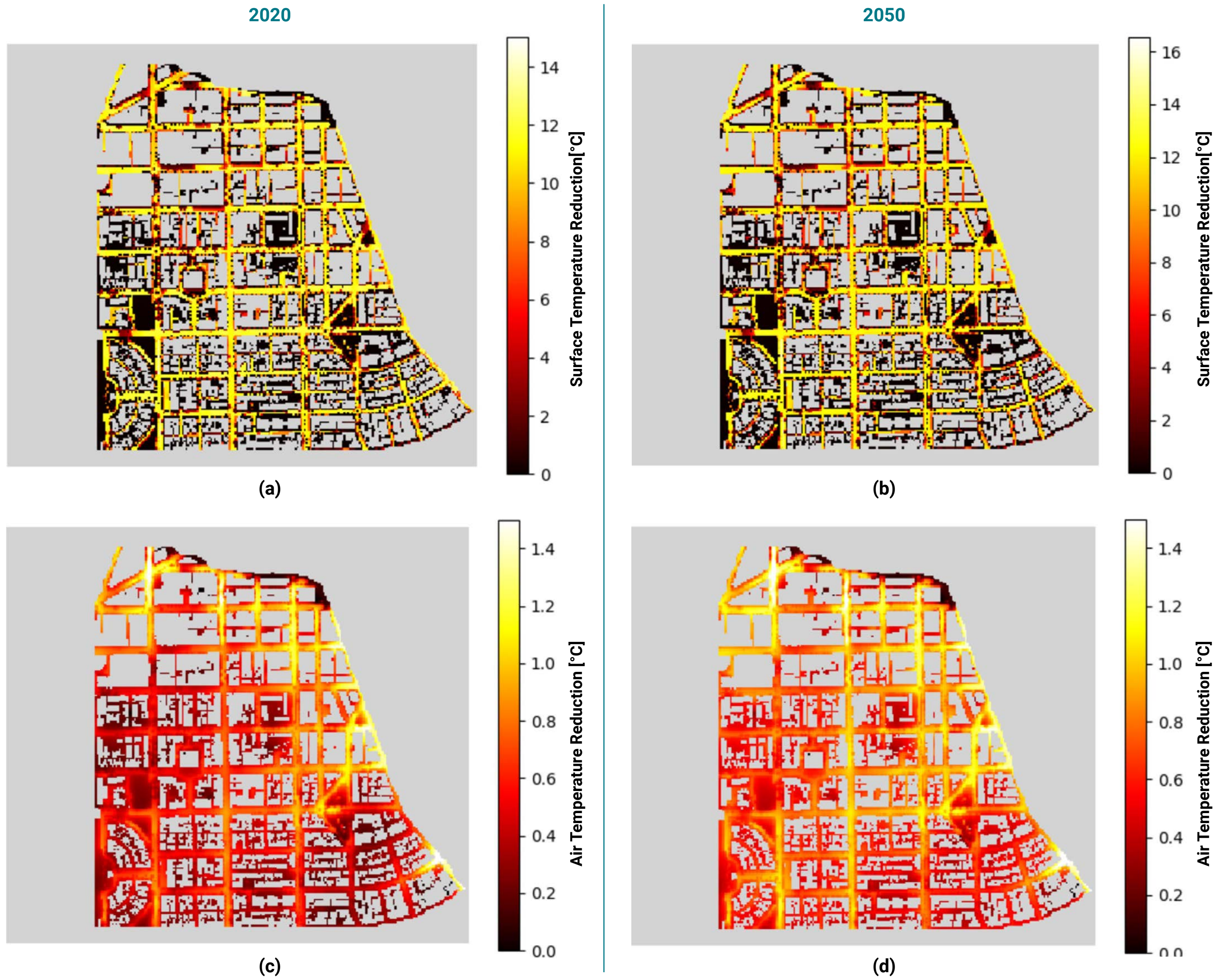


Figure 24: Surface temperature reductions for (a) 2020 and (b) 2050; and air temperature reductions for (c) 2020 and (d) 2050; from the application of cool materials (Scenario 4) compared to Scenario 1

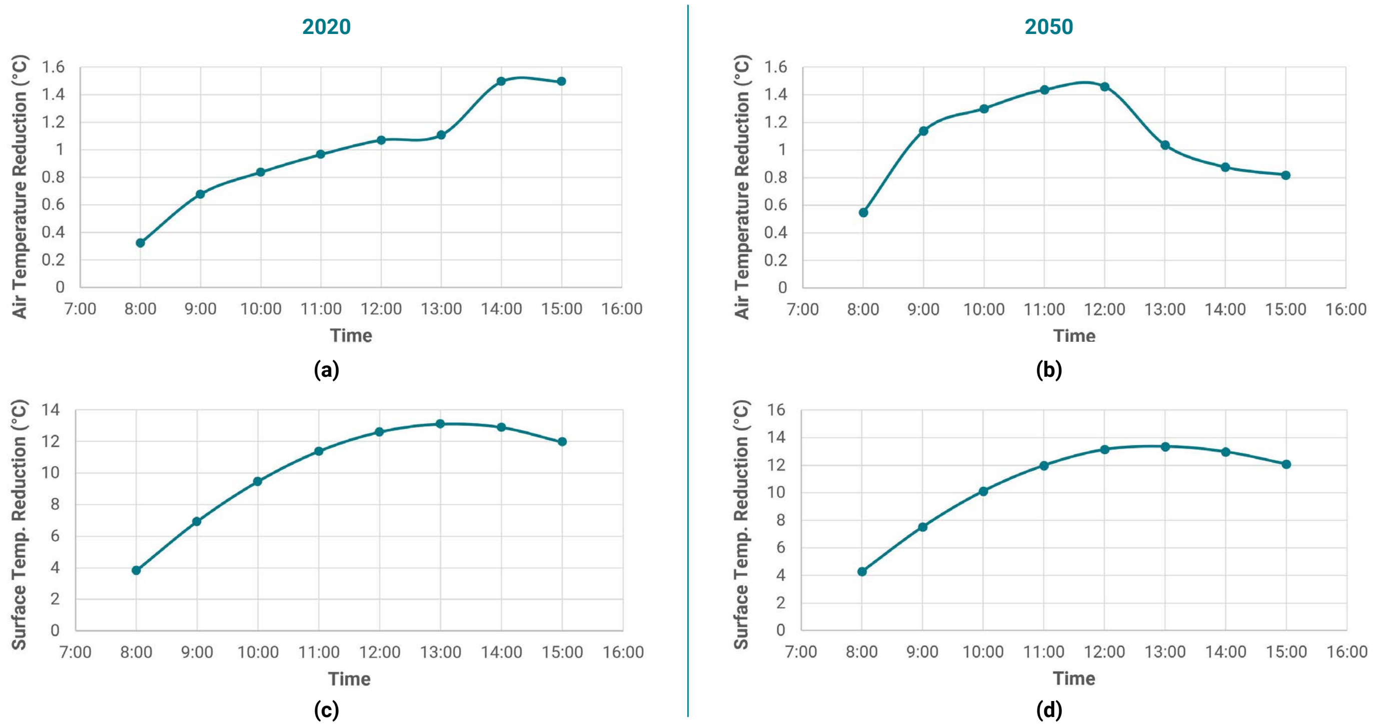


Figure 25: Maximum air temperature reductions for (a) 2020 and (b) 2050; and maximum surface temperature reductions for (c) 2020 and (d) 2050; from the application of cool materials (Scenario 4) compared to Scenario 1

Scenario 5 - New Buildings and Cool Roofs for all New and Existing Buildings

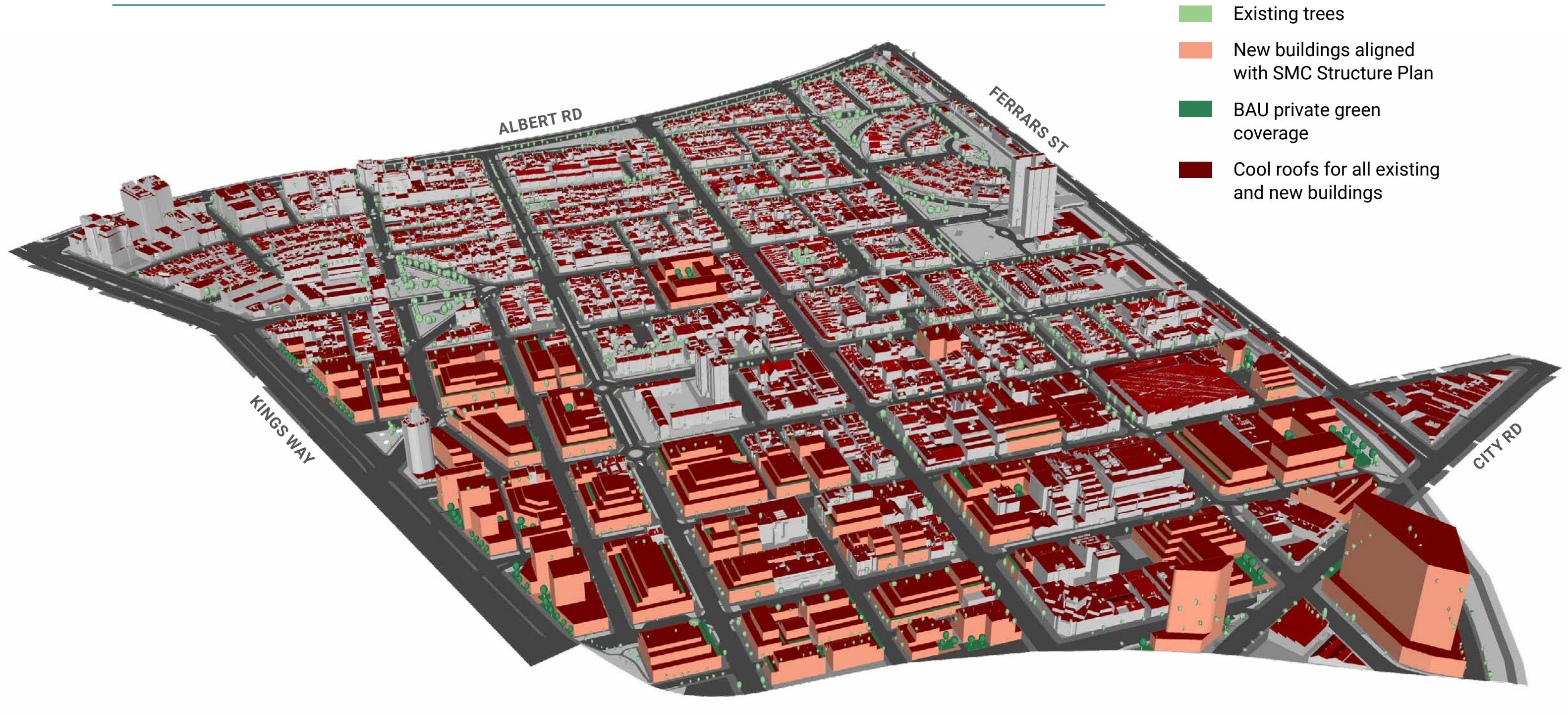
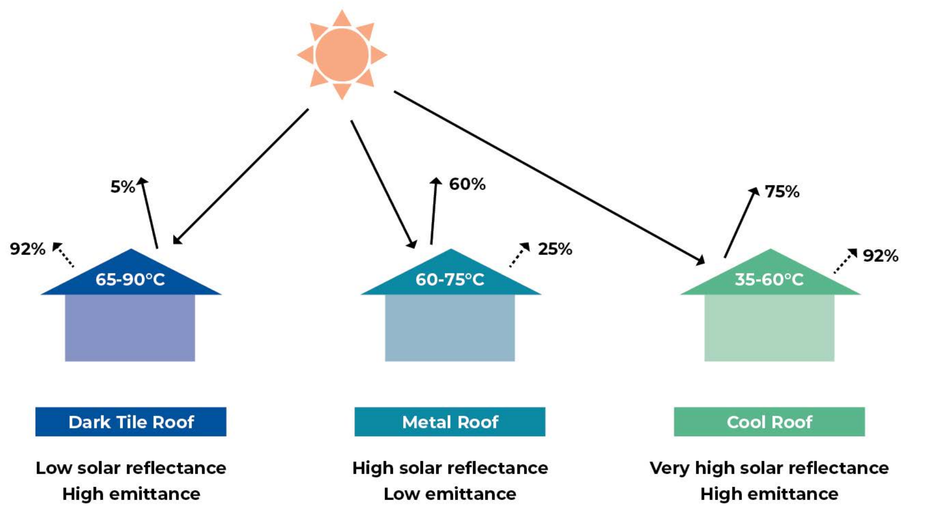


Figure 26: Overview of cooling intervention scenario 5

Description

Scenario 5 includes the same parameters as Scenario 1 but with cool roofs applied to all new and existing buildings in the South Melbourne Study Area to investigate its maximum possible cooling potential (Figure 26). These cool roofs have an increased albedo value of 0.6.



Left: Solar reflectance and emittance of roof materials (Osmond & Sharifi, 2017)

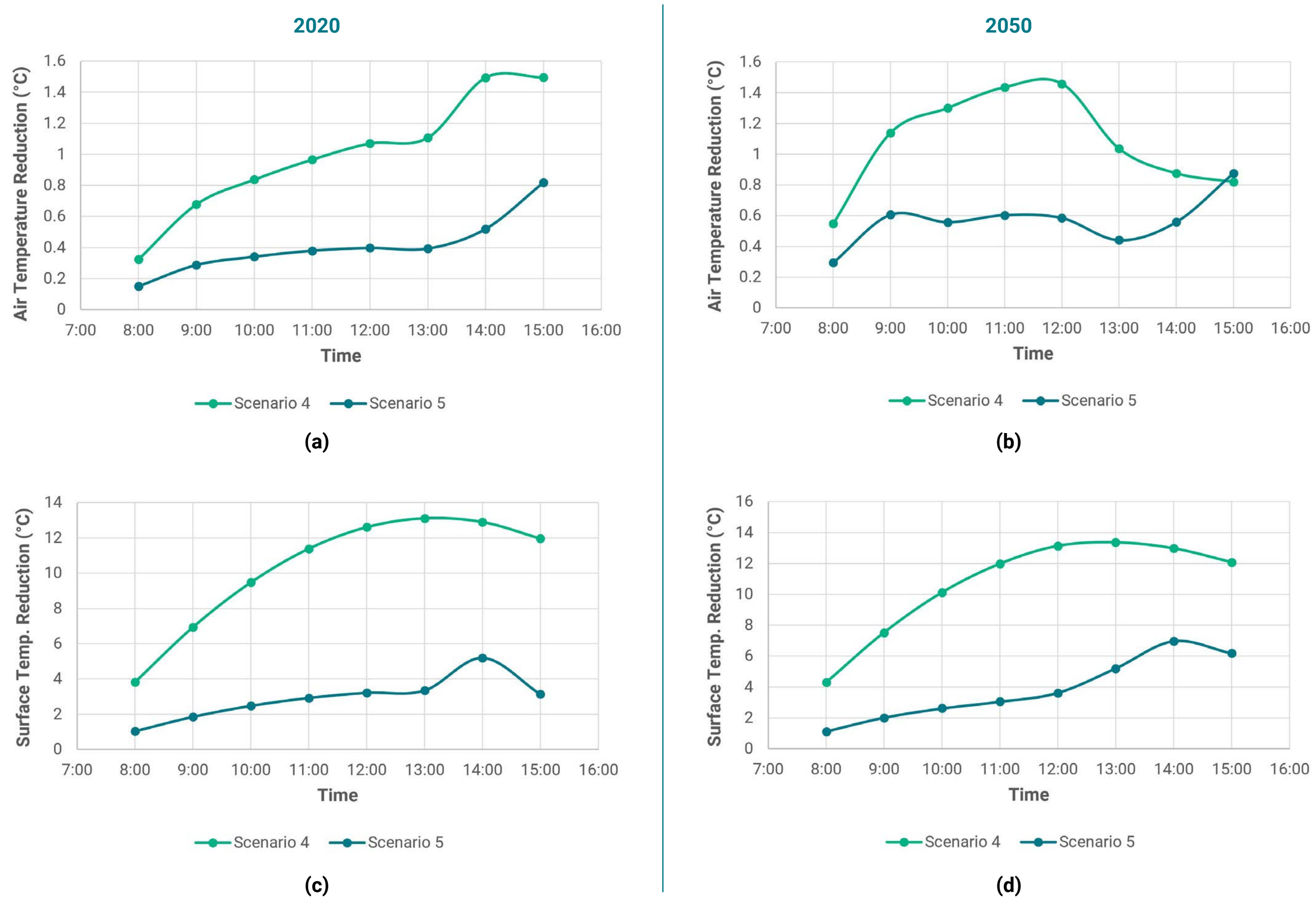
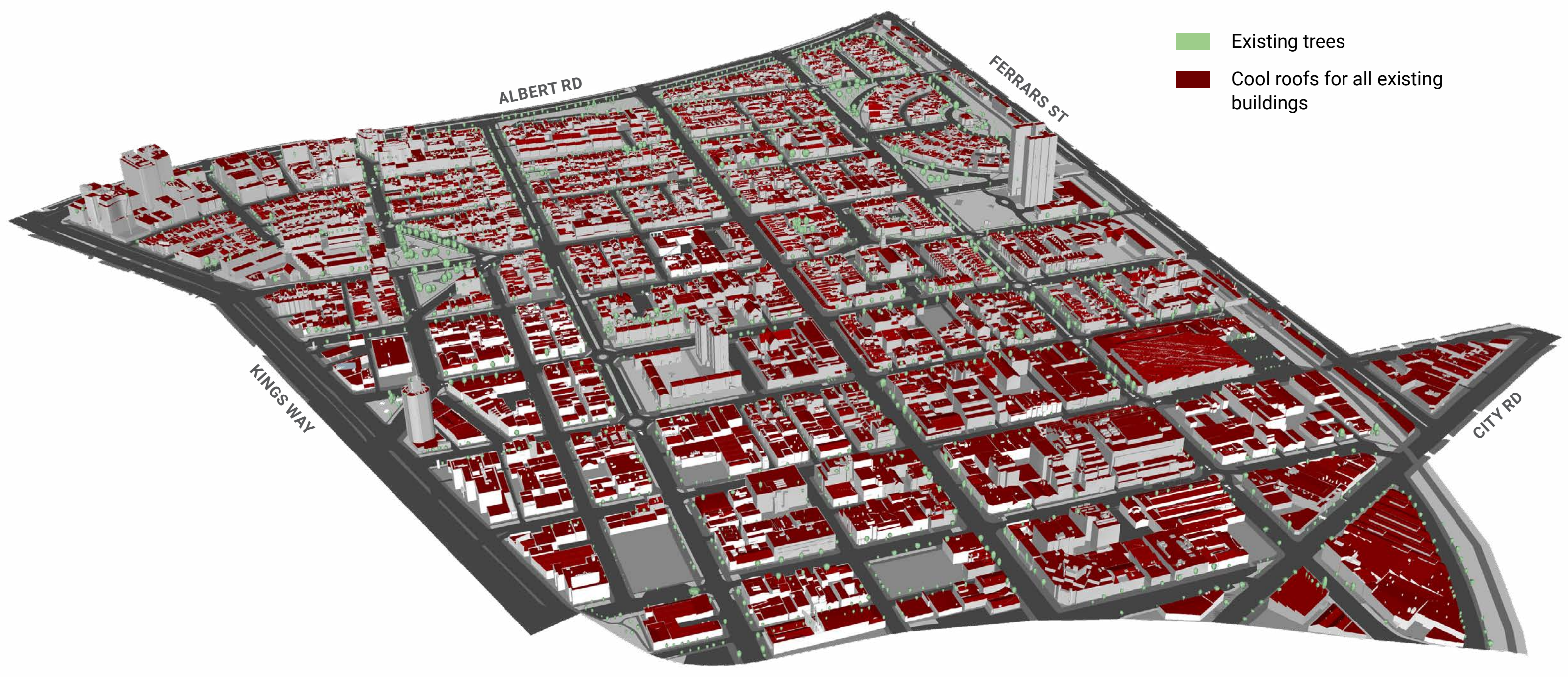


Figure 27: Maximum air temperature reductions for **(a)** 2020 and **(b)** 2050; and maximum surface temperature reductions for **(c)** 2020 and **(d)** 2050; from the application of cool roofs (Scenario 5) and cool materials (Scenario 4) in comparison with Scenario 1

Cooling Potential

Applying cool roofs for all new and existing buildings results in significant roof surface temperature reductions across the whole South Melbourne Study Area. However, the simulation results were conducted for street level air and surface temperature and as a result, the cooling effect of the cool roofs shown here is evenly distributed across the study area and not as effective as Scenario 4 (Figure 27). The maximum street level air and surface temperature reductions from applying these cool roofs is up to 0.82°C and 5.2°C respectively in 2020, and up to 0.88°C and 7.0°C respectively in 2050 (Figure 27).

Scenario 6 - Cool Roofs for all Existing Buildings

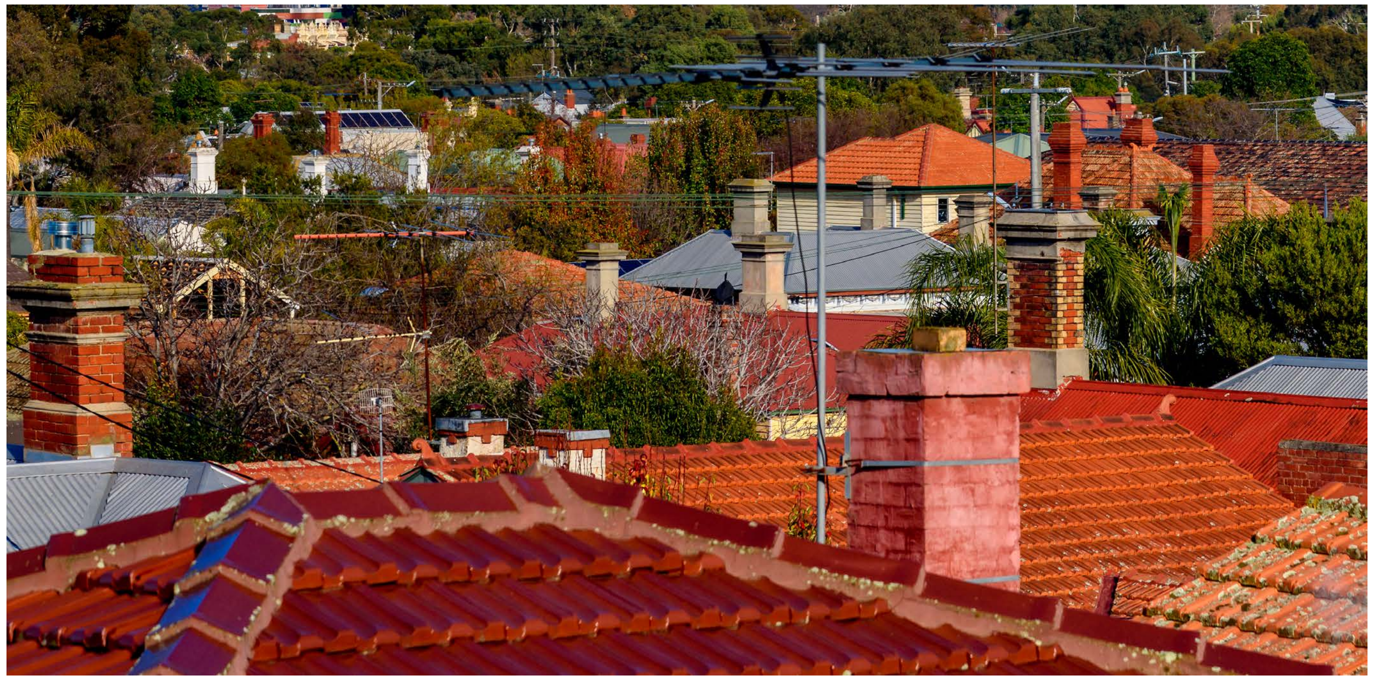


Description

Scenario 6, unlike the previous scenario, involves the application of cool roofs for all existing buildings. This scenario is compared to the base case without any new development (i.e. the South Melbourne Study Area's current urban context) and applies cool roofs to all existing buildings, including in heritage restricted areas, to investigate the maximum possible cooling potential of cool roofs (Figure 28).

Figure 28: Overview of cooling intervention scenario 6

Below: Darker residential roofs in Melbourne
Photo: Taras Vyshnya / Adobe Stock



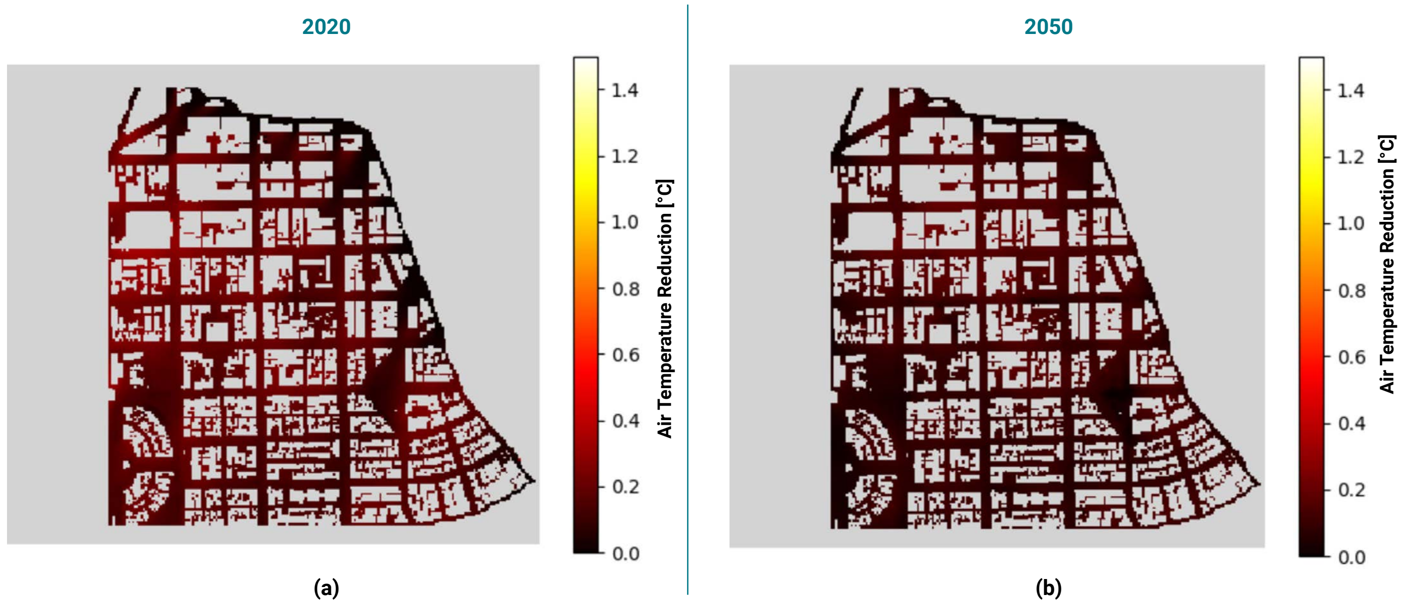


Figure 29: Air temperature reductions from applying cool roofs to all existing buildings in comparison to the base case in **(a)** 2020 and **(b)** 2050

Cooling Potential

Similar to applying cool roofs to all new and existing buildings, the street level cooling effect of cool roofs for all existing buildings is evenly distributed across the South Melbourne Study Area (Figure 29). This scenario also results in a significant reduction in roof surface temperatures but is not explicitly shown here due to the focus on outdoor thermal comfort. The maximum air temperature reductions possible through applying cool roofs to all existing buildings in the current urban context in comparison to the base case is up to 0.43°C in 2020 and up to 0.51°C in 2050 (Figure 30).

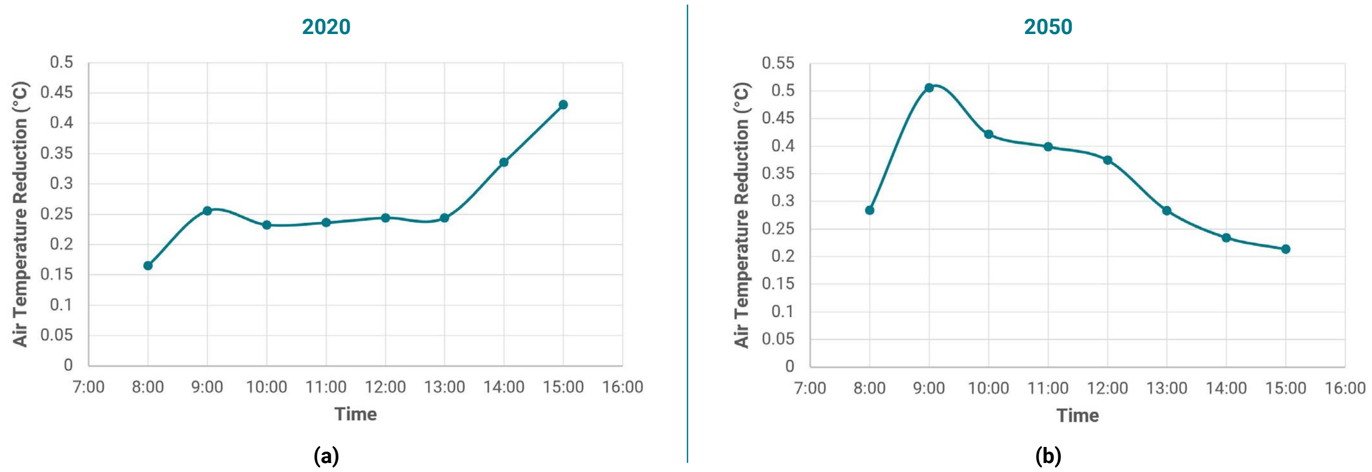


Figure 30: Maximum air temperature reductions from applying cool roofs to all existing buildings in comparison to the base case in **(a)** 2020 and **(b)** 2050

Scenario 7 - Combination of all Interventions

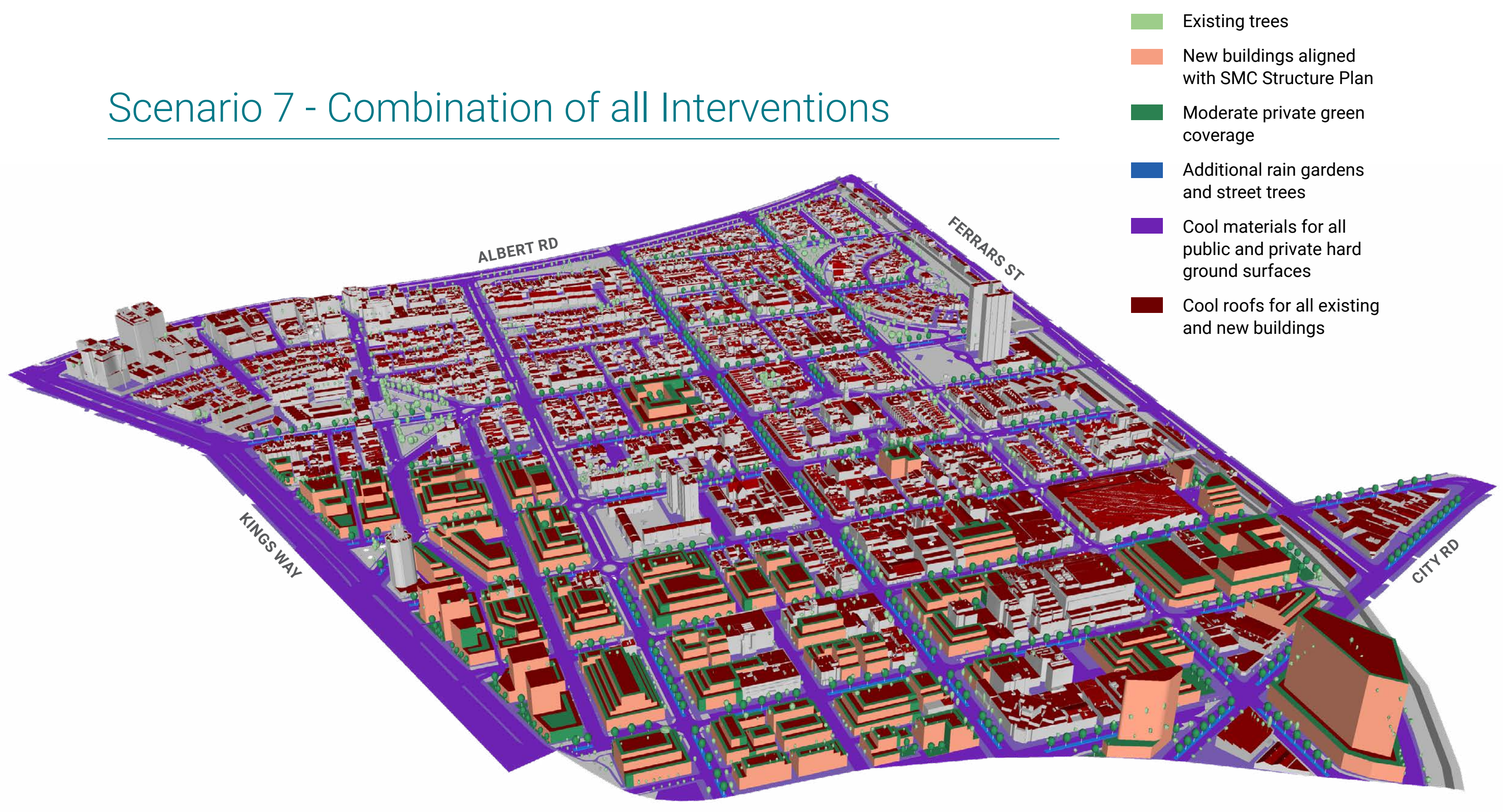


Figure 31: Overview of cooling intervention scenario 7

Description

Scenario 7 is a combination of Scenario 2 (new buildings with moderate private green coverage and additional public realm greenery), Scenario 4 (cool materials for street level urban surfaces) and Scenario 5 (cool roofs for all new and existing buildings), to investigate the maximum cooling potential of cooling interventions. An overview of Scenario 7 is shown in Figure 31.

Cooling Potential

Similar to the impact analysis for Greater Melbourne, a combination of cooling interventions is the most effective strategy to mitigate urban overheating. Figure 32 shows significant reductions in both air and surface temperature across the whole of the South Melbourne Study Area under both current and future climate conditions for Scenario 7. The combination of all cooling interventions in comparison to Scenario 1 can lead to maximum air temperature reductions of up to 1.6°C and 1.5°C for 2020 and 2050 respectively, as well as result in typical peak surface temperature reductions[7] of up to 15.5°C and 15.9°C for 2020 and 2050 respectively (Figure 33).

[7] Typical peak surface temperature reductions were used for Scenario 7 and 8 to increase the reliability of results

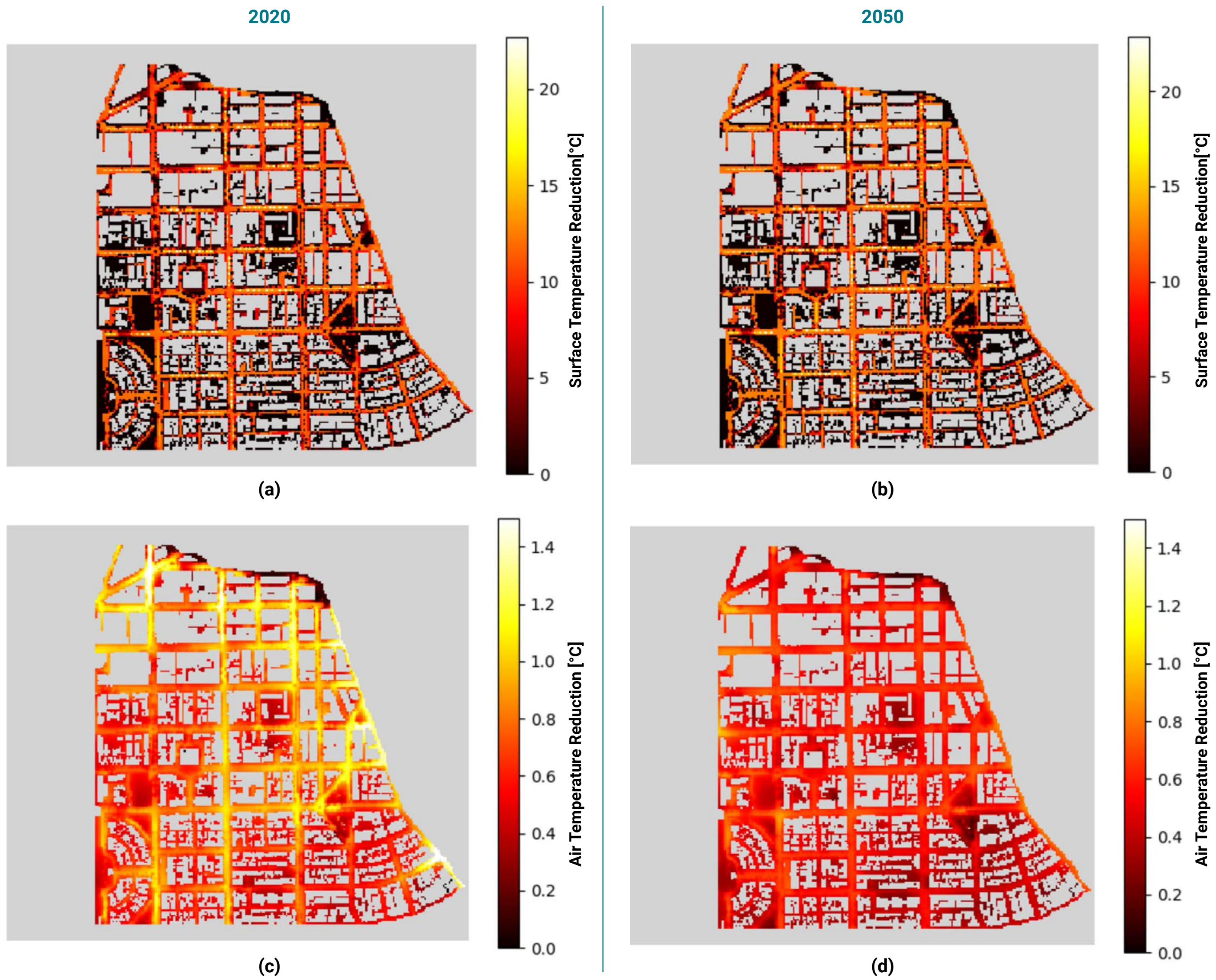


Figure 32: Surface temperature reductions for **(a)** 2020 and **(b)** 2050; and air temperature reductions for **(c)** 2020 and **(d)** 2050; from the combination of all cooling interventions (Scenario 7) compared to Scenario 1

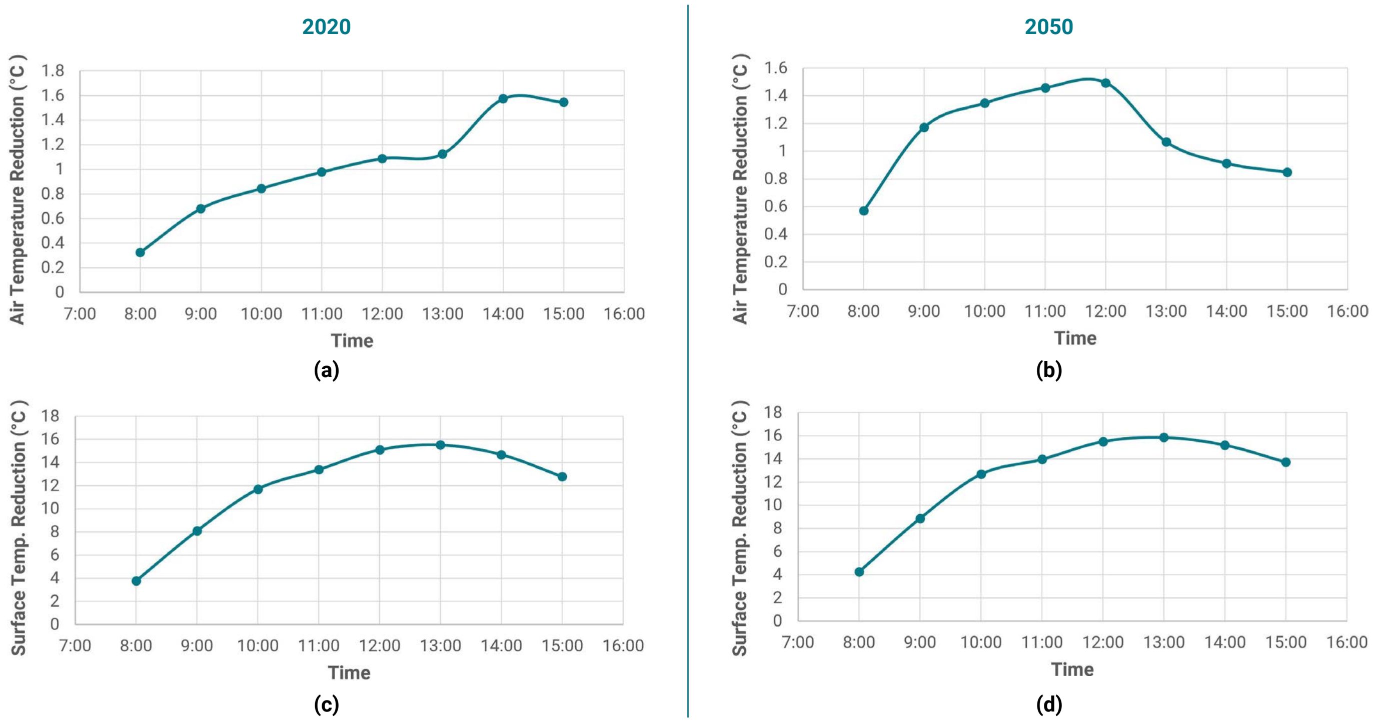


Figure 33: Maximum air temperature reductions for **(a)** 2020 and **(b)** 2050; and typical peak surface temperature reductions[6] for **(c)** 2020 and **(d)** 2050; from the combination of all cooling interventions (Scenario 7) compared to Scenario 1

Scenario 8 - Combination of all Interventions Including Water Misting

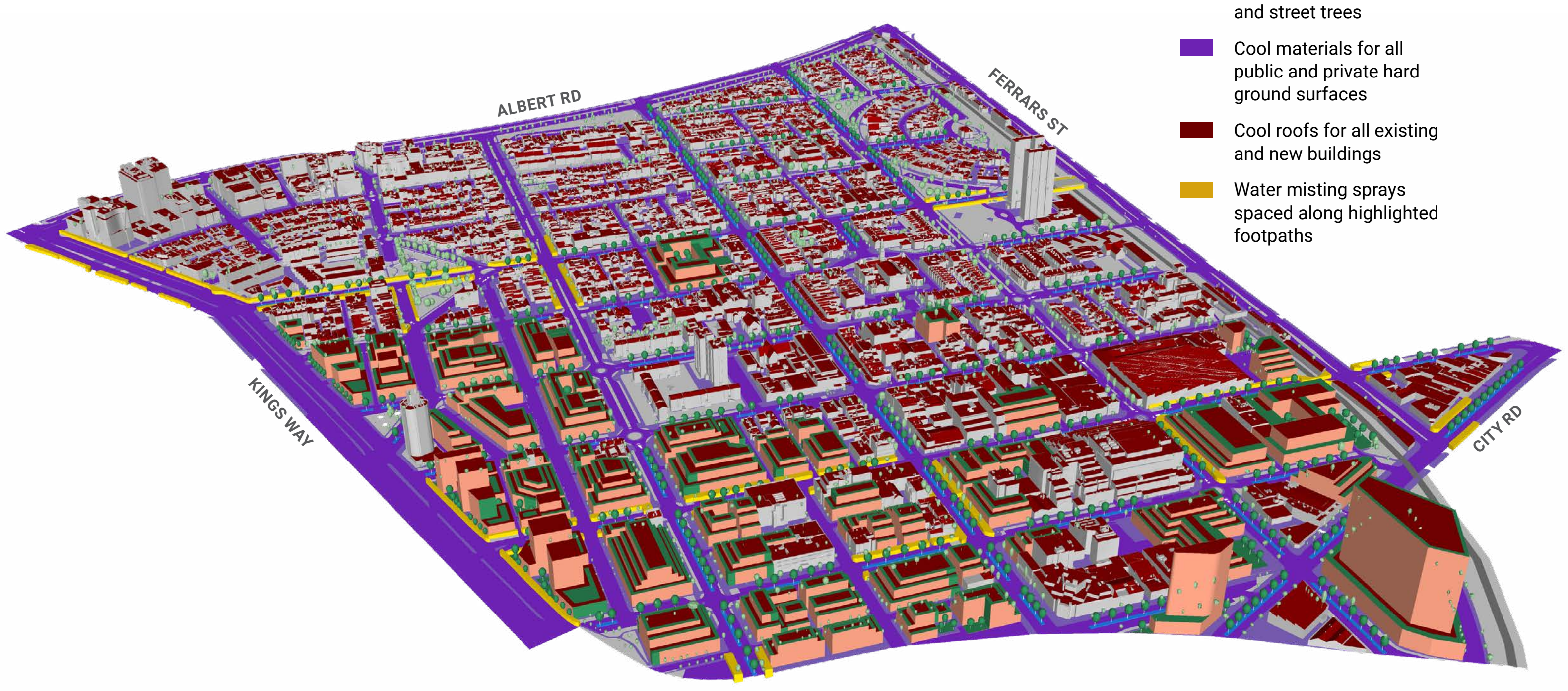


Figure 34: Overview of cooling intervention scenario 8

Description

Scenario 8 involves the same combination of cooling interventions as Scenario 7 but with outdoor water misting spray systems (4m) and fountains (4m) within the public realm (refer to the locations in Figure 34) to investigate their cooling potential (Figure 34). These water misting systems were placed in hot spot areas and at specific locations where their cooling potential would be maximised (highlighted in yellow in Figure 34).

Cooling Potential

The addition of water misting systems results in significant localised air and surface temperature reductions under current and future climate conditions, demonstrating a greater overall cooling effect than Scenario 7. Figure 35 shows extensive air temperature reductions across the South Melbourne Study Area for 2020 and 2050, in which prevailing winds from the north and west respectively play an important role in contributing to the combined cooling potential of the water misting systems and other interventions. The combination of cooling interventions with water misting systems, in comparison to Scenario 1, can lead to maximum air temperature reductions of up to 2.3°C and 2.9°C in 2020 and 2050 respectively, as well as typical peak surface temperature reductions of up to 15.5°C and 15.9°C for 2020 and 2050 respectively (Figure 36).

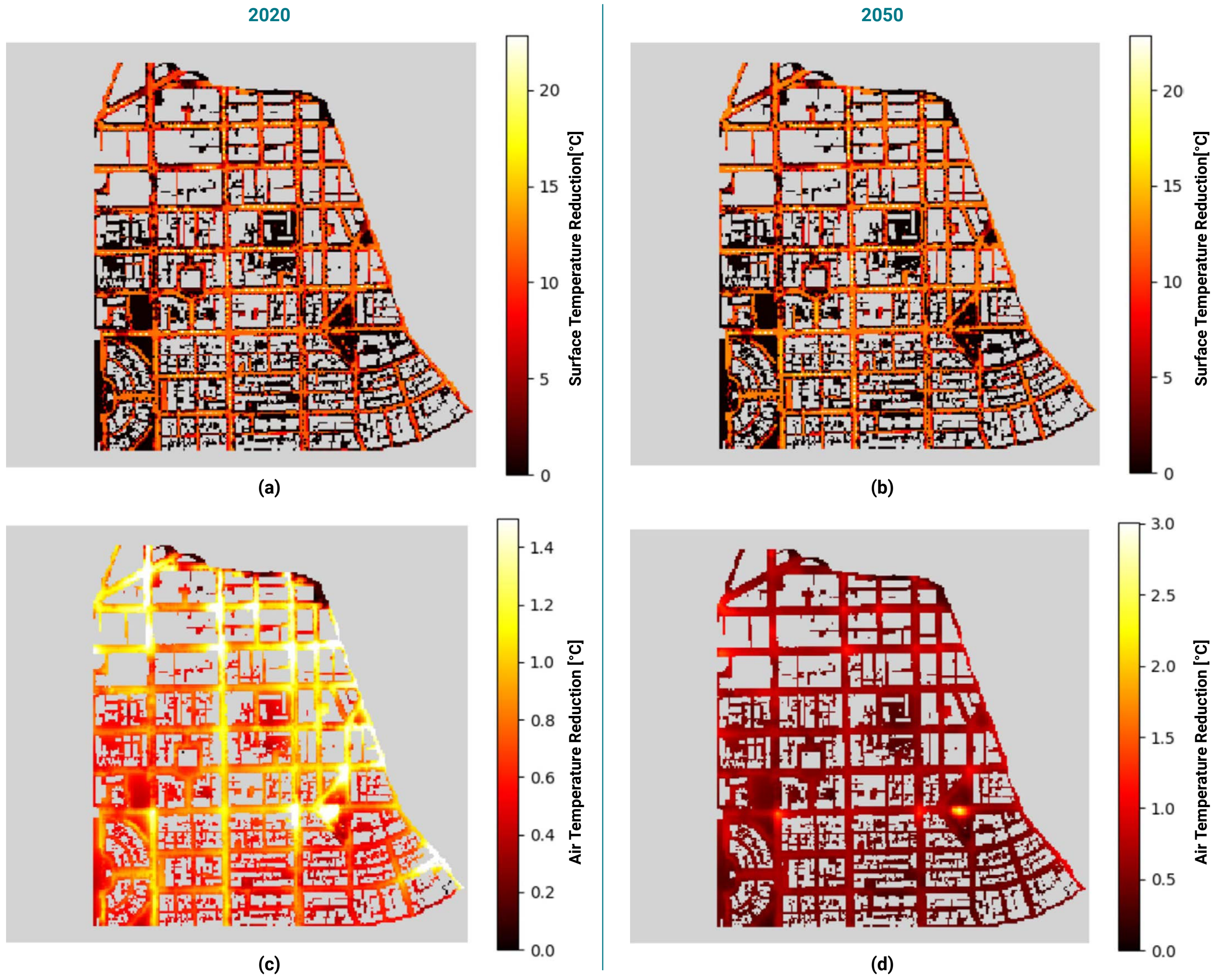


Figure 35: Surface temperature reductions for **(a)** 2020 and **(b)** 2050; and air temperature reductions for **(c)** 2020 and **(d)** 2050; from the combination of all cooling interventions including water misting (Scenario 8) compared to Scenario 1

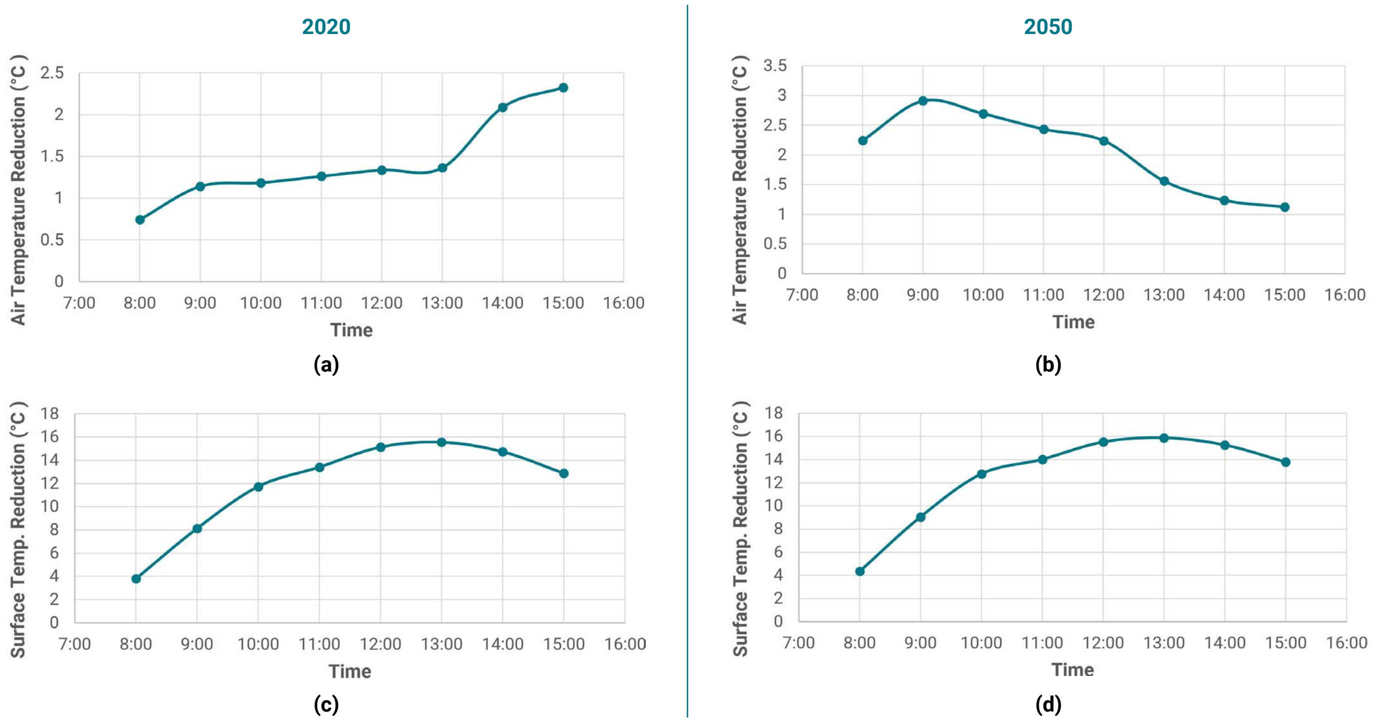
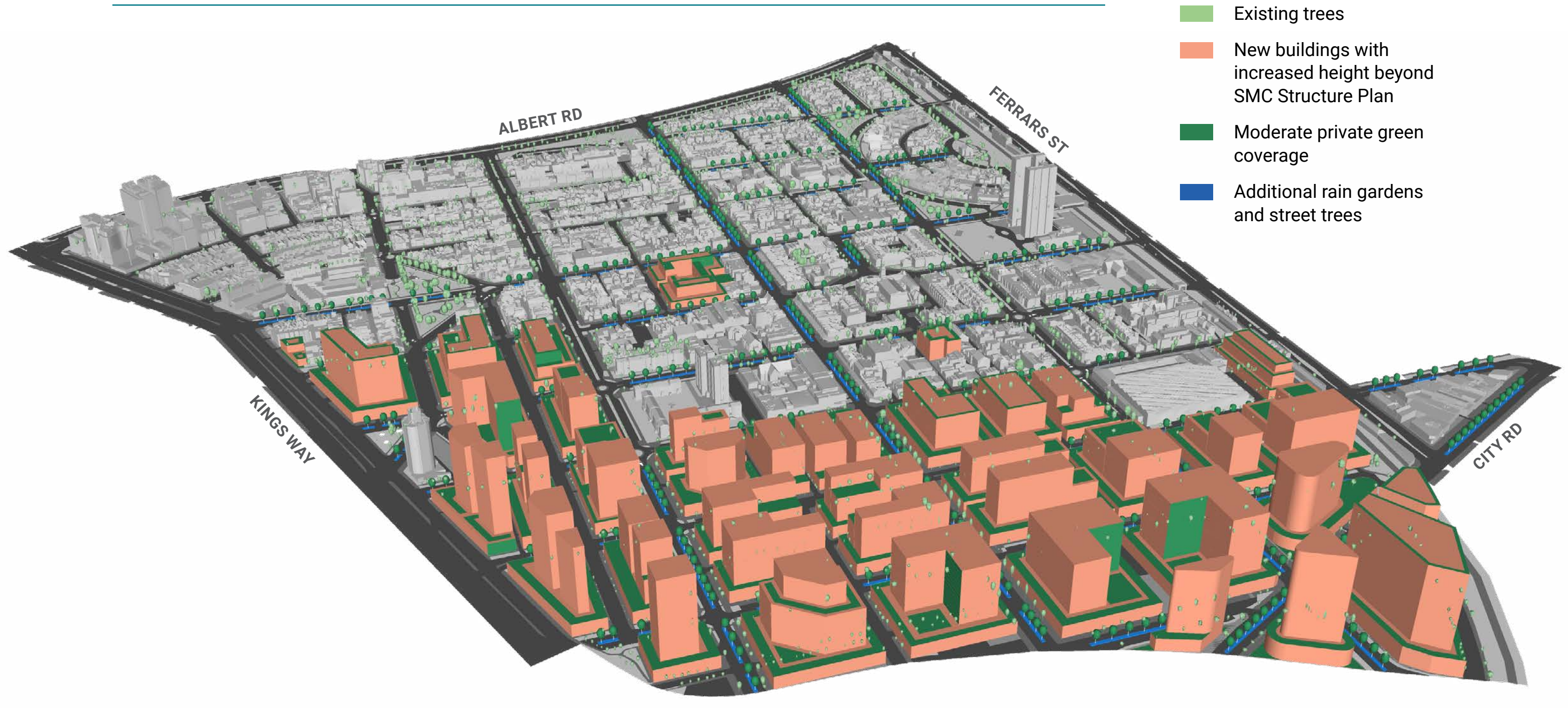


Figure 36: Maximum air temperature reductions for **(a)** 2020 and **(b)** 2050; and typical peak surface temperature reductions for **(c)** 2020 and **(d)** 2050; from the combination of all cooling interventions including water misting (Scenario 8) compared to Scenario 1

Scenario 9 - New Buildings with Increased Building Height



Description

Scenario 9 involves a new set of proposed buildings that exceed the maximum permissible planning controls set out by the SMC Structure and Implementation Plan and the SMC Urban Design Framework. These new buildings are still located in the key redevelopment precincts in the northern and eastern areas of the South Melbourne Study Area but have a significant increase in building height. To maintain the transitional scale of South Melbourne, the new buildings for Scenario 9 range from 8 storeys (32m) up to 24 storeys (96m) at the northern and eastern boundaries. These new buildings also maintain the 2-3 storey (8-12m) street wall with significant setbacks beyond this to facilitate urban ventilation.

Similar to Scenario 2, Scenario 9 also includes a moderate green infrastructure scenario for private green coverage for all new buildings (Figure 38) as well as additional urban greenery in the public realm. Therefore, the impact of this increase in building height will be investigated in comparison to Scenario 2. An overview of Scenario 9 is shown in Figure 37.

Figure 37: Overview of cooling intervention scenario 9

Figure 38: Example building with moderate private green coverage with increased height within the Kings Way Mixed Use Precinct

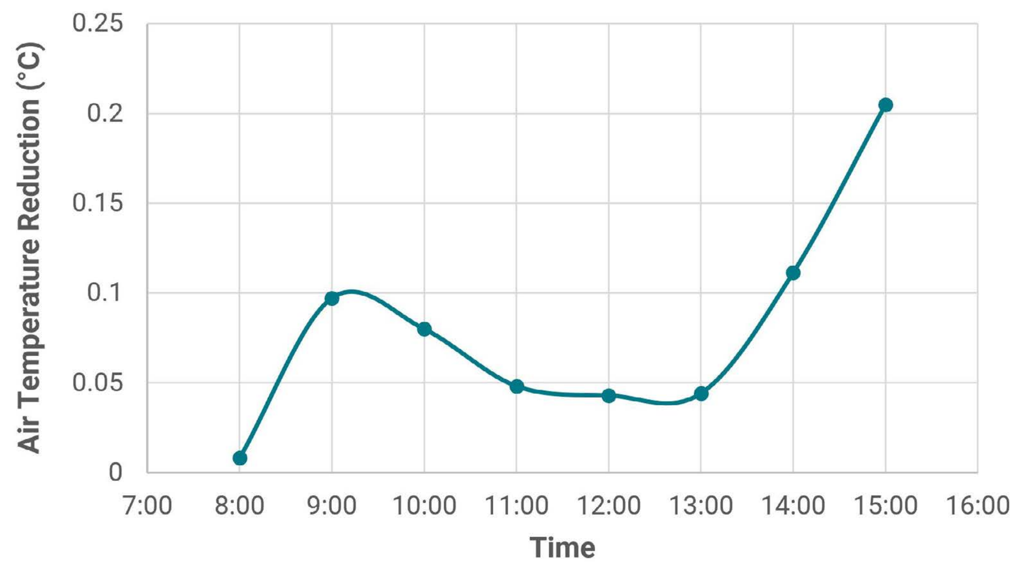


Figure 39: Average air temperature reductions from the increased building height (Scenario 9) in comparison to Scenario 2 for 2020
(Note: differences between 2020 and 2050 were negligible)

Cooling Potential

The increase in building height defined in Scenario 9 creates shaded areas in the morning and afternoon and as a result, has a slight decrease in surface and air temperatures under current and future climates when compared to Scenario 2. For example, Figure 39 shows a reduction in average street level air temperature from this increase in building height of up to 0.2°C during the afternoon.

This slight improvement of cooling potential is due to these new buildings being carefully considered in terms of scale, setbacks, shading, wind flow, building integrated urban greenery and materials to avoid negative impacts on street level thermal comfort. It is important to note that without these considerations, an increase in building height and density is likely to have negative impacts on outdoor thermal comfort within the South Melbourne Study Area.

Comparative Impact Analysis of Cooling Potential

The existing urban conditions (base case) of the South Melbourne Study Area includes extensive street tree canopy coverage, especially in the heritage residential areas to the south. Additional greening opportunities have been explored through extra street trees and rain gardens to maximise the cooling potential in the public realm as well as in private areas through the BAU, moderate and optimised private green coverage scenarios. The new buildings with a BAU private green coverage (Scenario 1) had only a minor impact on air temperature across the study area but cooling benefits were achieved once additional public and private urban greenery were added (Scenarios 2 and 3). The simulation results showed that there was only a minor cooling benefit in street level air temperature between a moderate and an optimised private green coverage scenario in the key redevelopment areas.

The cool roof intervention (Scenario 5) for all new and existing buildings resulted in an evenly distributed street level cooling effect across the South Melbourne Study Area that is slightly greater than changes to public and private urban greenery (Scenarios 2 and 3). Cool materials for all public and private hard surfaces (Scenario 4) demonstrated an increased cooling benefit with significant reductions in street level air and surface temperatures. The combination of all of these interventions (Scenario 7) provides an optimal solution to mitigate urban overheating across the study area through its effectiveness to reduce both localised and precinct wide air and surface temperatures across different times of the day. Further improvements to this were shown through water misting systems that have a significant cooling impact on localised air temperatures.

Each of these cooling intervention scenarios and their impact on average air and surface temperatures across the whole South Melbourne Study Area for 2020 and 2050 is shown in Figure 40 to show their comparative impact. In comparison to Scenario 1, the difference in average street level surface temperature reductions across the whole study area for the combination of interventions with and without water misting systems (Scenarios 7 and 8) is negligible due to its localised impacts, as well as for the moderate and optimised private green coverage scenarios (Scenarios 2 and 3) (Figure 40).

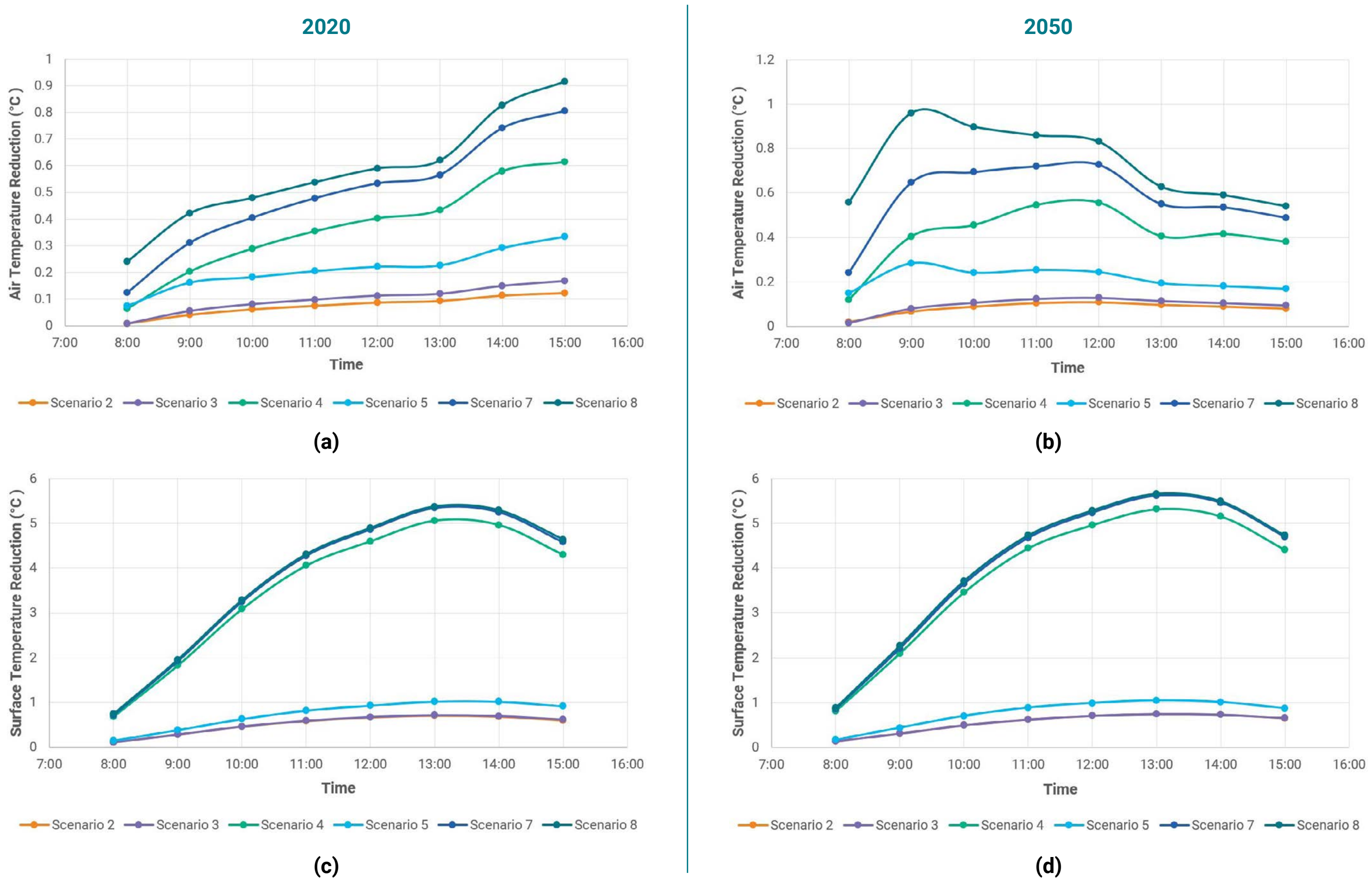


Figure 40: Intervention scenarios in comparison to Scenario 1 showing average air temperature reductions for **(a)** 2020 and **(b)** 2050; and average surface temperature reductions for **(c)** 2020 and **(d)** 2050

The Universal Thermal Climate Index (UTCI) provides a standard measure for outdoor thermal conditions, which is represented with a number indicating different levels of heat stress. The higher the number is, the higher heat stress is. Figure 41 shows the UTCI impacts of BAU (Scenario 1), moderate (Scenario 2) and optimised (Scenario 3) private green coverage for a section of Clarendon Street in the key redevelopment area on 14 February 2020 at 14:00. It shows that new buildings with a moderate or optimised private green coverage with additional street trees and rain gardens can improve outdoor thermal conditions and mitigate heat stress.

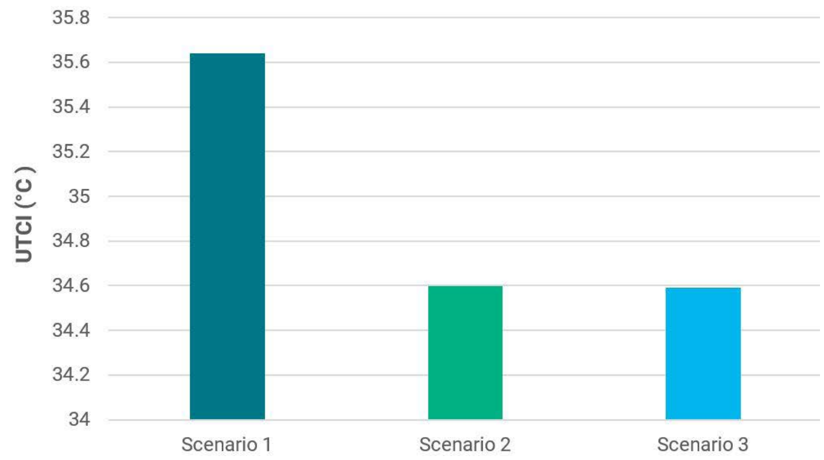


Figure 41: UTCI impacts for Scenario 1, 2 and 3 for a section of Clarendon Street in the key redevelopment area on 14 February 2020 at 14:00

Part 4 - Informing the South Melbourne Central Structure Plan

Left: Corner of Claredon and York Street
Photo: Port Phillip Council

Cooling Intervention Results in a Planning Context

The cooling intervention analysis results have highlighted the effectiveness of various urban overheating mitigation strategies in keeping South Melbourne cool under our current climate and in the future towards 2050. These results can help inform future developments to the South Melbourne Central Structure and Implementation Plan and ultimately, support the City of Port Phillip's strategic decision-making in ensuring a greener, cooler and more liveable city.

The analysis results have shown that increases of urban greenery in private areas, through moderate and optimised private green coverage scenarios, and in the public realm, through additional street trees and rain gardens, can help improve street level air and surface temperatures throughout the South Melbourne Study Area. Increased urban greenery in the public realm was proven to be effective for the wider, unshaded streets that characterise the business and retail precincts of the study area. Although some of these streets may require future changes to road and pedestrian configurations to accommodate this increased urban greenery, these results can help inform strategic and design decisions about keeping the existing and proposed pedestrian spines within the study area (e.g. Clarendon St, Market St, York St, Coventry St, Dorcas St, Moray St) comfortable during extreme heat events.

The intervention of cool materials for all streets, footpaths and private hard surfaces has proved to be highly effective at reducing street level air and surface temperatures across the whole South Melbourne Study Area. Currently, the key redevelopment precincts in the northern and eastern portion of the study area are predominantly paved in public spaces which leads to high surface and air temperatures during extreme heat events. The analysis results can help inform the future improvement or changes to South Melbourne's public spaces to ensure they do not become hot spots during the warmer months.

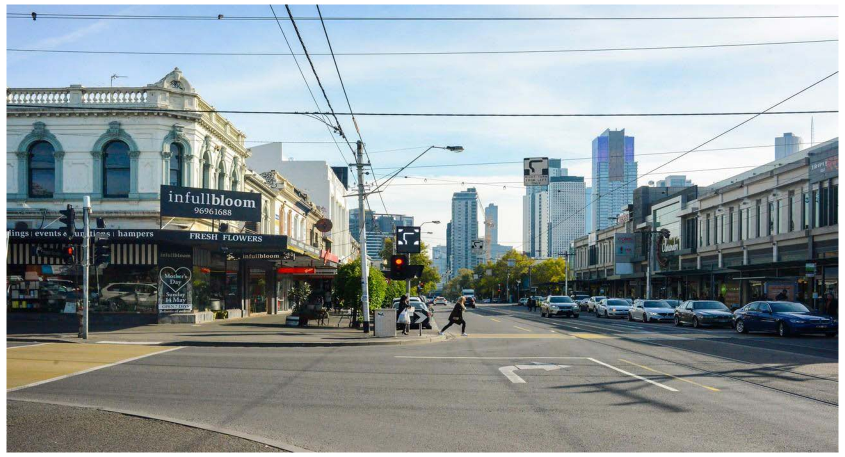
The large, exposed rooftops of the compact urban areas (e.g. Eastern and Western Business Precincts, Kings Way Mixed Use Corridor) and roof material properties of heritage buildings (e.g. Clarendon Street Core Local Shopping Strip, Emerald Hill Civic, Cultural and Community Hub) lead to high roof surface temperatures throughout the study area. The intervention of

Below: Wide and unshaded asphalt of Bank St

Photo: Mattinbgn / Wikimedia / CC BY-SA 3.0

cool roofs for all new and existing buildings showed an evenly distributed cooling effect across the entire South Melbourne Study Area. Cool roofs were presented as less effective than cool materials for public and private hard surfaces as the results were discussed in terms of street level air and surface temperature reductions. It is important to note, given the extent of existing buildings with aging roof materials, that cool roofs can lead to significant reductions in roof surface temperatures. This can potentially improve indoor thermal comfort, reduce energy and air conditioning use and thereby limit potential heating effects from the waste heat of air conditioning systems (Ding et al., 2019).

The combination of all interventions demonstrated the highest cooling potential for the South Melbourne Study Area. This combination of cooling interventions was able to respond to the diversity of land use and urban typologies throughout the study area (e.g. industrial compact low/medium-rise precincts to the north, compact heritage low-rise residential to the south, mixed use medium/high-rise to the east, new medium-rise mixed use in key redevelopment precincts, etc.), thereby maximising the cooling potential at different times of the day. The cooling potential was increased further through the addition of water misting systems in specific hot spot areas in the public realm. Within public open spaces and along wide streets, these water misting systems demonstrated



Above: Clarendon Street Core Local Shopping Strip

Photo: Boutique Stays

significant reductions in street level air temperature, especially when combined with prevailing wind flow patterns. The results of this highlight the maximum possible cooling potential for the South Melbourne Study Area.

An increase in building height within the key redevelopment precincts that exceeds the maximum permissible planning controls has shown only a minor impact on street level surface and air temperature. This is a result of the careful consideration of the transitional building scale, its integration with public and private green infrastructure, its material properties, and allowing prevailing wind flows through the study area. Without these considerations, an increase in building height and density over a larger scale could potentially have negative urban overheating impacts. These results show that if planning controls effectively address these factors, an increase in future density in the study area does not have to mean the impacts of the UHI effect are exacerbated.

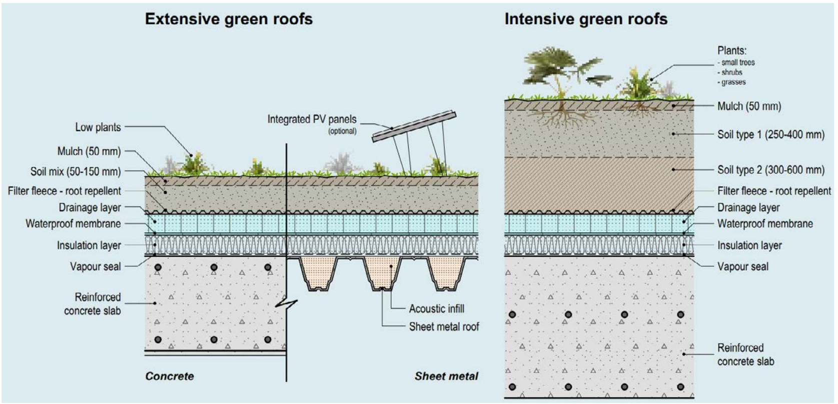
Recommendations to Inform the Future Planning of South Melbourne

Developed from the outcomes of this cooling intervention analysis, a set of recommendations are proposed to inform the City of Port Phillip's future planning of South Melbourne towards 2050. The recommendations outlined in this section can help cool the South Melbourne Study Area by reducing air and surface temperatures as well as improving outdoor thermal comfort. Specific provisions to consider when implementing these recommendations are provided where relevant.

Increase Green Infrastructure in the Public and Private Realm

Green infrastructure can be maximised in the public realm primarily through additional street trees and rain gardens, and in private areas through green roofs and vertical greenery.

The specific provisions for **green roofs** are provided here (refer to the UHI Mitigation Index).



Above: Typical cross sections of extensive and intensive green roofs (Osmond & Sharifi, 2017)

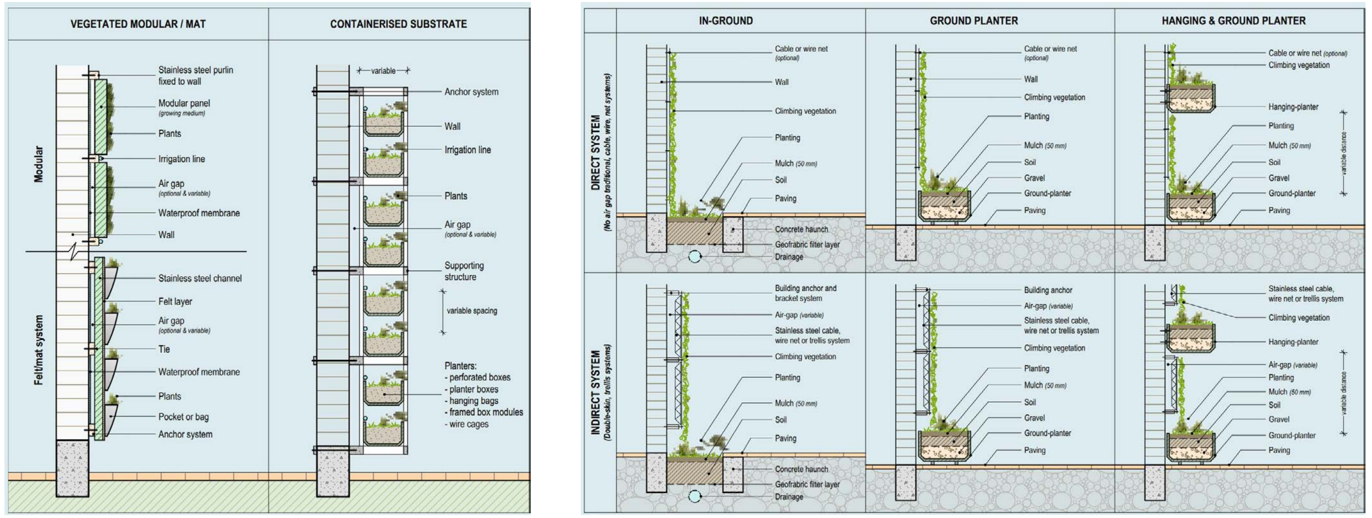
- Opportunities to install green roofs should be maximised for both new and existing buildings.
- **Extensive green roofs** (50-150mm growing medium) are suitable for buildings that require low maintenance and a lightweight structure. Can be applied to roof slopes up to 30° (Osmond & Sharifi, 2017).
- **Intensive green roofs** (150-400mm growing medium) are suitable for new buildings that can provide additional structural support and maintenance - typically commercial buildings with flat roofs that are accessible for recreation and relaxation (City of Adelaide, 2016; Osmond & Sharifi, 2017).
- **Plants species** that can tolerate extreme weather conditions (heat, wind, droughts and full sun) are preferred to reduce costs associated with irrigation, drainage installation and heat stress (City of Adelaide, 2016; Osmond & Sharifi, 2017; Santamouris 2015; Victorian Government, 2014).
- Harvesting rainwater for **irrigation** through water tanks can help maximise cooling benefits of green roofs and rainwater capture/reuse (City of Adelaide, 2016; Osmond & Sharifi, 2017; Santamouris 2015; Victorian Government, 2014).
- Extensive green roofs can be coupled with **solar PV** panels to provide energy and cooling. The cooling effects of green roof vegetation can improve PV energy generation efficiency depending on species, climate conditions, evapotranspiration and albedo (Osmond & Sharifi, 2017).

Moderate Private Green Coverage for New Development

Although optimised private green coverage represents world leadership in green infrastructure ambition (Ashley, 2020), the cooling effect at street level was found to be comparable to that of a moderate private green coverage scenario. Therefore, moderate private green coverage is recommended as an appropriate baseline for private green infrastructure for any new development in the South Melbourne Study Area.

The specific provisions for **vertical greenery** are provided here (refer to the UHI Mitigation Index).

Below: Typical cross sections of vertical greenery systems (Osmond & Sharifi, 2017)



On Walls

On Ground

- The **cooling effect** of vertical greenery is highly dependent on its orientation, plant density and water content (Osmond & Sharifi, 2017)
- Vertical greenery types: **Modular systems** are suitable for new or existing buildings where supporting structures can be fixed to walls through either vegetated modular/hydroponic systems, containerised substrates or hanging planters. **Green facades** are suitable for new or existing buildings where plants can be rooted on ground and grown either directly on walls or on a trellis or double skin. These can be effective at for shading low albedo materials (e.g. dark-coloured concrete, bricks, tiles) but is limited by building height. **Balcony** scale green walls (small, modular and self-containing systems) are suitable in apartment buildings when other vertical greening systems are not possible. **Hybrid systems** combine different structures and climbing plants that can be applied extensively to building facades at relatively low costs and water demand (City of Adelaide, 2016; Osmond & Sharifi, 2017; Victorian Government, 2014).
- **Plants species** that can tolerate extreme weather conditions (heat, wind, droughts and full sun) are preferred to reduce costs associated with irrigation, drainage installation and heat stress (City of Adelaide, 2016; Osmond & Sharifi, 2017; Santamouris 2015; Victorian Government, 2014).
- Installing vertical greenery in front of **glazed areas** is recommended where appropriate to reduce direct sunlight and heat load as well as any glare or reflection from the glazing (City of Adelaide, 2016; Victorian Government, 2014).

Increase Street Trees Along Wide Streets

Despite the relatively high street tree canopy coverage throughout the South Melbourne Study Area, it is recommended to explore opportunities to increase the number of street trees for the wider, unshaded streets (>28m). This may involve exploring alternatives to existing road and pedestrian networks.

The specific provisions for **street trees** are provided here (refer to the UHI Mitigation Index).

Above: Wide, unshaded street in the study area that could explore opportunities for increased street tree canopy coverage (Google Streetview, 2020)

- **Plant and tree selections** should include Australian native and exotic species that suit exiting soil conditions and are resistant to water and heat stresses (City of Adelaide, 2016).
- **Consistent and regularly-spaced** lines of trees with well irrigated grass along the length of the street is recommended where possible to provide constant solar protection and evapotranspiration during the day as well as facilitate wind circulation to ease heat dissipation at night. Factors such as underground or overhead services, bridges and building awnings must be considered when determining planting configurations (Bartesaghi Koc, 2018; Coutts & Tapper, 2017; City of Adelaide, 2016)
- **Soil and moisture conditions** should be adequate and constantly maintained depending on the type of species planted by (1) undertaking continuous trenching and soil improvements, (2) providing passive irrigation using harvested rainwater and stormwater runoffs, (3) planting trees in low-lying or drainage zones of the street, (4) installing permeable pavements in the vicinity of trees, and (5) constructing rainwater/stormwater infiltration pits near or next tree plantings (Bartesaghi Koc, 2018; Coutts & Tapper, 2017).
- **Small ornamental trees** can be implemented in areas where large and continuous rows of trees are not possible to be planted (City of Adelaide 2018; Bartesaghi Koc, 2018).
- In streets **without trams**, medians can accommodate large canopy trees to reduce solar exposure of asphalt and pavements. In streets **with trams**, it is recommended to use pervious surfaces and permeable pavements accompanied by trees of elongated crown shapes along both sides (Bartesaghi Koc, 2018; City of Adelaide, 2016; City of Melbourne, 2016; Coutts & Tapper, 2017).
- **Raised planter boxes** and seasonal planting can be implemented in strategic locations to provide maximum flexibility of public spaces and preserve the historic character of the street.
- Where trees are in footpaths, **deciduous trees** should be favoured in south and east-facing footpaths to allow for winter sun and **evergreen trees** in north and west-facing footpaths; while trees in medians can be predominantly evergreens (City of Adelaide, 2016; Bartesaghi Koc, 2018).
- Consider bundling and moving **power cables underground** to improve canopy coverage. This can also significantly improve pedestrian amenity and comfort as well as reduce ongoing maintenance of street trees around power lines and thereby reducing the OH&S risk of injury and electrocution (McIlwraith, 1996).
- Although **dense tree canopies** can provide significant temperature reductions during the day, depending on context and plant species, very dense tree canopies may trap a significant amount of pollutants (Bartesaghi Koc, 2018).
- **Lower scale landscape treatments** (low and medium size plants) should be provided where there is adequate space provision (City of Adelaide 2016; Coutts & Tapper 2017).
- **Climbing species and vertical greenery** can be used to complement street tree plantings (City of Adelaide 2016).

Improve the Amenity of Green Open Spaces

While green open spaces are quite limited in the South Melbourne Study Area, these smaller parks have relatively high surface and air temperatures. It is recommended to improve the amenity of the existing and any future green open spaces through additional urban greenery, external shading structures and water misting systems.

The specific provisions for **green open space** in general are provided here as well as those for **external shading structures** (which are not limited to green open spaces) (refer to the UHI Mitigation Index).

Above: Different types of external shading structures (Osmond & Sharifi, 2017)

Green Open Spaces:

- **Plant selections** should include Australian native and exotic species that suit existing soil conditions and that are highly suitable to harsh environments (i.e. heat resilient and drought tolerant). A diverse range of plants species and arrangements should be considered in the design of green open spaces, avoiding mass planting with single species (City of Adelaide, 2016).
- For existing hard surface areas such as car parks, surfaces can be partially or totally replaced by **low plantings and permeable materials** with extensive canopy crowns regularly distributed to increase shading (Bartesaghi Koc, 2018).
- Green open spaces should enable **community driven initiatives** like communal and edible gardens where possible (City of Adelaide, 2016).

External Shading Structures:

- Shading devices should be prioritised in **overexposed street canyons** (wide streets and footpaths, boulevards, pedestrian streets) and **open spaces** (plazas, squares, parks, playgrounds) with high pedestrian activity (Cancer Council NSW; Osmond & Sharifi, 2017; Santamouris & Feng, 2018).
- **Shading devices and technologies** that could be implemented include arbours, pergolas with climbing plants (trained vines), fixed, temporary or movable shading devices, integrated translucent PV panels, tension membrane structures, etc. (Osmond & Sharifi, 2017).
- Shading devices should use **light-coloured, high albedo and radiative cooling materials** while ensuring that the negative effects of glare are minimised for those within the public realm. They should generally avoid full glazing but can be combined with PV systems, fabric, canvas, mesh and solid material in areas where solar radiation is limited and/or natural light and energy generation is required (Osmond & Sharifi, 2017).
- Shading devices can also be used to (1) **harvest rainwater** for irrigation purposes provided that adequate downpipes, drainage and storage system are integrated; and (2) integrate **evaporative cooling technologies** such as ceiling fans, misting fans, water sprinklers or fountains for enhanced outdoor thermal comfort provided it is not in a humid climate (Osmond & Sharifi, 2017; Santamouris & Feng, 2018; Sydney Water, 2017).

Consider the Use of Cool and Permeable Surfaces for Streets and Paved Surfaces in the Public Realm

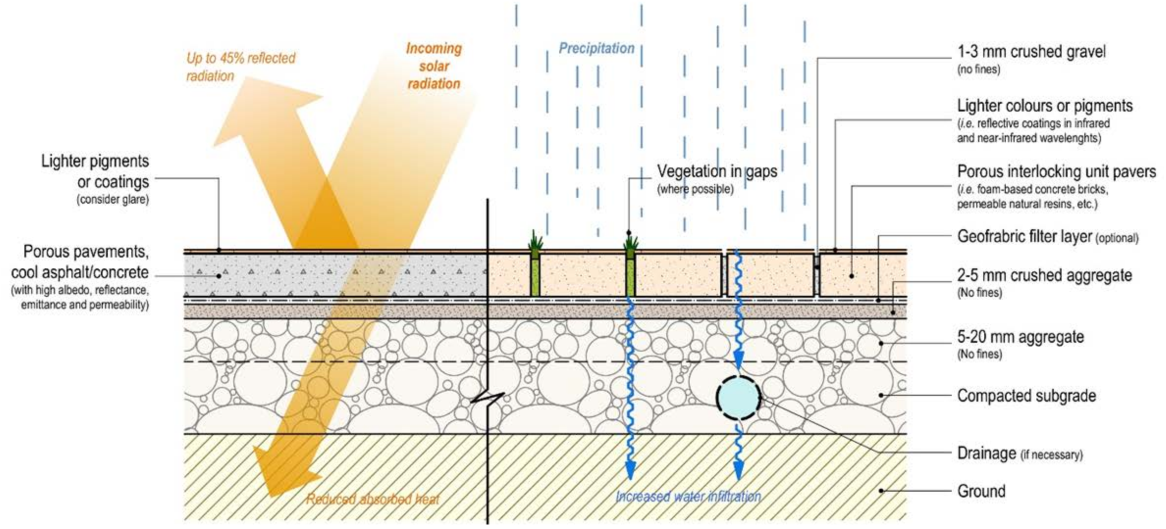
Due to the compact urban context of most of the South Melbourne Study Area, it is recommended that cool and permeable surfaces should be utilised for all streets and hard surfaces in the public domain, especially in the key redevelopment precincts where the street tree canopy is limited.

Successful case studies on cool surfaces in the public realm include: cool roads in Adelaide, cool paving materials in Flisvos Park in Athens (Santamouris et al., 2012), reflective roads in Los Angeles, and cool pavement studies in Berkeley Lab.

The specific provisions for **cool and permeable surfaces** are provided here (refer to the UHI Mitigation Index).

- **High albedo** and **high emittance** concrete and asphalt used in roads and footpaths should be designed to minimise the negative effects of glare on users of the public realm (Osmond & Sharifi, 2017; Santamouris, 2015).
- Conventional **construction materials** should include a higher proportion of lighter aggregates, additives, pigments and binders (fly ash, slag, chip and sand seals, reflective synthetic binders) (Santamouris, 2015; City of Sydney, 2019).
- When replacing existing roads and pavements is not an option, **light-coloured coatings** can be applied. Options include (1) high white coatings, (2) infrared reflective coatings, (3) heat reflecting coatings to cover existing asphaltic pavements, (4) colour changing coatings, and (5) fly ash, slag and recycled industrial by-products as aggregates of concrete pavements (Santamouris, 2015).
- Consider replacing conventional pavements with **permeable pavements** through (1) water holdings fillers as additive to porous asphalt, (2) fine texture pervious mortars as additive in pervious concrete, (3) fine blast-furnace powder in water retentive asphalt, (4) narrow particles of fly ash in bricks, (5) bottom ash as additives in pervious concrete, and (6) industrial waste as raw materials in ceramic tiles (Santamouris, 2015).
- Consider the application of **thermochromic materials** (intelligent coatings developed with nanotechnology) to enhance the thermal and optical properties of footpaths (Santamouris et al., 2011).
- For **heritage pavements** (e.g. bluestone surrounding the South Melbourne Town Hall), consider reducing the size of the pavers to form gaps which can increase permeability without losing its heritage character (Bloomberg Associates, 2019)

Below: Typical cross sections through cool and permeable pavements (Osmond & Sharifi, 2017)



Encourage the Use of Cool Roof Materials for New Buildings and for Retrofitting Existing Buildings

With a large portion of the South Melbourne Study Area made up of heritage buildings with darker and lower albedo roof materials, it is recommended that the use of high albedo and emissivity cool materials is encouraged for retrofitting these buildings where possible to improve indoor and outdoor thermal environments. It is also recommended to encourage the use of cool roof materials for all new buildings in the key redevelopment precincts.

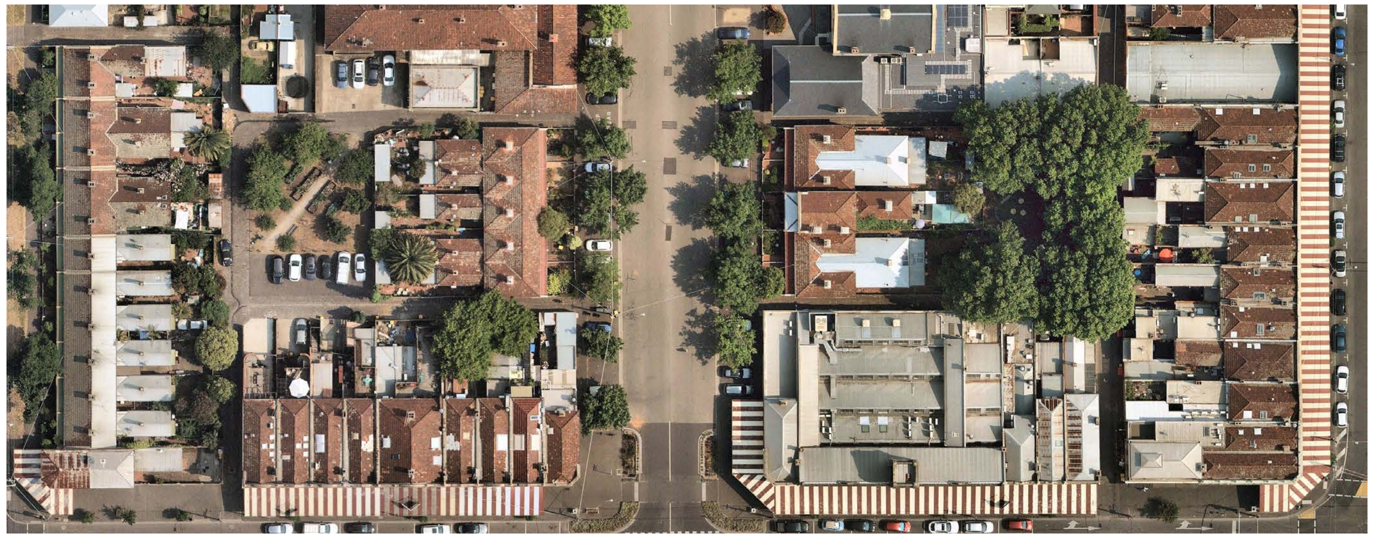
Case study best practice in cool roofs include: international case studies from Global Cool Cities Alliance (GCCA, 2012), guidelines for selecting cool roofs by US Department of Energy (2010), reflective coatings in roofs to improve outdoor and indoor conditions of low-income housing (Santamouris et al., 2007), an overview of the impact of cool roofs from the Yale School of the Environment, trial of cool roofs in California by Lawrence Berkeley National Laboratory (Vahmani et al., 2019).

The specific provisions for **cool roofs** are provided here (refer to the UHI Mitigation Index).

- Encourage the construction of roofs with **high emissivity, high albedo** and **low heat conductivity** but should be designed to minimise the impacts of **undesirable glare** (e.g. where the roof is highly prominent to other building occupants or to those in public spaces) (Santamouris et al., 2011; Santamouris, 2014; Osmond & Sharifi, 2017).
- For **heritage buildings** where replacing existing roof materials is not feasible, consider the use of white or light-coloured coatings (single ply or liquids) (Santamouris, 2015; Osmond & Sharifi, 2017).
- Consider the application of **thermochromic materials** (intelligent coatings developed with nanotechnology) to enhance the thermal and optical properties of roofs (Santamouris, 2014; Santamouris et al., 2011).
- Where possible, increase the proportion of lighter aggregates, pigments and binders in conventional **construction materials** (Santamouris, 2015).
- Minimise the use of dark-coloured, low solar reflectance, and low emittance materials (e.g. dark-coloured concrete or tiles); unless **'smart' materials** (which can reflect in the near-infrared/infrared) are used (Santamouris 2014; Santamouris et al., 2011).

Below: Heritage buildings in the South Melbourne Study Area that could consider cool roof coatings

Photo: NearMap, 2020



Encourage the Use of Cool Façade Materials to Reduce Surface Temperatures of Facades and Improve Building Cooling Energy Loads

Due to the compact urban context of the study area, the use of cool façade materials can be considered in conjunction with exterior shading devices for isolated or open arrangements of new and existing developments, e.g. Park Towers in an open area, low density scenarios, etc. Cool façade materials with high solar reflectance and infrared emittance result in decreasing the surface temperature of the façade, the amount of heat penetrating into the building, and the temperature of the ambient air as the heat convection intensity from a cooler surface is lower (Santamouris et al., 2011), as well as the building's cooling energy load (Paolini et al., 2017). However, use of cool façade materials should minimise pedestrians' discomfort glare and ensure visually pleasing and comfortable outdoor environment (Suk et al., 2017).

The specific provisions for **cool facades** are provided here (refer to the UHI Mitigation Index).

Left: Cool façade materials could be considered for Park Towers

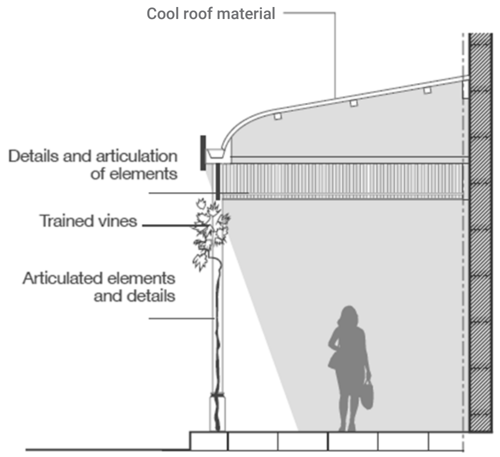
Photo: Mark Stewart / News Corp Australia

- Encourage the construction of facades with **high emissivity**, **high albedo** and **low heat conductivity** but should be designed to minimise the impacts of **undesirable glare** (e.g. neighbouring buildings, public spaces, roads and footpaths) (Santamouris et al., 2011; Santamouris, 2014; Osmond & Sharifi, 2017).
- When replacing existing façade materials is not feasible, consider the use of white or light-coloured coatings to walls of buildings (single ply or liquids) (Santamouris, 2015; Osmond & Sharifi, 2017).
- Consider the application of **thermochromic materials** (intelligent coatings developed with nanotechnology) to enhance the thermal and optical properties of facades (Santamouris, 2014; Santamouris et al., 2011).
- Where possible, increase the proportion of lighter aggregates, pigments and binders in conventional **construction materials** (Santamouris, 2015).
- Minimise the use of dark-coloured, low solar reflectance, and low emittance materials (e.g. dark-coloured concrete, bricks or stone); unless **'smart' materials** (which can reflect in the near-infrared/infrared) are used (Santamouris 2014; Santamouris et al., 2011).
- Minimise extensively glazed facades or **curtain walls** in areas of buildings that are largely exposed to solar radiation (especially north and west-facing facades)

Maintain and Encourage Building Integrated Shading Along Key Pedestrian Routes

The existing urban character of building integrated shading (i.e. awnings) along key pedestrian routes in the retail, activity and business precincts should be maintained and encouraged for any new development in the South Melbourne Study Area to reduce excess solar exposure for pedestrians.

The specific provisions for **building integrated shading** are provided here (refer to the UHI Mitigation Index).



Above: Example of building integrated shading that integrates multiple design considerations to help improve outdoor thermal comfort (City of Adelaide, 2016)

Right: Building integrated shading along Clarendon Street
Photo: realestate.com.au

- **Fixed and retractable awnings** of sufficient width (at least 3.5m) and height (3.5-4.5m) should be maintained and encouraged along active streets (and especially north-facing footpaths) to reduce solar exposure of surfaces, minimise solar penetration into buildings' ground floors and as weather shelters (i.e. rain, wind) (City of Adelaide, 2016).
- Fully glazed awnings should generally be avoided, but **partially glazed awnings with PV-integrated systems** may be appropriate for some areas where natural light and energy production is necessary (e.g. south-facing footpaths) (City of Adelaide, 2016).
- Consider the use of **non-continuous awnings** or with steps ups and breaks to promote air flow.
- Awnings, verandahs and shading structures should utilise **cool roof materials** but need to consider undesirable glare for occupants in neighbouring buildings.
- Consider using verandas and balconies as **supporting structures for vegetation** (i.e. trained vines). A suitable depth and distance from underground services should be considered to ensure adequate soil conditions that can support plant growing (Osmond & Sharifi, 2017; City of Adelaide, 2016).
- Awnings can be used to **harvest rainwater** for irrigation purposes provided that adequate downpipes, drainage and storage system are integrated and concealed (Osmond & Sharifi, 2017; City of Adelaide, 2016).

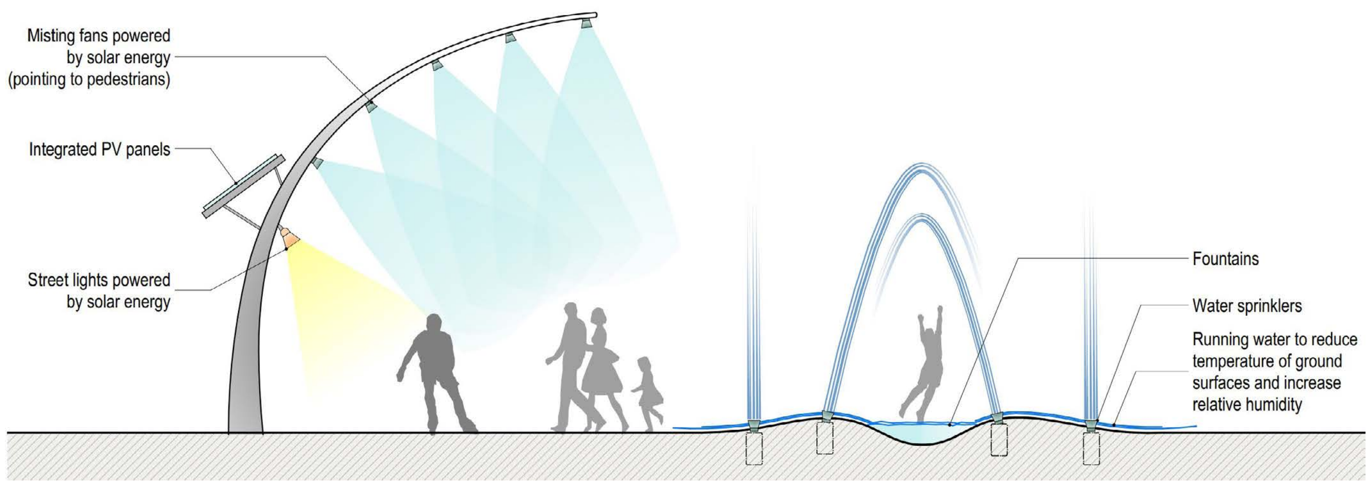
Consider the Use of Water Misting Systems Along Key Pedestrian Routes

For key pedestrian routes and identified hot spot areas in the South Melbourne Study Area, it is recommended to consider the use of water misting systems to reduce localised air temperatures and significantly improve outdoor thermal comfort.

The specific provisions for **cool facades** are provided here (refer to the UHI Mitigation Index).

- Consider utilising **passive and active evaporative cooling systems** strategically in public places. Passive systems include the provision of tree plantings and water features (fountains, lakes, ponds, rivers, etc.), while active systems correspond to evaporative/refrigerate air-conditioners such as multi-stage evaporative coolers, fine water sprays, and misting fans (with or without induced air velocity) (Bartesaghi Koc, 2018; Osmond & Sharifi, 2017).
- The intensity of cooling effects provided by water features can be controlled by modifying the **depth and extent of water**. That is, larger, deeper water bodies will provide a greater cooling potential (Bartesaghi Koc, 2018).
- Consider regular streetscape irrigation and pavement watering systems (i.e. surface running water) in the design or retrofit of public open spaces and streets. However, these should not be utilised in humid climates as this could result in increased relative humidity and decreased outdoor thermal comfort (Bartesaghi Koc, 2018; Osmond & Sharifi, 2017; Sydney Water, 2017).

Below: Evaporative spray cooling systems (Osmond & Sharifi, 2017)

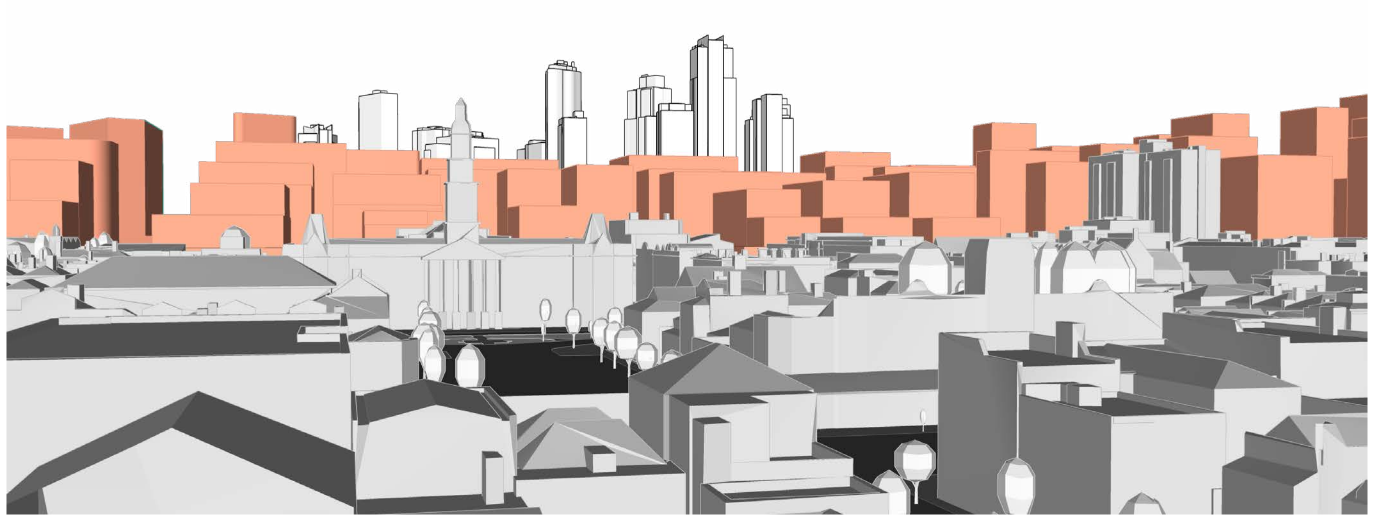


Any Increased Height Beyond Current Planning Controls Should Be Carefully Considered to Avoid Exacerbating the UHI Effect

The proposed new buildings with carefully considered increased building height in the South Melbourne Study Area were able to create shaded areas and cold spots for pedestrians for this study. However, it is important to note that urban canyons formed between high-density taller buildings could potentially trap heat at the street level. Therefore, it is recommended that if building heights are increased, guidance should be provided to ensure the urban heat island effect is not exacerbated.

Approaches with regard to taller buildings include: bioclimatic design (Yang & Chen, 2019); vertical green walls and skyrise greenery (Oldfield, 2018); street canyons that consider variations in height and distance between buildings, the position of taller buildings with respect to north (southern hemisphere) and shadowing, and the consideration of solar access, radiation and albedo (Pandya & Brotas, 2014).

Below: Stepped increase in building height (beyond current planning controls) towards the tall Southbank towers



Part 5 - Urban Heat Island Mitigation Decision-Support Tool

Left: Existing and proposed new buildings aligned with the SMC Structure Plan within the UHI-DS Tool

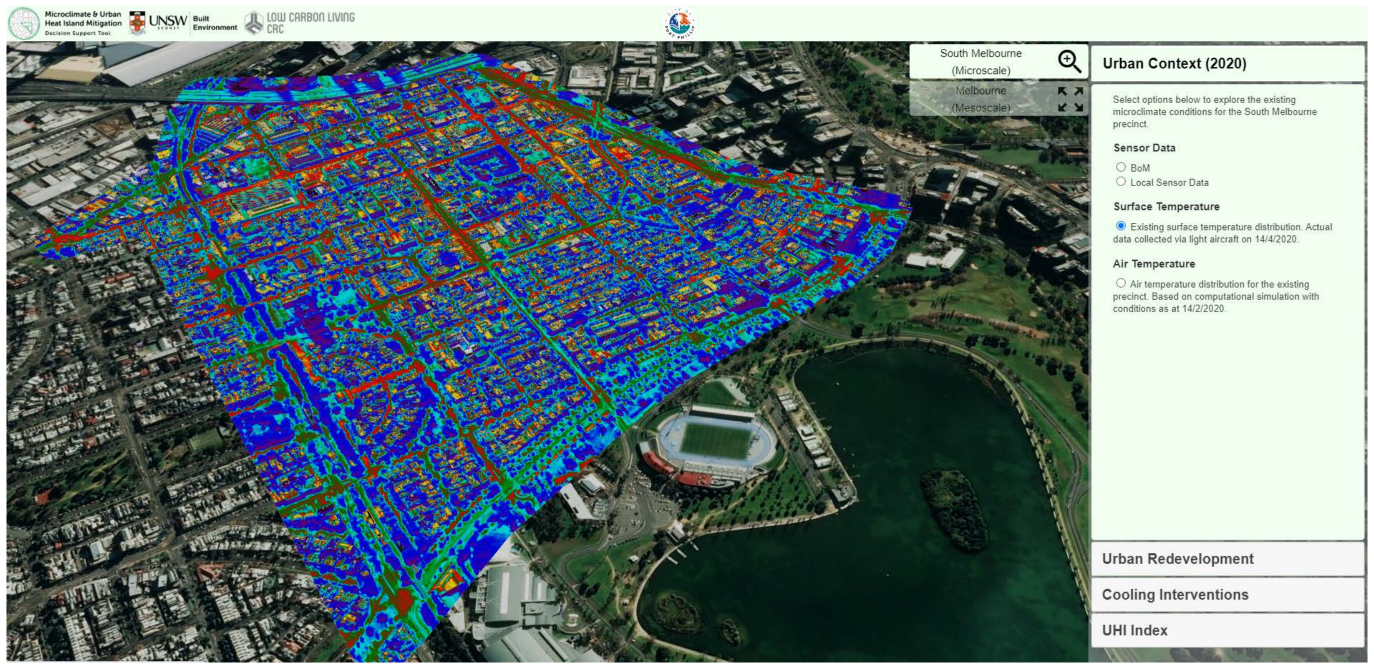
Overview of Key Functions

The Urban Heat Island Mitigation Decision-Support (UHI-DS) Tool was developed by the CRC for Low Carbon Living and the University of New South Wales to support well-informed decisions to mitigate urban overheating and is accessible online. The UHI-DS Tool has been extended to provide a cooling intervention scenario analysis for the South Melbourne Study Area.

Key functions of the UHI-DS Tool for the South Melbourne Study Area include:

- Inspection of **local heat profiles** for the study area, including a surface temperature heatmap collected by a light plane (Figure 42), air temperature through simulation, and sensor data collected through 10 weather stations installed throughout the study area.
- **3D visualisation** of the existing urban context, proposed new buildings, and cooling intervention alternatives.
- **What-if scenario analysis** showing the cooling effects of various intervention alternatives, which includes heatmaps of maximum and averaged reductions of air temperature resulting from each cooling intervention.
- Inspection of the **cooling effects for the intervention alternatives** under current climate conditions in 2020 and projected future climate conditions in 2050.
- A link to **UHI Mitigation Index** that provides broad guidelines to support decision-making by outlining the effectiveness of individual and a combination of urban overheating mitigation strategies for a range of urban contexts and climate regions.

Figure 42: Surface temperature distribution of the existing urban conditions in the South Melbourne Study Area

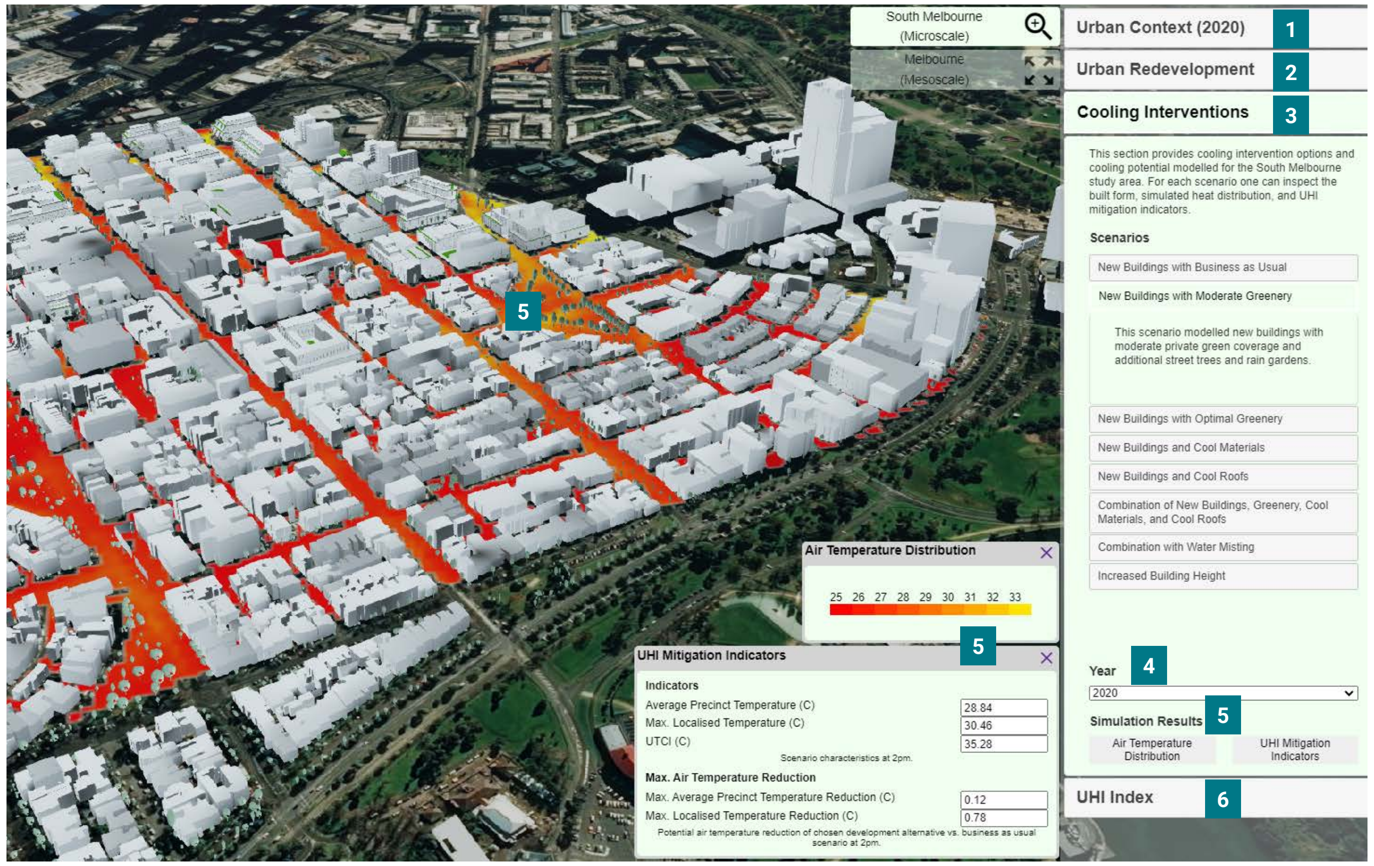


South Melbourne Cooling Interventions in a 3D Interactive Platform

The UHI-DS Tool allows users to interact with and visualise the cooling effects of the various cooling intervention scenarios reported in Part 3. An example of such an analysis is shown in Figure 43, where the key interactive functions include:

1. **Urban Context:** explore sensor data, surface temperature, and air temperature
2. **Urban Development:** explore exiting buildings, potential new buildings compliant with planning controls, and potential new buildings with increased height going beyond existing height limits
3. **Cooling Intervention Scenarios:** explore any of Scenarios 1 - 9 reported in Part 3
4. **Current and Future Climate Conditions:** explore cooling effects under climate conditions in 2020 and 2050
5. **Indicators of Results:**
   - Air temperature distribution – allowing users to select a cell of heatmap to view localised air temperature
   - Maximum and averaged air temperature reduction resulting from a selected cooling intervention
   - Universal Thermal Climate Index – showing the level of heat stress resulting from a selected cooling intervention
6. **UHI Mitigation Index:** explore urban overheating mitigation strategies for different urban contexts and climate conditions

Figure 43: Key interactive functions of the UHI-DS Tool for the South Melbourne Study Area



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