ACT Microclimate Assessment Guide

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alluvium

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Glossary of terms (*adapted from Osmond et al. 2017, except where indicated*)

Albedo	Reflectivity, the proportion of incident light reflected from a surface. Albedo is a general property and can apply to everything such as buildings materials like a road surface, sea ice, trees and clouds. Albedo is on a scale of 0 to 1 where 0 means a purely black body that absorbs all radiation and 1 indicates a pure white surface that no radiation can penetrate. In terms of the microclimate, high albedo materials are often used to mitigate the urban heat island as they reflect away radiation rather than absorb it.
Building envelope	Collective term for the building facades and roof.
Cool materials	Materials with high albedo and/or emissivity which stay cooler than conventional materials under solar radiation.
Dry bulb temperature	Air temperature as measured by a thermometer exposed to the air but shielded from radiation and moisture.
Emissivity	The efficiency with which an object can emit heat. A high emissivity object means that it can give away heat more easily, whereas a low emissivity object cannot give it away and becomes hotter. For microclimate purposes high emissivity materials are often paired with high albedo materials so that they reflect a lot of radiation and the radiation that is absorbed is readily given back to the atmosphere by the material.
Evaporation	The process of liquid water turning to a gas. Liquid water requires energy to become a gas and it often takes this energy from the atmosphere resulting in a reduction in air temperature. Water in an irrigated landscape evaporates reducing the air temperature, though raises the humidity. When people sweat, the water evaporates by taking energy from their skin, cooling them down.
Evaporative cooling	When water evaporates it uses energy from the air to change from liquid to gas, the air loses this energy and cools. This also occurs when water in plants evaporates.
Evapotranspiration	The sum of evaporation and plant transpiration. The evaporation refers to water coming from sources like soil or surface water on leaves, while transpiration is the movement and loss of water as vapour from within a plant such as through their stomata. Like evaporation, evapotranspiration reduces the air temperature when energy from the air is used.
Heat capacity	The ratio of heat added to or removed from an object to the resulting temperature change.
Heat resilience	The extent to which the built environment can support outdoor activities during heat stress conditions.
Heat stress	Heat stress occurs when our body is unable to cool itself enough (e.g. through sweating) to maintain a healthy temperature.
Heatwave	Three or more days of high maximum and minimum temperatures which are unusual for that location.
Land Surface Temperature	How hot the “surface” of the Earth would feel to touch in a particular location (NASA, 2021)

Latent heat The energy used by water to change state, such as from liquid water to a gas, or gas to liquid water. People cannot feel latent heat.

Mean Radiant Temperature The theoretical uniform surface temperature of an enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform enclosure.

Microclimate A local set of meteorological conditions.

Sensible heat The type of energy that people can physical feel and perceive, such as the heat coming from a hot asphalt surface.

Sky View Factor A popular metric to describe the urban form, which accounts for the influence of buildings and vegetation on solar radiation hitting the surface. The SVF is often calculated by using a fish eye camera pointed directly upwards, with the SVF defined as the fraction of sky that can be seen as opposed to buildings and vegetation. Areas with a high SVF are likely to be have a higher mean radiant temperature whereas low SVF places are likely to be cooler. The SVF for some global landmarks are shown below (Middel et al. 2018).

Solar exposure The total amount of solar energy falling on a surface. A north facing wall will have a higher solar exposure than a south facing wall as it experiences incident sunlight throughout the day.

Solar radiation The sunlight and energy from the sun.

Solar reflectance See albedo

Solar reflectance index A measure that combines the albedo and emissivity of materials. When a material has a low solar reflectance index it is likely to become hotter in the sunshine because it absorbs more solar radiation (low albedo) and cannot easily lose the heat back to the atmosphere (low emissivity).

Thermal comfort	The subjective feeling of temperature in the environment. The term often includes factors such as air temperature, solar radiation, wind and humidity (Health and Safety Executive, UK Government, 2021).
Thermal conductivity	The amount of heat per unit time per unit area which can be conducted through a plate of unit thickness of a given material.
Universal Thermal Climate Index	An index that estimates an individual's perceived temperature, based upon the air temperature, relative humidity, mean radiant temperature and wind speed (Gosling et al. 2014).
Urban boundary layer	The part of the atmosphere whose characteristics are affected by the presence of an urban area at its lower boundary.
Urban canopy layer	Sometimes referred to as urban tree canopy is a measurement that describes the birds eye view coverage of tree leaves, branches and trunks in an urban area. Urban canopy can cover natural surfaces such as in a park or can cover artificial surfaces such as street trees shading roads. Increasing the urban canopy is often seen as a method to improve the microclimate and urban canopy targets are common for local government areas.
Urban canyon	The area in a street that is flanked by buildings on both sides. A residential street with houses on both sides is an urban canyon, as is a street in the central business district with skyscrapers on each side. The geometry of the urban canyon (street width, building height, orientation and length) can all influence the microclimate.
Urban Heat Island	The phenomenon whereby the trapping of solar radiation and release of anthropogenic waste heat leads to higher temperatures in urban areas compared to their rural surroundings.

1 Introduction

1.1 Purpose of the Guide

The purpose of the Microclimate Assessment Guide is to provide guidance relating to when and how a microclimate assessment is required and the most appropriate platform for assessing microclimate in the Australian Capital Territory.

There is an ecosystem of platforms available to assess the microclimate of any given location, however, the application of particular tools is recommended for different scenarios considering the:

- Scale
- Timing
- Purpose of the development

A Microclimate Assessment can be applied to single dwellings, large scale commercial builds and new suburb developments. A microclimate assessment is applied to developments less than 100 Ha in area. Beyond this scale, the assessment is no longer considered a microclimate assessment, but a climate assessment. This Guide features microclimate and climate assessment options for the ACT. A Microclimate Assessment can be undertaken across all of the listed zoning areas, listed within The Territory Plan. A Microclimate Assessment can be undertaken for any development type or zoning.

1.2 Who should use the Guide?

Public and private land and infrastructure planners, developers, designers and managers in the ACT.

1.3 Scope of the Guide

This Guide provides information on the where, when, who, why and how of microclimate assessments and suggestions on what can be done to mitigate the negative impacts of urban heat and cold stress at different development scales (Block and building, Precinct to estate, and District to city-wide scales).

2 Microclimates, the Urban Heat Island and climate change

2.1 Microclimate

2.1.1 Meteorological variables of microclimate

The microclimate is a local set of meteorological conditions, where they may differ from surrounding areas (Oke 1987). For example, a large urban park has a microclimate which can often be cooler and more humid than a neighbouring residential area. Microclimates can apply on scales of a few metres to many square kilometres.

The microclimate can be measured through meteorological variables such as:

- Ambient temperature (otherwise known as air temperature), measured at a height above ground.
- Surface temperature of the ground or buildings and vegetation.
- Wind speed measured at a height above ground.
- Relative humidity measured at a height above ground.
- Solar radiation, and/or solar exposure, understanding when, where and how long a site is exposed to sunlight.

Understanding these meteorological variables together produces a more holistic understanding of the microclimate in urban areas such as determining hot and cool spots, wind tunnels and humid pockets.

Air temperature and surface temperature are the most commonly discussed and measured meteorological variables to describe microclimate. Air temperature is measured through weather stations, either through the Bureau of Meteorology network, or through sensors set up by individuals or organisations, and represents an observation at one point, though the results can be extrapolated for a larger area.

The surface temperature is often captured through satellites, or special flights with thermal cameras that provide a spatial snapshot in time of an area and can be used as a proxy for air temperature as heat emitted from the surface often affects the temperature of the air above it (Saaroni et al. 2000; Norton et al. 2015). The variability of surface temperature is also higher than the air temperature, where a 10˚C change in surface temperature could be similar to a 2˚C change in air temperature, though the exact relationship differs for each place and time. However, the relationship between air temperature and surface temperature is weaker during windy weather, as the air that was heated by a hot surface moves further downwind (Stoll and Brazel 1992). It is also worth noting that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot then requires further investigation into the cause of the hot or cool spot.

2.1.2 Factors that contribute to microclimate

Urban microclimates are affected by many features of the natural environment and by the design and make-up of an urban area. A natural environment with trees, water and vegetation is often cooler than an urban environment without these features due to the urban heat island effect (see 2.2 Urban heat island). The cooler air from more natural environments can move in the direction of the wind to a distance approximately the width of the natural area (Motazedian 2017). A 50m wide park can have a cooling effect on surrounding downwind areas to a distance of approximately 50m. Other factors that influence urban microclimates include slope and aspect, open spaces, building materials, and green and blue infrastructure. The slope and aspect of an area will impact on the amount of solar radiation received, e.g., the northern side of a sloped area will likely be warmer than the southern side.

The urban environment can positively or negatively influence the microclimate of an area, due to factors such as the orientation of streets, the height width ratio of urban form, the density or length of buildings and resulting solar radiation in the urban canyon (Figure 1) (Thom et al. 2016; Coutts and Tapper 2017):

- The **street orientation (O)** at the block and precinct city-scale is a big factor in the microclimate as it determines which streets are likely to be hotter than others when no microclimate treatments are applied. Street orientation influences access to light, sun and wind, which in turn can impact the microclimate and pedestrian comfort at street level. Treatment measures may differ depending on the orientation of the street

- The **Height Width Ratio (H:W)** where the height of the building is compared to the width of the road and affects shading at street level. Shade on streets is an important factor for microclimate assessments at the block and precinct scale. Wide streets are exposed to more solar radiation throughout the day and become hotter, though if they are bordered by tall buildings the buildings can provide a shading effect. Understanding the H:W helps to determine whether streets will be sunny or shady.

- The **length and density of buildings (L)** influences the microclimate as when buildings are close together, they reduce air flow and keep hot air stored between them. In general, denser, longer buildings also mean less vegetation which can have microclimate effects at the precinct to city scale, creating an urban heat island effect.

- The amount of **solar radiation** to accumulate on each side of the street and adjacent building walls affects the microclimate. Unshaded north-facing walls are exposed to direct solar radiation throughout the day while south facing walls are not. West facing walls are exposed to more solar radiation at the peak daytime heating period (maximum air temperatures occur in the afternoon), while east facing walls are exposed during the morning when temperatures are cooler.

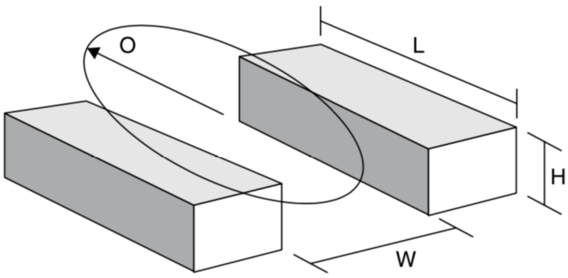


Figure 1. *Properties of the urban canyon (streetscape) – length (L), width (W; street width), height (H; building height) and orientation (O)* (Osmond and Irger 2016)

2.2 Urban heat island

2.2.1 What causes the urban heat island?

Urban areas tend to have a different microclimate from rural areas. They are often hotter and drier due to a phenomenon known as the urban heat island effect with the densest parts of the city often warmer than those that are less dense (Figure 2).

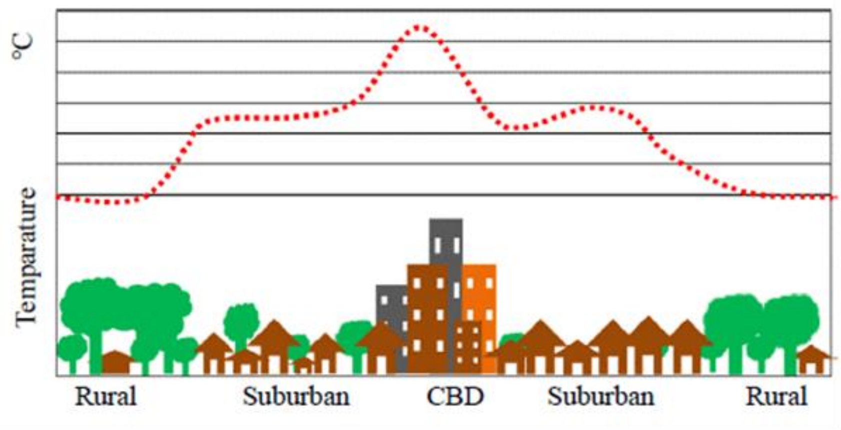


Figure 2. *Schematic of the urban heat island effect* (Bhargava et al. 2017).

The urban heat island has been observed worldwide and is caused by numerous factors demonstrated in Figure 3. Additional factors that add to the urban heat island are (Oke 1987):

- Heat emitted from air conditioning units, traffic and people.
- Street geometries and building morphology where a lack of shade and high exposure to the sun can increase the heat accumulation in urban areas.

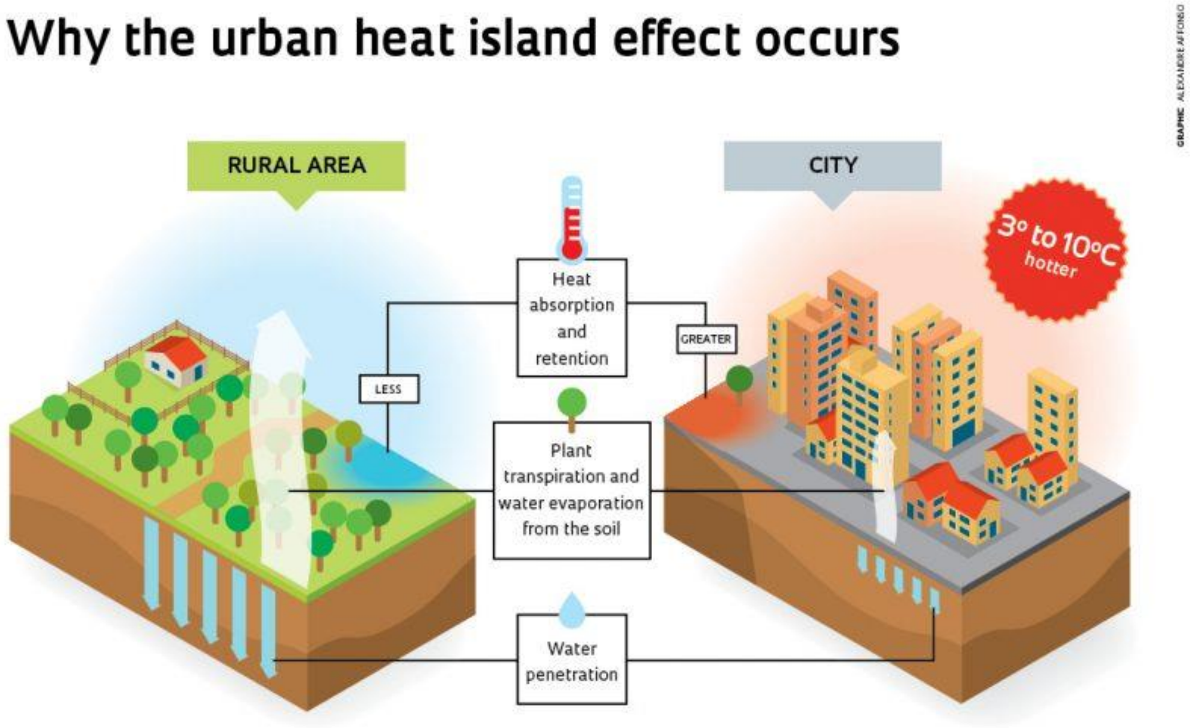


Figure 3. *Schematic of the causes of the urban heat island (https://land8.com/how-landscape-architecture-mitigates-the-urban-heat-island-effect/)*

2.2.2 Urban heat indicators

The urban heat island can be measured through the **air temperature** and/or the **surface temperature**, as both are affected and show warmer temperatures in urban areas than rural areas. Generally, the land surface temperature shows a larger urban heat island during the day since it is determined by the urban surfaces. At night the urban heat island is more prominent in the air temperature, as the urban surfaces which have been absorbing heat during the day release heat at night, warming the air.

As the urban heat island occurs in cities, it inherently affects people (Figure 4). Therefore, there are also human centric indicators of urban heat:

- The **mean radiant temperature** is an indicator of urban heat, though it is generally only appropriate to use during the day. The mean radiant temperature is the average temperature of the surfaces that surround a particular point with which it will exchange thermal radiation. The mean radiant temperature can differentiate between shaded areas and full sun areas, whereas the air temperature cannot as it is measured only in shaded conditions. The mean radiant temperature is often the largest determinant of outdoor human thermal comfort as it is the representation of radiation, and there can be large variations in radiation between areas of full sun and those of shade. Moreover, the mean radiant temperature can capture microclimate effects such as glare. This is crucial when dealing with reflective surfaces such as cool roads which reduce the air temperature and the surface temperature but often can cause discomfort to people due to the reflected radiation hitting people making them feel warmer.

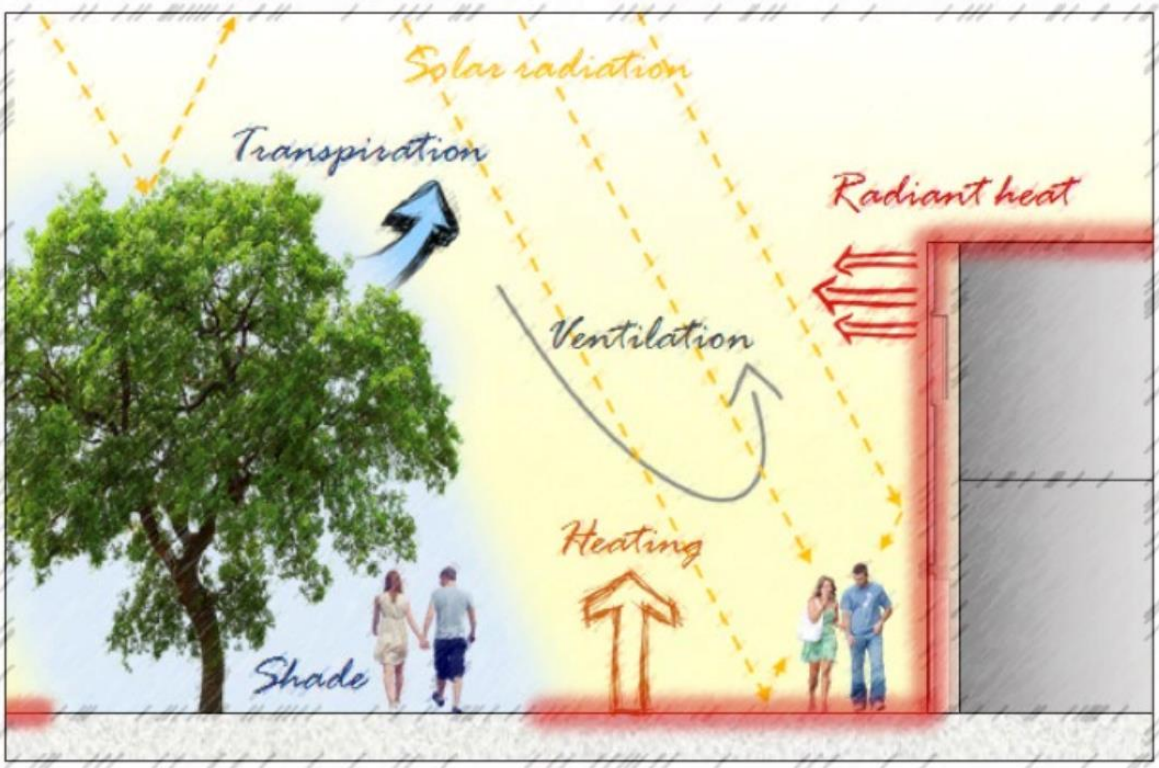


Figure 4. *A person's thermal comfort is determined by their exposure to air temperature, direct and reflected radiation, wind and humidity.* (Coutts and Tapper 2017)

The **Universal Thermal Climate Index (UTCI)** is one of many human centric indicators (see 0 In contrast, deaths from extreme heat often occur within a few days of the extreme heat event, overloading hospitals and morgues. This is seen in the slope of the relative risk (RR) in Figure 6 increasing much faster for deaths related to heat. As climate change continues to warm the planet it is expected that deaths due to extreme cold will decrease and deaths due to extreme heat will increase. Assessing the microclimate for heat and cold will help to ensure that new and retrofitted buildings are appropriate for their climate and able to moderate their temperatures to improve human health and mortality outcomes.

- Measuring the effects of heat and cold on humans) that describe how a microclimate 'feels' to an average person standing outside. The UTCI combines the air temperature, the mean radiant temperature, relative humidity and wind speed to form an equivalent temperature to describe what the meteorological conditions *feel like* outside. This method includes the warming effects of high radiation and high humidity, and the cooling effect of high wind speeds (wind chill effect). During hot weather the mean radiant temperature is the largest determinant of human thermal comfort in the

UTCI where a high mean radiant temperature will likely mean a high UTCI. During winter a high mean radiant temperature might raise comfort levels from cold thermal stress to no thermal stress as the radiation warms them.

- The **Heat Vulnerability Index (HVI)** is a human centric indicator that is often mapped spatially across a city at the Australian Bureau of Statistics Statistical Area 1 scale (SA1). The HVI combines the urban heat island, the amount of green space in an area and a measure of socio-economic status (SEIFA index), to create an understanding of how exposed and vulnerable people are to extreme heat. This indicator identifies where it is hot, but also where the local population is most likely to be negatively affected. For example, a hot area where people cannot afford to cool their homes will have a higher heat vulnerability index than a more affluent area.

2.2.3 Relationship between heat and materials

When assessing the microclimate of a site the composition of the surface (natural or artificial) as well as construction materials can influence the microclimate of a site. This is due to numerous factors such as the albedo, or reflectivity, of a material. For example, an asphalt road is a dark surface that absorbs heat and also re-emits the heat back into the atmosphere resulting in a warmer microclimate directly above the road. A site containing significant proportions of asphalt road will generally be hotter than a site with fewer asphalt roads. A way to mitigate this is to use a more reflective or lighter coloured material such as concrete for roads, or shade roads with tree canopy, which reduces the heat absorbed. Another material factor is how surfaces containing plants and water can reduce the surface temperature cooling the microclimate. Plants use sunlight to photosynthesise, resulting in less heat being absorbed into the surface. Additionally, water uses energy (heat) from the air to evaporate resulting in a cooler microclimate.

Monitoring campaigns of urban areas have found that the surface temperature can vary by nearly 10˚C on a 37˚C day, depending on the material (Coutts and Harris 2012). Table 1 demonstrates the observed surface temperature of various surfaces in South Melbourne.

Table 1: Average land surface temperatures of the major land surface types for the City of Port Phillip focus areas, on a 37˚C day and the following night (adapted from Coutts and Harris 2012).

Surface type	Day (˚C)	Night (˚C)
Concrete	50.45	31.63
Irrigated grass	42.81	25.59
Non-irrigated grass	48	26.27
Road	48.83	29.16
Tile roof	52.20	30.35
Galvanised steel roof	51.59	26.53
Trees	41.59	26.62
Water	44.41	27.72

In urban areas where there are limitations for where plants and water can go there are numerous solutions including:

- Permeable pavement
- Green walls

- Irrigated grass
- Irrigated roads

See Temperature moderating treatments at the Block and Building, and Precinct to Estate scales for more details.

2.2.4 Why do we are care about the urban heat island?

Urban populations are growing globally, including in Australia. Australia is one of the most urbanised countries in the world with 89% of the population living in cities (ABS, 2016). The urban microclimate can become compromised in high density areas such as a central business district, where high building densities have been shown to reduce sunlight, trap heat and reduce air flow (Duarte et al. 2015). The urban heat island effects the residential areas of cities too with urban densification and sprawl reducing the amount of public and private green space, causing stress to ecosystems and increasing the urban heat island effect (Davies et al. 2017). This results in a triple bottom line effect of the urban heat island effecting the environment, society and the economy through heat-related deaths, air pollution, water consumption, energy use and greenhouse gas emissions (Wilkinson & Dixon, 2016).

2.3 Climate change

Urban areas are also affected by climate change which places acute stresses on the community and the ecosystems on which we rely, reducing the liveability of cities. In the ACT, annual average temperatures have risen at a rate of 0.4˚C per decade since 1980 (Climate Chip 2020) (Figure 5). Maximum and minimum temperatures in the ACT are expected to increase by 1.4 – 2.3˚C in the far future (2060-2079), while the number of cold nights will decrease (NSW Government Office of Environment and Heritage 2015).

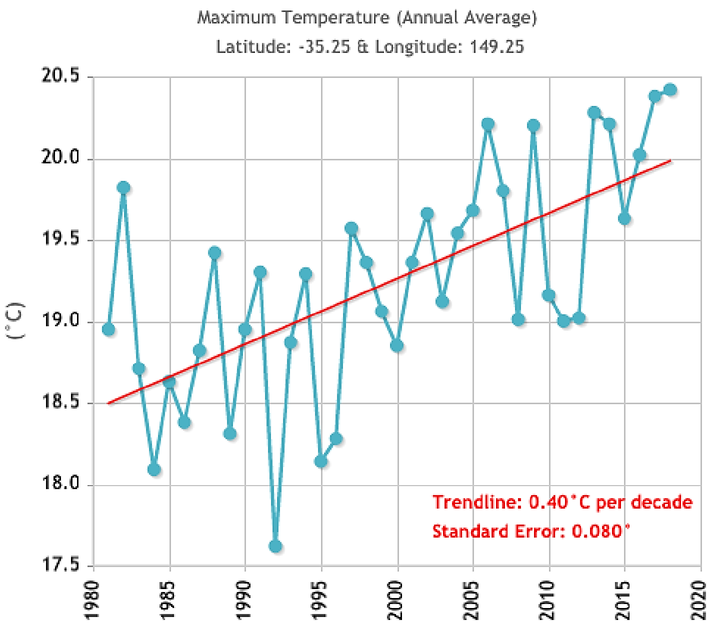


Figure 5. *Annual average temperature trend for Canberra from 1981 -2018* (Climate Chip 2020).

The ACT and surrounding region are projected to experience longer, hotter summers and increased frequency and severity of storm events. These conditions increase the level of threat from bushfires, heatwaves and violent storms to lives, property, economic activities and the natural environment. Key impacts identified include (Climate Change in Australia 2021):

- The climate will be hotter, with warm days starting earlier in spring, and with heatwaves more frequent and of longer duration.
- The climate of Canberra is projected to be more like the current climate of Albury-Wodonga

- The annual quantity of rainfall may remain the same but will likely decrease in winter and spring and increase in autumn.
- The storm season will likely extend from spring into autumn.
- Longer periods of hotter weather will likely result in the environment being drier overall. This would contribute to an increase in severe fire weather days over a longer fire season.
- Longer fire seasons with approximately 40% more very high fire danger days
- Approximately 20% fewer East Coast Lows under a high emission scenario, mainly due to a reduction of events in winter
- An increase in snowmelt and decline in snowfall.

ACT climate projections also indicate the frequency and intensity of extreme weather events is expected to increase (e.g., maximum and gusting wind speeds, rainfall intensity, etc). Canberra's rainfall averages 52.4 mm per month and 629 mm annually. The average is 108 rain days per year; however, local variability can mean no rain in some months, and the whole season's rain in just a few days. Climate projections indicate a further reduction in rainfall reliability. In the mid to longer term, winter and early spring rain will decrease, but there will be more intense rain events in the warmer months of late spring and summer.

2.4 Human health, heat and cold

The urban heat island effect poses a danger to human health through raising the temperature in cities, particularly during heatwaves. Heatwaves, known as the "silent killer", have caused more fatalities in Australia since 1890 than bushfires, floods, earthquakes, tropical cyclones and severe storms combined (Hughes et al. 2016). This is due to often vulnerable people such as young children and the elderly suffering heat stress and hyperthermia from elevated body temperatures, due to their poorer ability for thermoregulation.

Early symptoms of heat stress include headaches, dizziness, faintness, nausea and vomiting (ACT Government Health 2018). The risk of heat stress increases dramatically when the average of the maximum air temperature from one day and the subsequent night's minimum air temperature exceeds 28˚C (Nicholls et al. 2008; ACT Government Health 2018) e.g. this can occur when a 40˚C day is followed by a 20˚C night, resulting in an average air temperature of 30˚C. It is at this threshold when heat stress is likely to occur because it is too hot for people to cool down at night. The risk of exceeding the average air temperature 28˚C threshold is higher during heatwaves where there is prolonged periods of high day and night temperatures.

Heatwaves in Australia are expected to become hotter, longer and more frequent (Cowan et al. 2014; NSW Government Office of Environment and Heritage 2015). Therefore, the combination of the urban heat island and heatwaves raises the risk of deadly heat stress in cities in the current and future climate (Fischer et al. 2012).

Deaths in Australia increase by 20–30% during the colder months, often due to poor quality housing stock with minimal insulation (Gasparrini et al. 2015; ACT Government 2019). In the colder climates of Australia, including the ACT, increases in deaths during colder months and decreases in deaths during warmer months has been reported (Longden 2019). Generally, deaths in winter are spread throughout the season as there is no defined threshold where deaths increase dramatically. This is seen in the slope of the relative risk (RR) in Figure 6 which gradually increases for cold deaths.

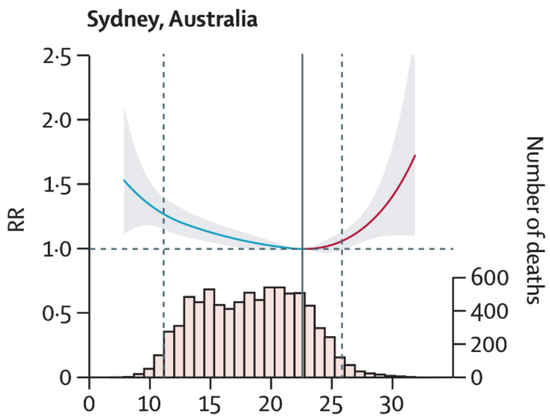


Figure 6. *Exposure-response associations as best linear prediction (with 95% empirical confidence intervals, shaded grey) in Sydney, Australia, with related temperature distributions. Solid grey lines are minimum mortality temperatures and dashed grey lines are the 2.5th and 97.5th percentiles. RR=relative risk. Adapted from Gasparrini, Guo and Hashizume 2015).*

In contrast, deaths from extreme heat often occur within a few days of the extreme heat event, overloading hospitals and morgues. This is seen in the slope of the relative risk (RR) in Figure 6 increasing much faster for deaths related to heat. As climate change continues to warm the planet it is expected that deaths due to extreme cold will decrease and deaths due to extreme heat will increase. Assessing the microclimate for heat and cold will help to ensure that new and retrofitted buildings are appropriate for their climate and able to moderate their temperatures to improve human health and mortality outcomes.

2.5 Measuring the effects of heat and cold on humans

To assess the effects of heat and cold on human health, a measure of outdoor human thermal comfort is often used (Goldie et al. 2017). This is because factors such as wind, humidity and radiation can alter how a person ‘feels’ in an environment (Anderson et al. 2013). A measure of human thermal comfort establishes an ‘equivalent temperature’ that aims to quantify how an average person feels based on the environment. For example, a cold and windy day would have an equivalent temperature lower than the air temperature as the wind makes it ‘feel colder’, otherwise known as wind chill. Conversely, a person standing in the sun as opposed to the shade would experience an equivalent temperature that is higher than the air temperature. Both the air temperature and equivalent temperature are given in degrees Celsius for easier comprehension and comparisons.

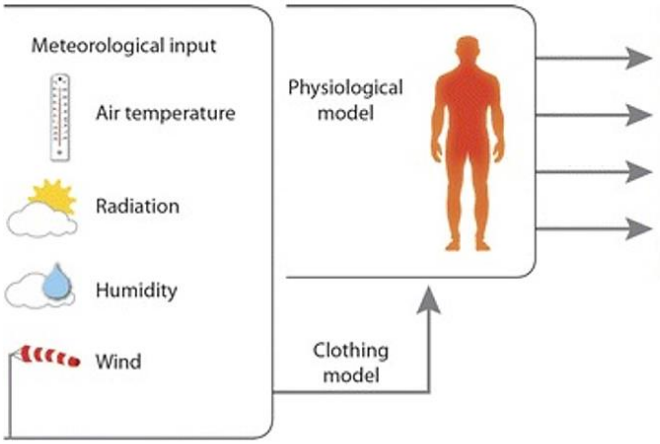
There are many measures of outdoor human thermal comfort used around the world. The Australian Bureau of Meteorology uses two metrics, the Apparent Temperature (AT) (Steadman 1994) and the Wet Bulb Globe Temperature (WBGT) (Budd 2008):

- The AT (displayed as ‘Feels like’ on the Bureau of Meteorology weather app) combines the effects of wind, humidity and air temperature and quantifies thermal comfort from extreme cold to extreme heat. It uses commonly available meteorological data and does not require special instrumentation. The AT is expected to increase in south eastern Australia due to climate change (Jacobs et al., 2013).
- The WBGT was created to determine safe times for athletes to exercise in extreme heat and only combines the effects of heat and humidity. The WBGT requires special instrumentation to calculate heat stress, and some of the assumptions are considered out of date as it does not consider modern sophisticated human energy budget models (Thorsson et al. 2020).

There are two metrics of human thermal comfort that more accurately predict the effects of weather on human health (Thorsson et al. 2020):

- Physiological Equivalent Temperature (PET) (Walther and Goestchel 2018)
- Universal Thermal Climate Index (UTCI) (Bröde et al. 2013).

Both of these metrics combine meteorological data including air temperature, humidity, wind speed and radiation with complex human clothing models and physiological energy budget models. It is the inclusion of radiation, whether direct from the sun or reflected off surfaces that greatly improves the accuracy of these metrics compared to others. The AT assumes people are standing in the shade, as this is how the air temperature is measured. The PET and UTCI quantify the warming effect of standing in the sunshine as well as standing in the shade. Both the PET and UTCI quantify human thermal comfort from extreme cold to extreme



heat. A schematic of the UTCI is shown in

UTCI (°C) range	Stress Category
above +46	extreme heat stress
+38 to +46	very strong heat stress
+32 to +38	strong heat stress
+26 to +32	moderate heat stress
+9 to +26	no thermal stress
+9 to 0	slight cold stress
0 to -13	moderate cold stress
-13 to -27	strong cold stress
-27 to -40	very strong cold stress
below -40	extreme cold stress

Figure 7 with the output scale advising the likely comfort level from the conditions. When assessing outdoor human thermal comfort, most microclimate tools and models use the UTCI and/or PET. Indoor human thermal comfort can also be calculated using these metrics as indoors the mean radiant temperature is the same as the air temperature.

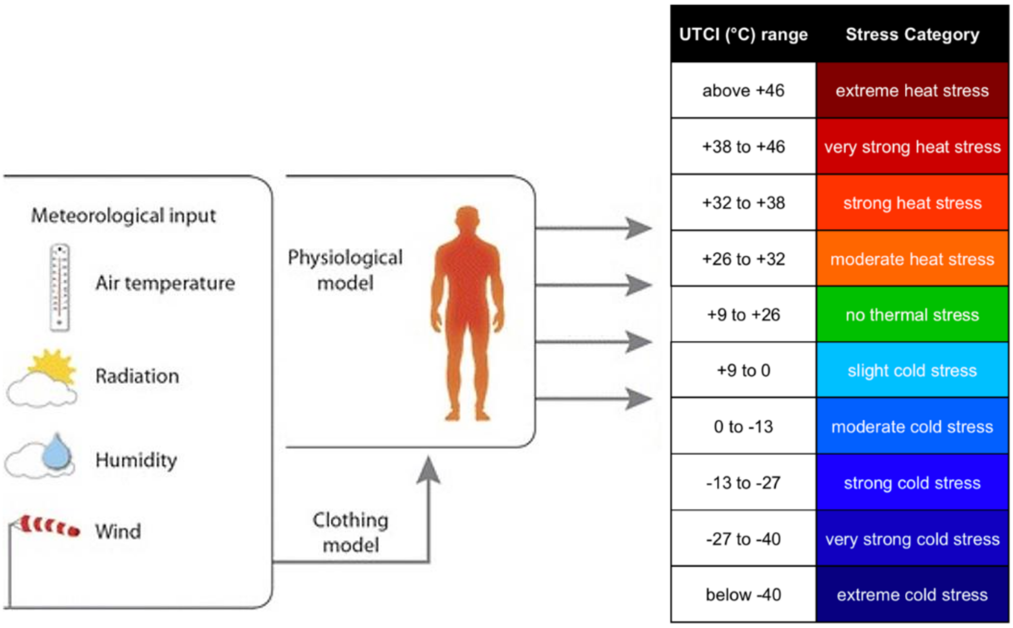


Figure 7. *Schematic of the Universal Thermal Climate Index (UTCI). Based on Błazejczyk et al., (2013) and (Pappenberger et al. 2015).*

2.6 Co-benefits to microclimate moderation

By understanding and addressing urban heat and extreme cold microclimates, numerous co-benefits can be achieved affecting the triple bottom line. Figure 8 lists co-benefits to microclimate moderation, though the list is not exhaustive as more benefits are continually being quantified in research and practice (sources of benefits: Plant et al. 2016; Zander et al. 2015; Castiglia Feitosa and Wilkinson 2018; Li et al. 2019; Victorian DELWP 2019; Jacobs et al. 2018; De Castro Pena et al. 2017; Atkins et al. 2012; Silva et al. 2010; Coty of Parramatta 2017)

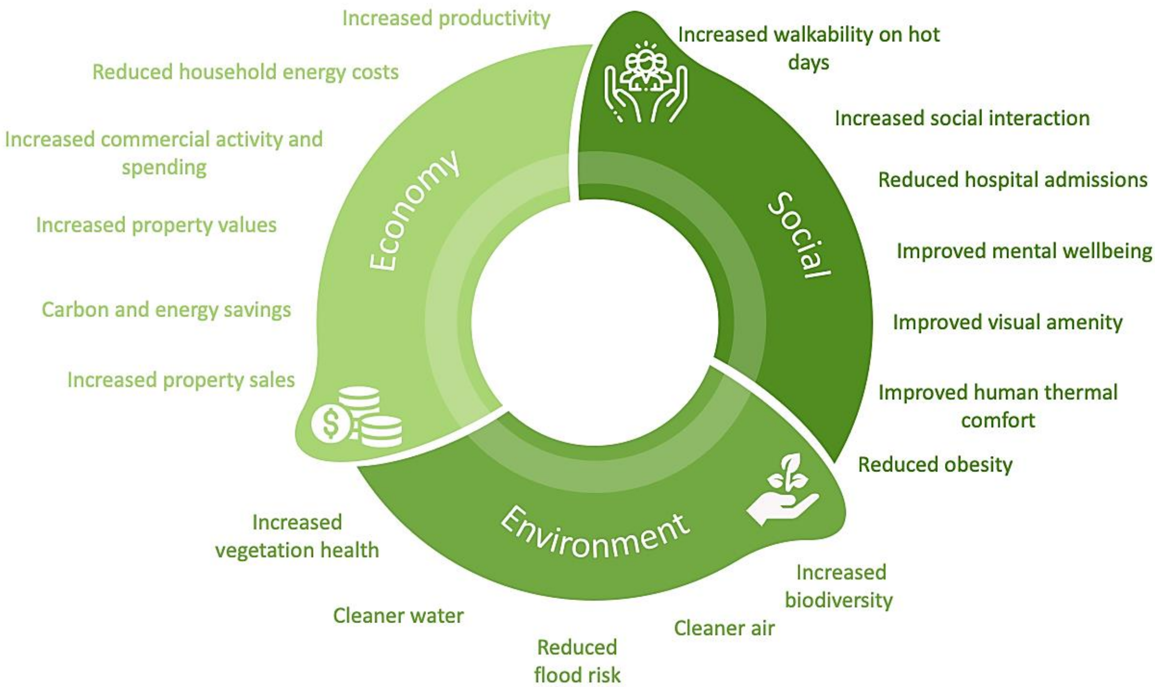


Figure 8. *Co-benefits of microclimate moderation based on the economic, environmental and social benefits.*

3 Urban microclimates in the ACT

3.1 Current priority areas for intervention and future challenges in Canberra

The CSIRO conducted an observational campaign for the ACT using satellite data from the Landsat8 satellite and the MODIS satellite (CSIRO Research Publications Repository 2017) to quantify the land surface temperature and urban heat across the ACT. Central urbanised areas in the northeast have surface temperatures considerably higher than the national parks in the southwest. The high-resolution data demonstrates the different temperatures across neighbourhoods in the ACT as well as cooler temperatures on the southern side of mountains as they are less exposed to the sun.

The CSIRO study extended to understanding the vegetation cover across the city and determining areas of heat vulnerability. Some of the hottest areas identified in the ACT were new housing developments, large shopping centres, the airport and industrial areas (Figure 9). Heatwaves and hot days will impact multiple service areas in the ACT including community health and well-being, settlements and infrastructure, disaster and emergency management and natural resources and ecosystems (Jacobs et al. 2014).

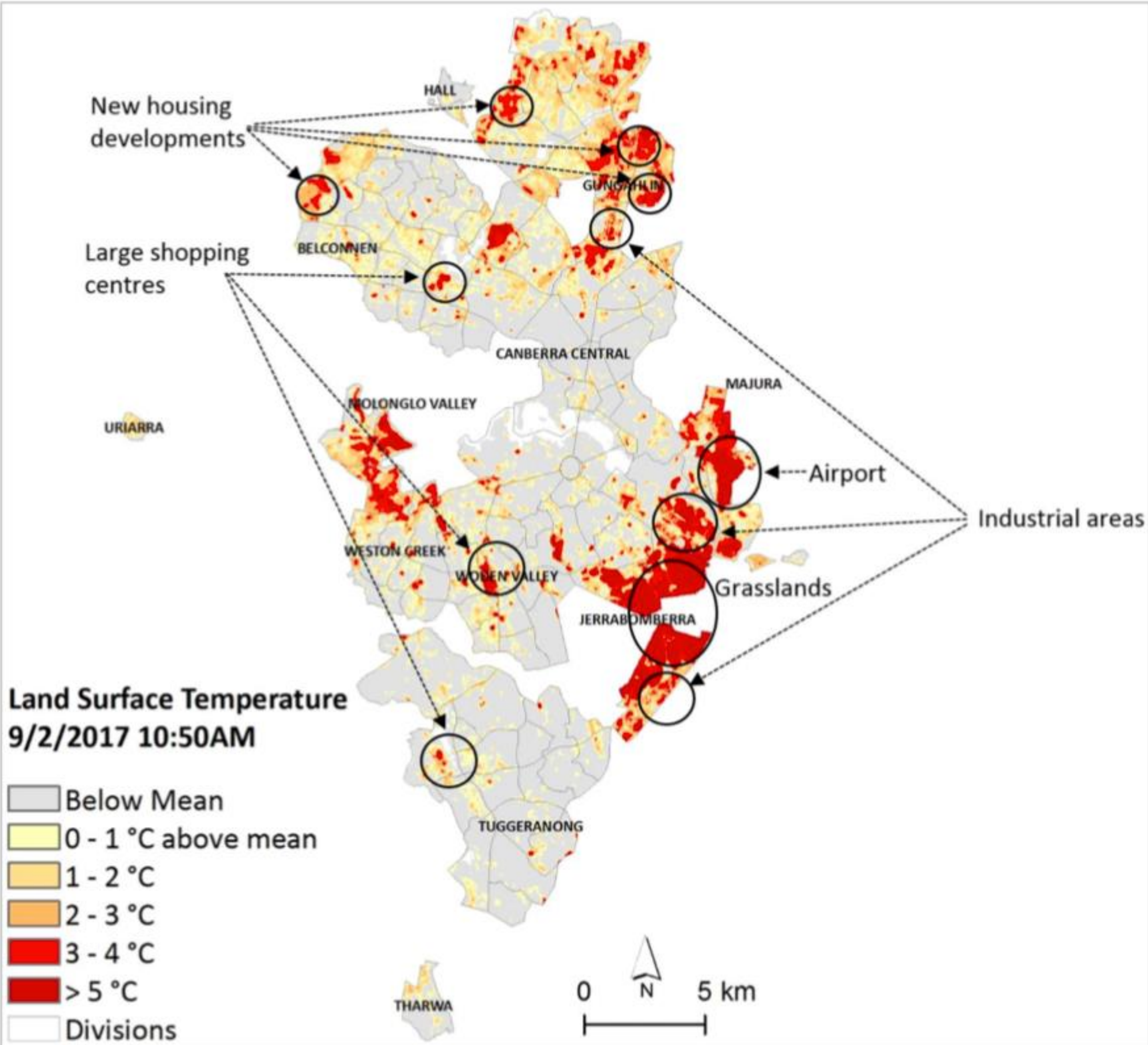


Figure 9. *Hot spots defined as departures from 35˚C, which is the mean land surface temperature for the area shown. Temperature is derived from Landsat8 thermal imagery on 9 February 2017 (10.50am AEDT).*

The ACT microclimate also captures extreme cold due to its inland location and relatively high altitude. Minimum air temperatures are regularly colder than 0˚C in the ACT exposing the population to the potential of cold stress and ensuring that buildings need to be heated in winter to remain comfortable.

As demonstrated in Figure 6, extreme cold can be just as deadly as extreme heat in Australia. This poses a challenge to urban designers and developers to ensure that planning and design accounts for comfortable indoor and outdoor microclimates throughout the year. Heat mitigating options like cool roofs reduce the temperature of buildings by reflecting sunlight away and are very effective at reducing cooling costs in summer. However, in winter, this may increase heating costs as the building does not get as warm from sunlight. In contrast, planting deciduous trees can increase shading in summer while also allowing for natural light penetration in winter, allowing for a more comfortable microclimate throughout the year. Treating the microclimate is a process of understanding competing values for a stakeholder and a site.

3.2 Policy context for microclimate assessments and interventions

The ACT Government is committed to addressing the urban heat island effect in Canberra. Key policy strategies are described briefly below.

3.2.1 2018 ACT Planning Strategy

The 2018 ACT Planning Strategy recognises that Canberra is already experiencing the effects of climate change and that improving 'living infrastructure' (plants, soils and waterways) will help reduce urban heat impacts. Multiple "Directions" within the Strategy that support urban heat mitigation including:

- Direction 2.3 Improve the character of our city centre to improve liveability and activity.
- Direction 3.2 Reduce vulnerability to natural hazard events and adapt to climate change.
- Direction 3.3 Integrate living infrastructure and sustainable design to make Canberra a resilient city within the landscape.
- Direction 4.2 Deliver recreation, open (green) space and public spaces that support social interaction, physical and mental health and engagement in public life.
- Direction 4.5 Encourage high quality design, built form and places for a changing climate.
- Direction 5.3 Create a better experience for walking and cycling into and within the city centre and our town centres.

'*Effective steps will need to be taken to manage the heat-island effect in urban intensification areas*' (ACT Government.,2018, p.69).

3.2.2 ACT Climate Change Strategy

Part of the Vision of the ACT Climate Change Strategy sees an ACT where 'urban heat impacts will be reduced by an established network of street trees, waterways and parks supported by healthy soils.' The intent behind this vision is outlined deeper in the strategy, where 'reducing the urban heat island effect will reduce health costs and impacts.' In particular, this project will support the implementation of the Strategy under Goal 4I: 'Reduce urban heat and improve liveability'.

Action 4.22 under this goal includes a note to 'assess local needs for managing heat'. The Strategy itself goes on to outline key aspects of the ACT Government's approach to reducing urban heat, including achieving a 30% tree canopy cover and reducing heat absorption of building surfaces and pavements. The way in which private and public developments respond to urban heat challenges will influence not only the achievement of canopy cover targets, but also the degree to which health costs and impacts are addressed.

3.2.3 Canberra's Living Infrastructure Plan

Canberra's Living Infrastructure Plan defines much of the intent behind addressing urban heat, stating a target in Action 2 of 30% canopy cover, and illustrating the effects of local urban heat on "comfort, health, energy use and costs".

This guide responds to Action 3 of the plan, to '*Prepare a Microclimate Assessment Guide and mandate its use to inform policy and forward planning studies for centres, urban renewal projects and urban intensification precincts, with initial assessment of priority locations to inform a city cooling works program*.' Action 4 builds on this by seeking to introduce requirements for microclimate assessments of significant developments.

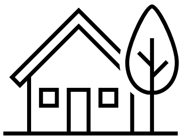
4 How to use this microclimate assessment guide

4.1 Structure of the Guide

This Guide provides information on the where, when, who, why and how of microclimate assessments and what can be done to mitigate the negative impacts of urban heat and cold stress.

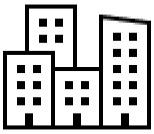
Where

The Guide has been structured into three sections that provide information at the following scales:



1. Block or single building scale (~4,000 sqm or less)
   (e.g., single dwelling, dual occupancy, apartment building, school, hospital, car park)

2. Precinct to estate scale (~4,000 sqm to ~100 ha)
   (e.g., town centre, park, large residential subdivision, industrial block/precinct, greenfield estate)



3. District to city-wide scale (> ~100ha)
   (e.g., city district, whole-of city)

The information you need to undertake a microclimate assessment at a particular scale is provided in these sections. A summary of the information in each section is shown below and illustrated in Figure 10.

When

Microclimate assessments can provide valuable and often critical information at each of the following development phases:

- **Early planning stage** – initial high-level investigations to inform site selection, strategic planning and design concepts.
- **Detailed design and approval** – the user has a design of the site and the microclimate assessment will inform design and detailed layout options, including likely hot and cold spots in their design
- **Planning and conducting infrastructure maintenance or renewal** – the user is assessing existing microclimate treatment infrastructure or renewing an existing site to improve the microclimate and inform the selection of treatment options where the built environment remains largely the same
- **Monitoring and performance evaluation** – the user is measuring the effectiveness of the microclimate prevention/treatment solutions at a site.

The assessments can be undertaken at any time of the year, though observational assessments are best undertaken on sunny days with minimal wind. This is because wind mixes warm and cool air reducing the contrast between hot and cool spots that can be observed at a site.

Why
The Guide also provides information on why microclimate assessments are useful at different stages of development and the benefits these assessments can provide to improve and support comfortable microclimate conditions at different scales.

Who
The Guide provides information on who should / can perform microclimate assessments at each development phase. The guide lists who is primarily responsible for undertaking microclimate assessments, and secondary contractors who are likely to have the technical expertise to carry out assessments if required.

What
The guide outlines different methods to assess and understand the microclimate of your subject area.

The guide is not intended to advise on the best treatment solutions for the specific site. Instead, the guide provides information on potential solutions for managing microclimates. It outlines treatment options that are available and appropriate specific to each scale. This includes urban layout such as the orientation of streets, building design layout such as cool roofs and nature solutions such as canopy trees and irrigated green space.

How
The Guide provides information on how to complete a microclimate assessment appropriate for each development phase. There are numerous methods and approaches of varying difficultly. These include information on data sources, tools and models that are most appropriate to microclimate assessments in the ACT. The methods are split into:

- Observational methods – methods that require either desktop and/or on-site investigation of the site area and surrounds that will affect the microclimate
- Data analysis – methods that utilise Ratings tools (see below) such as satellite land surface temperature datasets to determine existing microclimate conditions
- Modelling methods – methods that rely on Simulation Tools (see below) such as software applications to simulate design scenarios to assess the microclimate of a possible development. As these software applications are often complex and require specialist expertise, additional information such as the software costs and applicability are discussed.

The microclimate assessment methods include information such as:

- Skills – refers to the expertise required to conduct the assessment method
- Scale (where applicable) – some methods have a scale limitation and cannot be applied to the maximum size of their development scale. For these cases the scale is indicated.
- Access and costs – refers to whether a method requires data or a tool that uses a licence, and the cost associated with procuring the tool or sourcing data for the assessment.
- Outputs – the expected outputs from the microclimate assessment method.
- Limitations – limitations of the methods
- Risks – risks involved with applying the method

Most of the microclimate assessment methods are standalone, though some require data or analysis from other methods. This is indicated within the instructional steps.

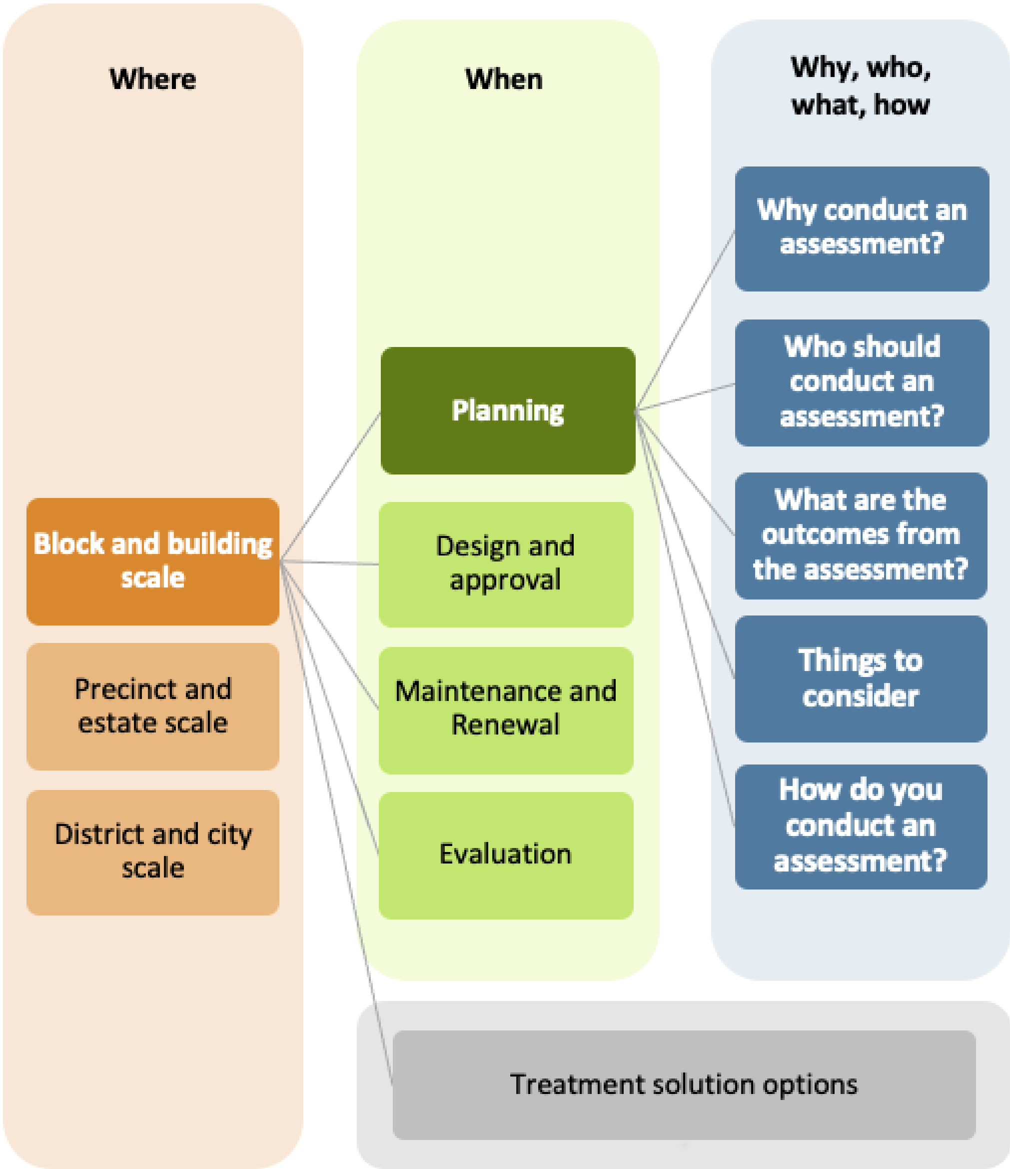


Figure 10. *Summary of information provided in this Guide*

4.2 Which method to use

The methods range in difficulty from easy (qualitative microclimate assessment) to medium (spatial data analysis) to difficult (modelling methods). Each of the methods will produce a different level of information and degree of assessment. It is important to consider which method(s) are most appropriate on a case by case basis.

The cost, time and the skills associated with each method requires consideration when conducting a microclimate assessment. Easier methods can take less than an hour and cost nothing, while harder methods such as microclimate modelling can cost tens of thousands of dollars and take more than a month to complete depending on the software, whether external consultants are needed and the project parameters. While all assessment methods give an understanding of the microclimate of the site, the modelling methods enable more flexibility and nuance, as well as giving quantitative results. In contrast, the easier qualitative methods give an understanding of hot and cold spots based on the location, design or surrounding environment.

In general, lower value or community-led projects should focus on quick and easy methods. In each section these have been indicated with a star ( ) next to the title. It is advised that if only one method can be completed for the microclimate assessment, it is this method. Conversely, high value projects like major developments should ideally do more and harder microclimate assessments and consider using modelling methods. The best but most expensive microclimate assessment methods are marked with a circle ( ).

If you are delivering a project for the ACT Government, or seeking approval from the ACT Government for a proposal, you may be required to use specified methods at specified stages of the project.

4.3 Rating and simulation tools for the microclimate

There are numerous tools that can be used to assess the microclimate and they can be defined as either Ratings tools or Simulation tools.

Rating tools are used to determine the urban heat of a particular setting at a particular point in time. An example of this is aerial heat mapping of an entire city using thermal imagery. This allows the viewer to identify hot and cold spots within a defined area. Rating tools provide a snapshot of a particular landscape and are useful for identifying certain materials that may be contributing to the UHI effect. For example, synthetic Astroturf may be identified as a hot spot. However, these tools are typically only recording Land Surface Temperature. Using GIS on a site is considered a Rating tool, as it does not simulate future changes to land use or offer scenario options. Rating tools are not necessarily an accurate measure of thermal comfort and should only be used to assess surfaces that may absorb and emit heat.

A Simulation tool is a platform that allows for the future projection of urban heat based on changes to land use, development and climate. Simulation tools are beneficial as they allow the user to assess the microclimate and apply a range of scenarios such as testing whether planting trees or using reflective pavements would provide a larger cooling effect. In effect, Simulation tools let you "try before you buy" in terms of understanding hot and cool spots at a site or in the design, and for moderating the microclimate. There are numerous microclimate models that are simulation tools, where an example of a simulation tool would be the models ENVI-met, SOLWEIG and Target. These three models feature in the Microclimate Assessment Guide where their positives and negatives are discussed, to aid decision-making. A limitation of Simulation Tools is they often require computer science expertise, urban climate expertise and are usually financially and computationally expensive to run. A further limitation is that they require detailed plans to be used in the simulation.

4.4 Summary of microclimate assessment methods

The following table lists every microclimate assessment method in the Guide, separated by scale, development stage, method type and the name of each method. Most methods are appropriate for more than one scale and development stage and are listed multiple times in the table. The free and simple microclimate methods have been indicated with a and expensive yet the top performing have been indicated with a , as they have been in sections 5–7 of the Guide.

Scale	Development stage	Method type	Name
Building and block	Early planning	Observational methods	Thermal imaging cameras
			Meteorological monitoring with weather stations
	Design and approval	Observational methods	ACTmapi
			Qualitative assessment of building plans
		Data analysis	CSIRO land surface temperature and urban heat island data

Scale	Development stage	Method type	Name
		Modelling methods	ENVI-met model
			SOLWEIG model
			CRC for Water Sensitive Cities Scenario Tool
	Maintenance and renewal	Observational methods	Inspection of infrastructure
		Modelling methods	ENVI-met model
			SOLWEIG model
			CRC for Water Sensitive Cities Scenario Tool
	Evaluation	Observational methods	Inspection of infrastructure
			Thermal imaging cameras
			Meteorological monitoring with weather stations
		Modelling methods	ENVI-met model
			SOLWEIG model
			CRC for Water Sensitive Cities Scenario Tool
Precinct to estate scale	Early planning	Observational methods	ACTmapi
			Surface temperature monitoring campaign with drones
		Data analysis	CSIRO land surface temperature and urban heat island data
			Wind direction on extreme heat and cold days
			A holistic prioritisation method for microclimate assessment
	Design and approval	Observational methods	Principles of urban climate to qualitatively assess your site
		Data analysis	CSIRO land surface temperature and urban heat island data
			Wind direction on extreme heat and cold days
			A holistic prioritisation method for microclimate assessment
			TARGET model

Scale	Development stage	Method type	Name
		Modelling methods	ENVI-met model
			SOLWEIG model
			CRC for Water Sensitive Cities Scenario Tool
	Maintenance and renewal	Observational methods	Observational microclimate checklist and principles of urban cooling to qualitatively assess your site
			Thermal imaging cameras
		Modelling methods	TARGET model
			ENVI-met model
			SOLWEIG model
			CRC for Water Sensitive Cities Scenario Tool
	Evaluation	Observational methods	Site monitoring checklist
			Meteorological monitoring with weather stations
			Surface temperature monitoring campaign with drones
			Survey precinct residents and workers
		Data analysis	Landsat8 land surface temperature
		Modelling methods	TARGET model
			ENVI-met model
			SOLWEIG model
			CRC for Water Sensitive Cities Scenario Tool
District to city scale	Early planning	Observational methods	ACTmapi
			Surface temperature monitoring campaign with drones
		Data analysis	CSIRO land surface temperature and urban heat island data
			Global air temperature and outdoor human thermal comfort dataset
			Bureau of Meteorology spatial maximum and minimum temperature

Scale	Development stage	Method type	Name
			Wind direction on extreme heat and cold days
			A holistic prioritisation method for microclimate assessment
	Evaluation	Data analysis	Landsat8 land surface temperature
			Hospital admissions, ambulance call outs and mortality data relating to extreme heat and cold

5 Block-scale microclimate assessments (~4,000 sqm or less)

Microclimate assessments at the block scale are beneficial as they can help to:

- Inform where in a block is likely to be more exposed to heat
- Inform block and building design
- Inform where microclimate treatment will be most beneficial

Assessments are effective at the early planning and detailed design stages as the building layout can have long-term implications for the local microclimate, and these should be addressed when designing the block. Assessments at this scale can also be useful for assessing existing infrastructure to identify opportunities for retrofitting microclimate treatment measures and in monitoring and evaluating the performance of microclimate moderation measures to inform renewal needs.

When assessing the urban microclimate at the block scale it is important to understand building footprints, solar radiation and shading, and existing vegetation at the site, as these are the main determinants of microclimate at this scale. Understanding these can inform design but also prioritise areas for retrofitting microclimate treatments.

Examples of block scale activities where a microclimate assessment could be used include:

- Block-scale Territory Plan variations such as rezoning
- Development applications where building design and landscape layout is determined
- Retrofitting buildings
- Community learning from the evaluation outcomes

Early planning

(e.g., new dwellings, new mixed-use buildings, block scale Territory Plan variations such as rezoning)

Why do an assessment at this stage?	• To improve early site development plan considerations and decisions for new buildings and facilities. • To understand potential site constraints and opportunities with respect to microclimate impacts.
Who should do them?	***Primary responsibility:*** Leaseholders, land and property managers, including government agency staff in the case of public land and buildings (e.g., hospitals, schools, government offices and public facilities such as galleries libraries, museums and memorials).
	Secondary contractors: Planning and design consultants
What are the outcomes from the assessment?	• Understanding the existing microclimate conditions of a site to better inform design outcomes.
Things to consider when doing the assessment	1. What are the hot and cool spots across the block and neighbouring areas? 2. Is there existing vegetation at the site? 3. Are there existing buildings on site – will they be reused / redesigned or removed? 4. How does the height of the existing buildings or new design compare with others in the area? 5. Does the site have good solar access? 6. Will the site receive shade from neighbouring buildings? Will the site shade neighbouring buildings? 7. Which direction is the block facing? 8. How exposed are the existing or proposed north and west walls to summer heat and south and east walls to winter cold? 9. How does stormwater move across the site? 10. Can green infrastructure be incorporated to maximise a comfortable microclimate? 11. Does the block design require that trees are removed? If so, how can the effects of this be ameliorated? 12. Is there room for a vegetated set back from the street?

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13. What is the end use for the site – a public space with a large area needed for outdoor use? Or a fully developed site?
14. Will people be spending large amounts of time in the facility or in the outdoor spaces? What time of day / night will people be present/gathering?

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<tr><td>How do you do them?</td><td>Observational methods</td><td>

★ Thermal imaging cameras or spot thermometers (instantaneous surface temperature measurements)

Skills required: None

Access and cost: Thermal imaging cameras or thermometers need to be purchased. (Climate Change and Sustainability Division have access to this equipment)

Outputs: Images of the surface temperature across the site which demonstrate whether areas with microclimate treatments are cooler than areas without microclimate treatments.

Limitations: Ensuring observations are comparable can be difficult, particularly if background weather conditions can influence the surface temperature. Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.

Risks: Monitoring is not conducted on a sufficient scale to consistently determine the hot and cool spots of the site.

These cameras can be used to produce thermal images of the surface temperature of a site. The surface temperature can be used as a proxy for air temperature, except on windy days. These cameras and thermometers can be obtained from many resources including Bunnings, Amazon and other sellers. Some cameras can become an attachment to mobile phones.

1. Plan where observations will be taken around the site. Consider sites that will measure the temperature of the north, south, east and west facing walls of the building or block.
2. Go to each site, adjust the site if necessary, to provide better imagery (e.g. if a tree is in the way of the original planned site). Geolocate the site. This can be done through dropping a pin on Google Maps, which records the latitude and longitude to seven decimal places.
3. Note the time of observation and meteorological conditions at your site:
   - Is it sunny or cloudy?
   - Is it windy or calm?
   - Is it raining?
4. Take photos with the thermal imaging camera or spot thermometer of your site. Note the height above the ground that you are taking the photos/recording the temperature. Record the observations.
5. When analysing data look for hot and cool spots across the site. The surface temperatures should be mitigated by the microclimate moderation technology.
6. Repeat on days with similar meteorological conditions and at a similar time of day.

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Meteorological monitoring with weather stations

Skills required: GIS, weather station installation expertise.

Access and cost: Weather stations and equipment need to be purchased. Each weather station usually costs more than $100

Outputs: Time series and maps of the average air temperature across the site, highlighting the hot and cool spots. These measurements will form a baseline from before construction, which can be compared with measurements taken during a monitoring and evaluation period.

Limitations: A sufficient spatial and temporal coverage of weather stations is required to properly assess the microclimate of the site

Risks: The location of the weather stations may need to change once the site design is complete.

Before construction, place a minimum of four weather stations around the site. Weather stations can be procured from this website, though cheaper options are available. All weather stations should be the same make and brand. The weather station would ideally measure air temperature, relative humidity, wind speed and radiant temperature. They would also have Wi-Fi capability so that data is directly stored on a cloud server.

1. Place the weather stations a consistent height above the ground, make sure the weather station has full access to the wind from all directions. Ensure an even spread of weather stations across the site, though areas previously identified as hot or cool spots, or flagged for microclimate moderation can have more weather stations.
2. Geolocate the site. This can be done through dropping a pin on Google Maps, which records the latitude and longitude to seven decimal places.
3. Throughout the monitoring period record the air temperature, relative humidity, wind speed and radiant temperature
4. Select the hottest or coldest 5% of days within the most recent complete season of summer or winter for each weather station.
5. Calculate the average of the hottest or coldest 5% for each weather station.
6. Interpolate the weather station data spatially across the site using GIS software.
7. Plot the spatial average temperature across the site.
8. Look for hot spots and cool spots.
9. Repeat steps 4-8 for each monitoring period.

Design and approval

(e.g. development application phase where building design, landscape layout etc is determined)

Why do an assessment at this stage?	• To ensure building and landscape design supports comfortable outdoor microclimates. • To reduce whole of lifecycle costs by avoiding creating uncomfortable outdoor microclimate that require retrofitting in future.
Who should do them?	***Primary responsibility:*** Planning and urban design professionals, landscape architects, project managers.
	Secondary contractors: Urban climate scientists or environmental consultants with specialist expertise in microclimate assessment and GIS.
What are the outcomes from the assessment?	• Qualitative or quantitative understanding of hot and cool spots from building plans and designs. • Inform design and detailed layout options
Things to consider when doing the assessment	1. What are the hot and cool spots across the block and neighbouring areas? 2. Is there existing vegetation at the site? 3. Are there existing buildings on site – will they be reused / redesigned or removed? 4. How does the height of the block existing buildings or design compare with others in the area? 5. Does the site have good solar access? 6. Will the site receive shade from neighbouring buildings? Will the site shade neighbouring buildings? 7. Which direction is the block facing? 8. How exposed are the existing or proposed north and west walls to summer heat and south and east walls to winter cold? 9. How does stormwater move across the site? 10. Can green infrastructure be incorporated to maximise a comfortable microclimate? 11. Does the block design require that trees are removed? If so, how can the effects of this be ameliorated? 12. Is there room for a vegetated set back from the street? 13. What is the end use for the site – a public space with a large area needed for outdoor use? Or a fully developed site? 14. Will people be spending large amounts of time in the facility or in the outdoor spaces? What time of day / night will people be present/gathering?

How do you do them?	*Observational methods*	ACTmapi viewer *Skills required: Urban design skills or experience desirable* *Access and cost: Free* *Outputs: Information on existing factors contributing to undesirable microclimate conditions and recommendations on design alterations and/or microclimate moderation/treatment options* *Limitations: This is a qualitative method using satellite images, potentially resulting in missed analysis opportunities gained from a site visit.* *Risks: The satellite data may not be up to date, resulting in the analysis being performed on out of date images.* ACTmapi is the ACT Government's interactive mapping service that provides a convenient and fast way to analyse ACT spatial data 1. Open ACTmapi and select basic map 2. Zoom to your site. 3. Observe and look at the size of the site, and neighbouring blocks. 4. Consider whether the building footprint could be reduced in favour of plantings for microclimate moderation. 5. Which direction is your site facing? How exposed or shaded is the site? How will this affect your design? 6. Is there significant existing vegetation at the site?
		Qualitative assessment of building plans *Skills required: Urban design skills or experience desirable* *Access and cost: Free* *Outputs: Information on existing factors contributing to undesirable microclimate conditions and recommendations on design alterations and/or microclimate moderation/treatment options* *Limitations: This is a qualitative method that does not account for all specialist design options in a site that could affect the microclimate, such as green walls.* *Risks: If the designs change this assessment may need to be repeated.* 1. Look at the layout of your site, understand which direction is north. 2. Due to the position of the sun throughout the day sunlight is always shining onto north facing walls, and west facing walls during the afternoon. 3. Note which direction the walls of the building(s) are facing, labelling north and west facing falls as hotter and south and east facing walls as cooler. North and west facing walls are always hotter, particularly in the afternoon, because they receive more sunlight throughout

		the day for north facing walls and during hottest times in the day for west facing walls. South or east facing walls are cooler because they are often in shadow or receive less incident sunlight throughout the day. 4. Due to the position of the sun throughout the day, in the afternoon buildings will cast their shadows to the east, with a small shadow to the south. 5. To understand the length of shadows to the east of buildings use a shadow calculator. In the calculator type: • Object height: the height of your building • Date and time: any date of interest, though 3pm on the summer and winter solstice will produce the most extreme results • Latitude: 35˚ 16' 55" S • Longitude: 149˚ 7' 44" E • Time Zone: 10 (or 11 if during daylight savings) • E.g. At 3pm on the summer solstice during daylight savings in the ACT, a 5 m tall building will produce a shadow that is 2.7 m long. Therefore, at this time a 5m tall building would almost completely shade an east or south facing courtyard if it is smaller than 3m. If considering microclimate moderation look at Temperature moderating treatments applicable at the precinct scale at the end of this section. Prioritise cooling options in the hot spots of your site . If using trees consider deciduous trees to ensure adequate sunlight during winter.
	Data analysis	CSIRO Land surface temperature and urban heat island data *Skills required: GIS* *Access and cost: Free from CSIRO data website.* *Outputs: Information on the proximity of the site to 'hot spots' and recommendations on design alterations and/or microclimate moderation/treatment options* ***Limitations: The data has a spatial resolution of 25m meaning that it can be too coarse at the Block to single building scale. Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.*** ***Risks: This data is from summer 2015/16 and will become out of date as development continues in the ACT.*** Land surface temperature and urban heat island data is available for the ACT. 1. Download data from CSIRO website. 2. Load into GIS software. 3. Determine whether your site of interest is in a hot spot compared to neighbouring areas in the ACT.

		If located in a hot spot, the site design may need to consider microclimate moderation, particularly if urban densification of the site is planned. Temperature moderating treatments applicable at the building / block scale are provided at the end of this section of the Guide.
	Modelling methods	ENVI-met model ***Skills required:** GIS, urban climate science or microclimate assessment would be a benefit but is not essential.* *Scale: Suited from Block scale to smaller precincts up to 10 Ha* *Access and cost: Annual licence fee **for ENVI-met (~$5000AUD), Bureau of Meteorology data available** for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website* ***Outputs: quantified maps of the air temperature and Universal Thermal Climate Index (UTCI) for the design of the site. If modelling microclimate treatments, outputs will also be maps of the air temperature and UTCI across the site incorporating microclimate treatments.*** ***Limitations: ENVI-met requires a significant investment in hardware (powerful computers to run the model), software (buying a licence to the program), expertise and time (to set up and run the model).*** ***Risks: The high costs associated with setting up and running ENVI-met may not be economical for a Block scale microclimate assessment.*** ***Special notes: ENVI-met is considered the best Simulation Tool at the Block scale, as it can simulate meteorological parameters such as sun and shade, wind, humidity and the interactions between blue and green infrastructure and the environment. However, ENVI-met is a time and resource intensive model to set up and run. An annual licence is approximately $5000AUD and requires powerful desktop computers to run simulations, as well as specialist knowledge to set up and run the model. Additionally, it requires detailed designs and data.*** ENVI-met is a comprehensive microclimate model that combines an atmospheric model, a vegetation model and a building model to produce spatial maps of meteorological variables such as the air temperature, land surface temperature and outdoor human thermal comfort. 1. Obtain birds eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the raster or shapefile format, which can be read by GIS programs. 2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide. 3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are: • Wind speed. • Wind direction • Air temperature. • Relative humidity.

		• Rainfall. 4. Use this shapefile of the design and meteorological information as inputs into the ENVI-met model. 5. Output spatial maps of the air temperature between 0 and 2m above the surface, the surface temperature and the UTCI for different times of the day. Pay special attention to the air temperature in the afternoon, the hottest time of the day if interested in extreme heat, and just before dawn if interested in extreme cold. 6. Look for hot spots and cool spots including areas that are shaded. 7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 7. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 8. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 9. Rerun the ENVI-MET model using the new site design inputs. 10. Compare to the original simulation and identify whether the hot or cold spots have been reduced. 11. Look for hot spots and cool spots including areas that are shaded.
		Solar and LongWave Environmental Irradiance Geometry (SOLWEIG) model *Skills required: GIS* *Scale: Suited from Block scale to smaller precincts up to 10 Ha* *Access and cost: Free in UMEP plugin in QGIS, Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.* *Outputs: quantified maps of the mean radiant temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments.*

		Limitations: The only temperature variable SOLWEIG outputs is the Mean Radiant Temperature, which is highly related to radiation, shadows and surface materials. This is not a standard meteorological variable and may be difficult for people to interpret. ***Risks: SOLWEIG is an open source platform, which may not be appropriate for sensitive data.*** ***Special notes: SOLWEIG is an easy to use Simulation tool that is well established and commonly used. SOLWEIG requires detailed information on the site including building dimensions to run. SOLWEIG is an open source platform hosted on QGIS, another open source platform. Open source platforms are not always considered a safe space for recording sensitive data. The nature of open-source platforms is that they are not owned or managed by an individual or company meaning that updates to the platform occur through the input of individuals, another potential avenue for compromising sensitive information.*** The SOLWEIG model uses the land surface, building geometry and the position of the sun to create spatial maps of the mean radiant temperature, a large determinant of outdoor human thermal comfort. The mean radiant temperature can be used as a proxy for the air temperature (though the scales are different) as the hot spots and cool spots would be very similar. 1. Obtain birds eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the raster or shapefile format, which can be read by GIS programs. 2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide. 3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are: • Incoming short wave radiation (if this cannot be found from the Bureau of Meteorology, download the variable Mean surface downward short wave radiation flux from the ERA5 data set). • Wind speed. • Air temperature. • Relative humidity. • Barometric pressure. • Rainfall. 4. Use this information as inputs into the SOLWEIG model. 5. Plot spatial maps of the mean radiant temperature for different times of the day, paying particular attention to the afternoon, the hottest time of the day. 6. Look for hot spots and cool spots including areas that are shaded.

7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index.
   - Objectives: Outdoor Thermal Comfort (and others if desired).
   - Climate Regions: Canberra.
   - Urban Context: choose which best suits your site.
8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects.

If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps.

9. Select which microclimate moderation technique will be used at the site and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2.
10. Rerun the SOLWEIG model using the new site design inputs.
11. Compare to the original simulation and identify whether the hot or cold spots have been reduced.

CRC for Water Sensitive Cities Scenario Tool

Skills required: GIS skills.

Access and cost: Free if CRC for Water Sensitive Cities industry partner, CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.

Outputs: Quantified maps of the air temperature and land surface temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments and time series comparing the two simulations.

Limitations: The CRC Scenario Tool is best applied to larger areas rather than Block to building scale as the preferred resolution of the model is 20m.

Risks: The CRC for Water Sensitive Cities will end in 2021 with the Water Sensitive Institute likely to commercialise the Tool with a subscription fee.

This online Tool, free for CRC for Water Sensitive Cities industry partners, enables users to quantify the air temperature, land surface temperature and human thermal comfort of a user defined region ranging from residential blocks up to the suburb area scale.

1. Select chosen area of interest in the Scenario Tool.
2. Add own surface cover data from design, such as building locations and where grass and roads are located.
3. Select Land Surface Temperature and TARGET Urban Heat Island assessment modules.

4. Select where your data is located.
5. By default, the Scenario Tool generates a map during extreme heat conditions.
6. Select weather module in the scenario builder to simulate an alternative date such as colder conditions.
7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index.
    - Objectives: Outdoor Thermal Comfort (and others if desired).
    - Climate Regions: Canberra.
    - Urban Context: choose which best suits your site.
8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects.

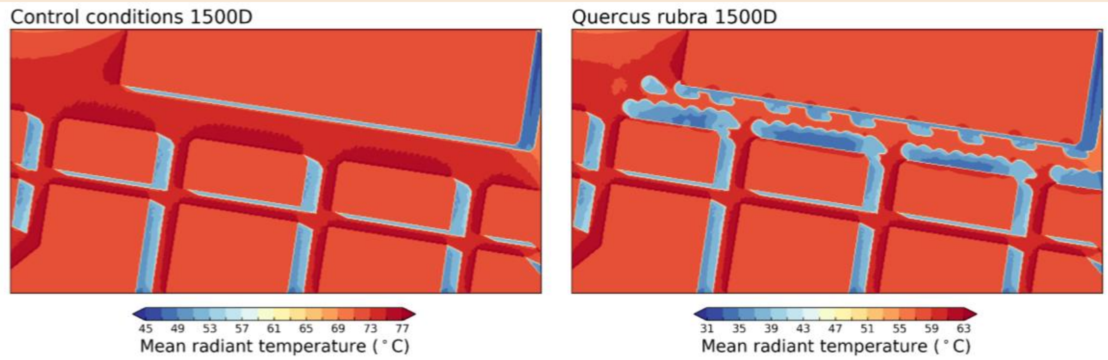
If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps.

9. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2.
10. Rerun the CRC for Water Sensitive Cities Scenario Tool using the new site design inputs.

Compare to the original simulation and identify whether the hot or cold spots have been reduced.

Case study – Minta

A microclimate assessment was conducted on a proposed greenfield urban development in south-east Melbourne predominantly comprising single story residential dwellings. Modelling with SOLWEIG on an extreme heat day found that the mean radiant temperature, a large determinant of human thermal comfort reached more than 70˚C in front of north and west facing walls, and these were the hottest in the modelling area. North facing walls receive more direct sunlight throughout the day than south facing walls, making them hotter and causing them to emit more heat. West facing walls receive more direct sunlight during warmer times of the day when surfaces have been able to accumulate heat, resulting in them being hotter. The shadows to the east of the buildings were the coolest in the modelling area as they were shielded from the majority of the sunlight by the buildings. As the north facing walls in the development are adjacent to a large pedestrian walkway, the decision was made to plant red oak trees (*Quercus rubra)* densely along this passage to ensure pedestrians are shaded. This resulted in a drop of 30˚C of mean radiant temperature, cooling the hottest location in the development. Credit: Mosaic Insights, Stockland and City of Casey 2019.



Maintenance and renewal

(e.g. retrofitting buildings with shading, living infrastructure)

Why do an assessment at this stage?	• To establish whether there are opportunities to improve microclimates through infrastructure asset maintenance or renewal processes. • To establish whether existing green or blue infrastructure is working to its full capacity as part of maintenance and renewal processes.
Who should do them?	***Primary responsibility:*** Leaseholders, land and property managers
	Secondary contractors: Planning and design consultants; urban climate scientists and environmental consultants
What are the outcomes from the assessment?	• Gain insights as to extent, if any, of existing microclimate moderating infrastructure. • Define need for microclimate moderation treatments
Things to consider when doing the assessment	1. What are the hot and cool spots across the block and neighbouring areas? 2. Is there existing vegetation at the site? 3. Are there existing buildings on site – will they be reused / redesigned or removed? 4. How does the height of the block existing buildings or design compare with others in the area? 5. Does the site have good solar access? 6. Will the site receive shade from neighbouring buildings? Will the site shade neighbouring buildings? 7. Which direction is the block facing? 8. How exposed are the existing or proposed north and west walls to summer heat and south and east walls to winter cold? 9. How does stormwater move across the site? 10. Can green infrastructure be incorporated to maximise a comfortable microclimate? 11. Does the block design require that trees are removed? If so, how can the effects of this be ameliorated? 12. Is there room for a vegetated set back from the street? 13. What is the end use for the site – a public space with a large area needed for outdoor use? Or a fully developed site? 14. Will people be spending large amounts of time in the facility or in the outdoor spaces? What time of day / night will people be present/gathering? 15. Has this site been designed and constructed with microclimate in mind?

<table>
<tr><td></td><td colspan="2">If yes, are the microclimate adaptations and features evident on site? Have you access to the plans? Proceed to Observational methods below.
If no, use the questions and tools recommended in Block scale Infrastructure design and approval stage.</td></tr>
<tr><td rowspan="2">How do you do them?</td><td>Observational methods</td><td>Inspection of infrastructure

Skills required: None specifically, but landscape design and/or infrastructure construction and maintenance experience is desirable

Access and cost: Free

Outputs: Visual inspection of the site to check whether microclimate treatments are in working order.

Limitations: This is a qualitative method that does not account for all specialist design options in a site that could affect the microclimate.

Risks: If the infrastructure is not performing well, a new microclimate assessment may be required.

Review building plans and visit the site to determine the following:

Trees and vegetation
Is vegetation at the site healthy and growing as expected? Is there enough water to sustain the vegetation?
Water
Is the blue infrastructure constructed according to plan?
Is the blue infrastructure functioning?
Are irrigation systems installed and working correctly (e.g. passive irrigation of street trees)?
Is there enough shading and sunlight at the site from trees?
- Do the cool spots have adequate solar access?
- Do the hot spots have adequate shade?
Building and landscape materials
Are the “cool” materials in use clean, to maximise reflective abilities?
Are shade structures in working order and providing shade where needed?
Is solar access available as planned?</td></tr>
<tr><td>Modelling methods</td><td>ENVI-met model

Skills required: GIS, urban climate science or microclimate assessment would be a benefit but is not essential.

Scale: Suited from Block scale to smaller precincts up to 10 Ha</td></tr>
</table>

		Access and cost: Annual licence fee for ENVI-met (~$5000AUD), Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website *Outputs: quantified maps of the air temperature and Universal Thermal Climate Index (UTCI) for the design of the site. If modelling microclimate treatments, outputs will also be maps of the air temperature and UTCI across the site incorporating microclimate treatments.* *Limitations: ENVI-met requires a significant investment in hardware (powerful computers to run the model), software (buying a licence to the program), expertise and time (to set up and run the model).* *Risks: The high costs associated with setting up and running ENVI-met may not be economical for a Block scale microclimate assessment.* *Special notes: ENVI-met is considered the best Simulation Tool at the Block scale, as it can simulate meteorological parameters such as sun and shade, wind, humidity and the interactions between blue and green infrastructure and the environment. However, ENVI-met is a time and resource intensive model to set up and run. An annual licence is approximately $5000AUD and requires powerful desktop computers to run simulations, as well as specialist knowledge to set up and run the model. Additionally, it requires detailed designs and data.* ENVI-met is a comprehensive microclimate model that combines an atmospheric model, a vegetation model and a building model to produce spatial maps of meteorological variables such as the air temperature, land surface temperature and outdoor human thermal comfort. 1. Obtain birds eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the raster or shapefile format, which can be read by GIS programs. 2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide. 3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are: • Wind speed. • Wind direction • Air temperature. • Relative humidity. • Rainfall. 4. Use this shapefile of the design and meteorological information as inputs into the ENVI-met model.

		5. Output spatial maps of the air temperature between 0 and 2m above the surface, the surface temperature and the UTCI for different times of the day. Pay special attention to the air temperature in the afternoon, the hottest time of the day if interested in extreme heat, and just before dawn if interested in extreme cold. 6. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 7. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 8. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 9. Rerun the ENVI-MET model using the new site design inputs. 10. Compare to the original simulation and identify whether the hot or cold spots have been reduced. 11. Look for hot spots and cool spots including areas that are shaded.
		Solar and LongWave Environmental Irradiance Geometry (SOLWEIG) model *Skills required: GIS* *Scale: Suited from Block scale to smaller precincts up to 10 Ha* *Access and cost: Free in UMEP plugin in QGIS, Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.* *Outputs: quantified maps of the mean radiant temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments.* *Limitations: The only temperature variable SOLWEIG outputs is the Mean Radiant Temperature, which is highly related to radiation, shadows and surface materials. This is not a standard meteorological variable and may be difficult for people to interpret.* *Risks: SOLWEIG is an open source platform, which may not be appropriate for sensitive data.* *Special notes: SOLWEIG is an easy to use Simulation tool that is well established and commonly used. SOLWEIG requires detailed information on the site including building dimensions to run. However, at the Maintenance and renewal development stage SOLWEIG is*

		limited in its ability to simulate various heat mitigation options, as it only allows for surface material changes to grass or trees added. SOLWEIG is an open source platform hosted on QGIS, another open source platform. Open source platforms are not always considered a safe space for recording sensitive data. The nature of open-source platforms is that they are not owned or managed by an individual or company meaning that updates to the platform occur through the input of individuals, another potential avenue for compromising sensitive information. The SOLWEIG model uses the land surface, building geometry and the position of the sun to create spatial maps of the mean radiant temperature, a large determinant of outdoor human thermal comfort. The mean radiant temperature can be used as a proxy for the air temperature (though the scales are different) as the hot spots and cool spots would be very similar. 1. Obtain birds eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the shapefile format, which can be read by GIS programs. 2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide. 3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are: • Incoming short wave radiation (if this cannot be found from the Bureau of Meteorology, download the variable Mean surface downward short wave radiation flux from the ERA5 data set. • Wind speed. • Air temperature. • Relative humidity. • Barometric pressure. • Rainfall. 4. Use this information as inputs into the SOLWEIG model. 5. Plot spatial maps of the mean radiant temperature for different times of the day, paying particular attention to the afternoon, the hottest time of the day. 6. Look for hot spots and cool spots including areas that are shaded. 7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra.

		• Urban Context: choose which best suits your site. 8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 9. Select which microclimate moderation technique will be used at the site and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 10. Rerun the SOLWEIG model using the new site design inputs. 11. Compare to the original simulation and identify whether the hot or cold spots have been reduced.
		CRC for Water Sensitive Cities Scenario Tool ***Skills required: GIS skills.*** ***Access and cost: Free if CRC for Water Sensitive Cities industry partner, CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free <u>from website</u>.*** ***Outputs: Quantified maps of the air temperature and land surface temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments and time series comparing the two simulations.*** ***Limitations: The CRC Scenario Tool is best applied to larger areas rather than Block to building scale as the preferred resolution of the model is 20m.*** ***Risks: The CRC for Water Sensitive Cities will end in 2021 with the Water Sensitive Institute likely to commercialise the Tool with a subscription fee.*** This online Tool, free for CRC for Water Sensitive Cities industry partners, enables users to quantify the air temperature, land surface temperature and human thermal comfort of a user defined region ranging from residential blocks up to the suburb area scale. 1. Select chosen area of interest in the Scenario Tool. 2. Add own surface cover data from design, such as building locations and where grass and roads are located. 3. Select Land Surface Temperature and TARGET Urban Heat Island assessment modules. 4. Select where your data is located. 5. By default, the Scenario Tool generates a map during extreme heat conditions. 6. Select weather module in the scenario builder to simulate an alternative date such as colder conditions.

		7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from highly suited to less suited. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 9. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 10. Rerun the CRC for Water Sensitive Cities Scenario Tool using the new site design inputs. Compare to the original simulation and identify whether the hot or cold spots have been reduced.

Evaluation

(e.g. post development)

<table>
<tr><td>Why do an assessment at this stage?</td><td colspan="2">To Assess impact of microclimate moderation treatments.</td></tr>
<tr><td rowspan="2">Who should do them?</td><td colspan="2">Primary responsibility: Leaseholders, land and property managers.</td></tr>
<tr><td colspan="2">Secondary contractors: Universities and liveability consultants.</td></tr>
<tr><td>What are the outcomes from the assessment?</td><td colspan="2">• Comparable and quantifiable measures and indicators of microclimate conditions at the site.</td></tr>
<tr><td>Things to consider when doing the assessment</td><td colspan="2">Evaluation could include:
1. Inspections
2. Short to medium term monitoring of site microclimate conditions
3. Locations of heat refuges and cool oases</td></tr>
<tr><td>How do you do them?</td><td>Observational methods</td><td>Inspection of infrastructure
Skills required: None specifically, but landscape design and/or infrastructure construction and maintenance experience is desirable
Access and cost: Free
Outputs: Visual inspection of the site to check whether microclimate treatments are in working order.
Limitations: This is a qualitative method that does not account for all specialist design options in a site that could affect the microclimate.
Risks: If the infrastructure is not performing well, a new microclimate assessment may be required.
After 12 months, 2 years, 5 years, 10 years, undertake inspections of infrastructure to determine the following:
Trees and vegetation
• Is vegetation at the site healthy and growing as expected? Is there enough water to sustain the vegetation?</td></tr>
</table>

		Water
		• Is the blue infrastructure constructed according to plan?
		• Is the blue infrastructure functioning?
		• Are irrigation systems installed and working correctly (e.g. passive irrigation of street trees)?
		• Is there enough shading and sunlight at the site from trees?
		  - Do the cool spots have adequate solar access?
		  - Do the hot spots have adequate shade?
		Building and landscape materials
		• Are the “cool” materials in use clean, to maximise reflective abilities and/or permeability?
		• Are shade structures in working order and providing shade where needed?
		• Is solar access available as planned?

		Meteorological monitoring with weather stations ***Skills required: GIS, weather station installation expertise.*** ***Access and cost: Weather stations and equipment need to be purchased. Each weather station usually costs more than $100*** ***Outputs: Time series and maps of the average air temperature across the site, highlighting the hot and cool spots. These measurements will form a baseline from before construction, which can be compared with measurements taken during a monitoring and evaluation period.*** ***Limitations: A sufficient spatial and temporal coverage of weather stations is required to properly assess the microclimate of the site*** ***Risks: The location of the weather stations may need to change once the site design is complete.*** Immediately post construction place a minimum of four weather stations around the site. Weather stations can be procured from this website, though cheaper options are available. All weather stations should be the same make and brand. The weather station would ideally measure air temperature, relative humidity, wind speed and radiant temperature. They would also have Wi-Fi capability so that data is directly stored on a cloud server. 1. Place the weather stations a consistent height above the ground, make sure the weather station has full access to the wind from all directions. Ensure an even spread of weather stations across the site, though areas previously identified as hot or cool spots, or flagged for microclimate moderation can have more weather stations. Record the location of each weather station. 2. Throughout the monitoring period record the air temperature, relative humidity, wind speed and radiant temperature. 3. Select the hottest or coldest 5% of days within the most recent complete season of summer or winter for each weather station.

4. Calculate the average of the hottest or coldest 5% for each weather station.
5. Interpolate the weather station data spatially across the site using GIS software.
6. Plot the spatial average temperature across the site.
7. Look for hot spots and cool spots. The extreme heat or cold should be mitigated by the microclimate moderation technology.
8. Repeat steps 3-7 for each monitoring period.

★ Thermal imaging cameras or spot thermometers (instantaneous surface temperature measurements)

Skills required: None

Access and cost: Thermal imaging cameras or thermometers need to be purchased. (Climate Change and Sustainability Division have access to this equipment)

Outputs: Images of the surface temperature across the site which demonstrate whether areas with microclimate treatments are cooler than areas without microclimate treatments.

Limitations: Ensuring observations are comparable can be difficult, particularly if background weather conditions can influence the surface temperature. Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.

Risks: Monitoring is not conducted on a sufficient scale to consistently determine the hot and cool spots of the site.

These cameras can be used to produce thermal images of the surface temperature of a site. The surface temperature can be used as a proxy for air temperature, except on windy days. These cameras and thermometers can be obtained from many resources including Bunnings, Amazon and other sellers. Some cameras can become an attachment to mobile phones.

1. Plan where observations will be taken around the site. Consider sites that will measure the temperature of the north, south, east and west facing walls of the building or block.
2. Go to each site, adjust the site if necessary, to provide better imagery (e.g. if a tree is in the way of the original planned site). Geo locate the site. This can be done through dropping a pin on Google Maps, which records the latitude and longitude to seven decimal places.
3. Note the time of observation and meteorological conditions at your site:
   i. Is it sunny or cloudy?
   ii. Is it windy or calm?
   iii. Is it raining?

		4. Take photos with the thermal imaging camera or spot thermometer of your site. Note the height above the ground that you are taking the photos/recording the temperature. Record the observations. 5. When analysing data look for hot and cool spots across the site. The surface temperatures should be mitigated by the microclimate moderation technology. 6. Repeat on days with similar meteorological conditions and at a similar time of day.
	Modelling methods	ENVI-met model ***Skills required:* GIS, urban climate science or microclimate assessment would be a benefit but is not essential.** ***Scale: Suited from Block scale to smaller precincts up to 10 Ha*** ***Access and cost:* Annual licence fee *for ENVI-met (~$5000AUD), Bureau of Meteorology data available* for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website** ***Outputs: quantified maps of the air temperature and Universal Thermal Climate Index (UTCI) for the design of the site. If modelling microclimate treatments, outputs will also be maps of the air temperature and UTCI across the site incorporating microclimate treatments.*** ***Limitations: ENVI-met requires a significant investment in hardware (powerful computers to run the model), software (buying a licence to the program), expertise and time (to set up and run the model).*** ***Risks: The high costs associated with setting up and running ENVI-met may not be economical for a Block scale microclimate assessment.*** ***Special notes: ENVI-met is considered the best Simulation Tool at the Block scale, as it can simulate meteorological parameters such as sun and shade, wind, humidity and the interactions between blue and green infrastructure and the environment. However, ENVI-met is a time and resource intensive model to set up and run. An annual licence is approximately $5000AUD and requires powerful desktop computers to run simulations, as well as specialist knowledge to set up and run the model. Additionally, it requires detailed designs and data and at the Evaluation stage will require site field data.*** ENVI-met is a comprehensive microclimate model that combines an atmospheric model, a vegetation model and a building model to produce spatial maps of meteorological variables such as the air temperature, land surface temperature and outdoor human thermal comfort. 1. Obtain birds eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the raster or shapefile format, which can be read by GIS programs. 2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide. 3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are:

- Wind speed.
- Wind direction
- Air temperature.
- Relative humidity.
- Rainfall.

4. Use this shapefile of the design and meteorological information as inputs into the ENVI-met model.
5. Output spatial maps of the air temperature between 0 and 2m above the surface, the surface temperature and the UTCI for different times of the day. Pay special attention to the air temperature in the afternoon, the hottest time of the day if interested in extreme heat, and just before dawn if interested in extreme cold.
6. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index.
   - Objectives: Outdoor Thermal Comfort (and others if desired).
   - Climate Regions: Canberra.
   - Urban Context: choose which best suits your site.
7. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from highly suited to less suited. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects.

If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps.

8. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2.
9. Rerun the ENVI-MET model using the new site design inputs.
10. Compare to the original simulation and identify whether the hot or cold spots have been reduced.

Look for hot spots and cool spots including areas that are shaded.

Solar and LongWave Environmental Irradiance Geometry (SOLWEIG) model

Skills required: GIS

Scale: Suited from Block scale to smaller precincts up to 10 Ha

Access and cost: Free in UMEP plugin in QGIS, Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.

Outputs: quantified maps of the mean radiant temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments.

Limitations: The only temperature variable SOLWEIG outputs is the Mean Radiant Temperature, which is highly related to radiation, shadows and surface materials. This is not a standard meteorological variable and may be difficult for people to interpret.

Risks: SOLWEIG is an open source platform, which may not be appropriate for sensitive data.

Special notes: SOLWEIG is an easy to use Simulation tool that is well established and commonly used. SOLWEIG requires detailed information on the site including building dimensions to run, and at the Evaluation stage will require site field data to run. SOLWEIG is an open source platform hosted on QGIS, another open source platform. Open source platforms are not always considered a safe space for recording sensitive data. The nature of open-source platforms is that they are not owned or managed by an individual or company meaning that updates to the platform occur through the input of individuals, another potential avenue for compromising sensitive information.

The SOLWEIG model uses the land surface, building geometry and the position of the sun to create spatial maps of the mean radiant temperature, a large determinant of outdoor human thermal comfort. The mean radiant temperature can be used as a proxy for the air temperature (though the scales are different) as the hot spots and cool spots would be very similar.

1. Obtain birds eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the shapefile format, which can be read by GIS programs.
2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide.
3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are:
   - Incoming short wave radiation (if this cannot be found from the Bureau of Meteorology, download the variable Mean surface downward short wave radiation flux from the ERA5 data set.
   - Wind speed.
   - Air temperature.
   - Relative humidity.
   - Barometric pressure.
   - Rainfall.
4. Use this information as inputs into the SOLWEIG model.
5. Plot spatial maps of the mean radiant temperature for different times of the day, paying particular attention to the afternoon, the hottest time of the day.

		6. Look for hot spots and cool spots including areas that are shaded. 7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from highly suited to less suited. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 9. Select which microclimate moderation technique will be used at the site and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 10. Rerun the SOLWEIG model using the new site design inputs. Compare to the original simulation and identify whether the hot or cold spots have been reduced.
		CRC for Water Sensitive Cities Scenario Tool *Skills required: GIS skills.* *Access and cost: Free if CRC for Water Sensitive Cities industry partner, CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.* *Outputs: Quantified maps of the air temperature and land surface temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments and time series comparing the two simulations.* *Limitations: The CRC Scenario Tool is best applied to larger areas rather than Block to building scale as the preferred resolution of the model is 20m.* *Risks: The CRC for Water Sensitive Cities will end in 2021 with the Water Sensitive Institute likely to commercialise the Tool with a subscription fee.* This online Tool, free for CRC for Water Sensitive Cities industry partners, enables users to quantify the air temperature, land surface temperature and human thermal comfort of a user defined region ranging from residential blocks up to the suburb area scale. 1. Select chosen area of interest in the Scenario Tool. 2. Add own surface cover data from design, such as building locations and where grass and roads are located.

		3. Select Land Surface Temperature and TARGET Urban Heat Island assessment modules. 4. Select where your data is located. 5. By default, the Scenario Tool generates a map during extreme heat conditions. 6. Select weather module in the scenario builder to simulate an alternative date such as colder conditions. 7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from highly suited to less suited. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 9. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 10. Rerun the CRC for Water Sensitive Cities Scenario Tool using the new site design inputs. Compare to the original simulation and identify whether the hot or cold spots have been reduced.

Temperature moderating treatments applicable at the Block and building scale

The purpose of these treatments is to create a more comfortable and moderate microclimate throughout the year in the ACT, improving human thermal comfort. The treatment measures are effective as they reduce the amount of solar radiation reaching or being absorbed by impervious and pervious surfaces, generally through shading. As such, impervious surfaces such as buildings and courtyards become cooler and moderate the microclimate. Increasing vegetation also has a moderating effect on microclimate through increasing shade but also creating an insulation effect in winter. It is important to note that there is no single design solution for microclimate treatment at the block scale, all design solutions have advantages and disadvantages, and different buildings may have competing objectives.

Information in this section, including the suitability ranking has been adapted from the CRC for Low Carbon Living Heat Island Mitigation Performance Index Tool.

Strategy	Suitability	Description	Retrofit and design considerations
Trees	Highly suited	Trees take time to grow and to reach their maximum benefit, which includes cooling benefits. As such, it is important that existing trees be retained and integrated into the design of a new building, where possible. Mature trees reduce the temperature and improve human thermal comfort at the site through shading and evapotranspiration. The effectiveness of trees can be maximised through considering microclimate elements such as the building orientation, building setbacks from the street and ideal plant species. **Advantages:** Mature trees are largest and create the most cooling potential as well as enhanced biodiversity, amenity, human health benefits, social cohesion, energy savings and air quality **Disadvantages:** Deciduous trees can cause leaf litter	• Existing trees should be maintained at the site wherever possible • Consider tree species that are appropriate to the site in terms of resistance to climate change, water needs, soil conditions, biodiversity, diversity of tree species to protect against disease • Trees take time to grow, it is essential that growing trees are protected from vandalism. • Location is very important. Deciduous trees are ideal on the northern and western side of blocks as they will provide shade in summer and allow sun to penetrate in the cooler months.
Misting	Highly suited	Misting systems are effective at reducing temperatures during the day, particularly on a dry and hot day. Ideally misting systems are strategically placed in public spaces to maximise their cooling benefit to people as the cooling effect does not travel far.	• Misting is best suited to areas where it will have the largest cooling effect, i.e. in a pedestrian thoroughfare or on the deck of the house. • Mistering can be set up with motion sensors so it is only active when people are nearby

Strategy	Suitability	Description	Retrofit and design considerations
		Advantages: Effective at reducing the temperature in a small local area if located appropriately near openable windows, misting systems can also help to cool inside buildings **Disadvantages:** Require potable water	• Mistering requires a potable water source. Consider prevailing wind directions as this may assist in determining the location and direction of misting systems.
Shading devices (awnings and verandas)	Highly suited	Building elements such as awnings, verandas and arbours can reduce solar radiation penetrating buildings as well as reducing heat reflection into adjacent open spaces. **Advantages:** Reduced temperature inside and outside buildings, solar protection for pedestrians **Disadvantages:** Require space between buildings for awnings	• Shading devices need to be appropriately designed having consideration of design details including orientation, angle, length, width, height above ground and materiality of any device. • Continuous awnings can trap heat, having breaks allows hot air to be released. • Awnings can be covered with cool roof paint, see cool roofs
Cool facades	Somewhat suited	Certain building materials absorb heat which can lead to higher surface temperatures and higher levels of heat transfer to buildings and the environment. Using materials with high albedo and/or high emissivity can reduce these impacts leading to improved indoor and outdoor thermal comfort. **Advantages:** Reduced temperature inside and outside buildings, increased life of walls, decreased energy costs in summer. **Disadvantages:** Can increase heating costs in winter. Not recommended for houses that predominantly require heating than cooling. Can create glare for occupants of neighbouring buildings and adjacent outdoor spaces. When they are dirty, they are less effective	• Cool facades can be created by using materials that are inherently light coloured or reflective. This can reduce maintenance time and costs. • For retrofitting, white, light coloured or reflective paint can be applied to facade surfaces to create a cool facade. This will require repainting as part of maintenance. • Cool facades require cleaning as part of maintenance to keep them working to their full potential. • The requirement for cool materials on the façade is less if the solar exposure on the wall is minimised due to building orientation or its height: width ratio. • Cool facades can create glare for neighbouring buildings. Advise to use them when glare is minimised such as neighbouring buildings do not have an overlooking window or to use in combination with shading devices.

Strategy	Suitability	Description	Retrofit and design considerations
Green roofs	Somewhat suited	Roofs that are wholly or partially covered in plants. They often require irrigation but are effective at reducing the temperature inside and outside of buildings and can act as insulation for the building. **Advantages:** Reduced temperature inside and outside buildings, insulation for building, stormwater harvesting, reduced runoff, increased thermal insulation, increased biodiversity, amenity if access is allowed, reduced energy demand **Disadvantages:** Can require irrigation to survive Canberra's hot dry summers, plants that can survive on a green roof are not necessarily best to provide cooling effects	• The installation of green roofs needs to consider many built factors (roof shape/slope) and environmental factors that will influence vegetation growth (solar exposure, wind speed, temperature, humidity). • Irrigation systems using recycled water from the buildings can also be considered in the design of a green roof. • Green roofs are not always appropriate for retrofits, if the building structure cannot fit the weight of the green roof • More information can be found in: o Growing Green Guide o Green roof retrofit o RICS guidance note green roofs and green walls
Built form and Design	Somewhat suited	Considering the building set back from the street and the height of the building. This determines the street level shading from the building itself as well as whether radiation can become trapped between buildings. **Advantages:** Can result in cool pockets between buildings that are well ventilated and appropriately shaded **Disadvantages:** It is difficult to get right without creating other microclimate effects, i.e. deep and narrow urban canyons create shading, but they can also trap radiation	• Covered balconies should have a minimum depth of 1.5m and a width of 3m to ensure sufficient shading for indoor spaces in summer. • Fixed and moveable sunscreens and shutters should be provided in north and west facing balconies. • Arrange the different heights of buildings in a way that adequate ventilation is provided • Tall buildings should consider a base, medium and top composition each with their own setbacks to avoid creating very deep urban canyons • Avoid the conversion of building setbacks into parking areas, driveways or paved areas and instead used to increase vegetation cover and rainwater infiltration

Strategy	Suitability	Description	Retrofit and design considerations
Cool roofs	Somewhat suited	Roof surfaces that are lighter coloured or that are reflective can help reduce roof surface temperature and reduce heat absorption into a building. This can help to reduce cooling energy demand in summer and support more comfortable microclimates. **Advantages:** Reduced temperature inside and outside buildings, increased life of roof, decreased energy costs in summer. **Disadvantages:** Can increase heating costs in winter. Not recommended for houses that predominantly require heating than cooling. Can create glare for neighbouring buildings that are higher than the cool roof. When they are dirty, they are less effective. NatHERS often suggests darker roofs for heating loads in winter. This could also be met by providing adequate roof insulation.	• Cool roofs can be created by using materials that are inherently light coloured or reflective. This can reduce maintenance time and costs. • For retrofitting, white, light coloured or reflective paint can be applied to roof surfaces to create a cool roof. This will require repainting as part of maintenance. • Cool roofs require cleaning as part of maintenance to keep them working to their full potential. • Cool roofs can create glare for neighbouring buildings overlooking the cool roof. Advise to use them on the tallest building or when all blocks are of similar height.

Vertical greenery (green wall/facades)	Somewhat suited	Vegetation growing on building walls that reduces the temperature of buildings, inside and out, through insulation and evaporative cooling.
		Advantages: Reduced temperature inside and outside buildings, lower building operating costs.
		Disadvantages: Outdoor cooling from green walls dissipates less than 1 m from the wall (Wong et al. 2009), can difficult to grow plants, often requires irrigation
			• A support structure as a growing medium often needed for green walls
			• Green walls can be more successful if they are rooted into the ground
			• It is recommended to use plants that can tolerate heat, wind, drought and full sun
			• Irrigation is recommended though the installation of drainage layers can help too
			• More information can be found in:
			  o RICS guidance note green roofs and green walls
			  o Adelaide Design Manual - Greening

6 Precinct and estate-scale microclimate assessments (~4,000 sqm to 100 Ha)

Microclimate assessments at the precinct to estate scale are beneficial as they can help to:

- Inform early concept planning and design frameworks for greenfield estates and urban intensification precincts
- Inform appropriate rules and/or criteria for Territory Plan variations
- Inform estate development plans for approval

Assessments are effective at the early planning and detailed design stages as the microclimate effects from urban layout can have long-term implications and these should be addressed when designing the whole development or precinct. Assessments at this scale can also be useful for assessing existing infrastructure to identify opportunities for retrofitting microclimate treatment measures and in monitoring and evaluating the performance of pre-existing microclimate moderation measures to inform renewal needs.

When assessing the urban microclimate at a precinct scale it is important to consider the existing and or proposed geometry of streets, blocks and buildings, building height, width between buildings and the orientation of the blocks. Together these influence the local microclimate, affecting temperature, wind speed, solar radiation and humidity. Poor decisions made at this stage around these fundamental structural issues can have a long-term effect which is difficult and costly to modify or retrofit (e.g. street and block orientation), therefore it is critical that the microclimate is considered at this stage). Understanding the convergence of street geometry and meteorological variables such as temperature helps bridge the gap between urban planners and designers and urban climate scientists.

Examples of precinct to estate-scale activities where a microclimate assessment could be used include:

- Planning investigations to inform concept layout and design frameworks
- Urban infills
- Territory Plan variation stages (e.g. rezoning)
- Estate development planning
- Capital work upgrades to existing open spaces, town centres, streets and infrastructure
- Monitoring and evaluating precincts to inform business cases for future microclimate treatment options

Early planning

(e.g. planning investigations to inform concept layout and design frameworks, urban infill, Territory Plan variations (e.g. rezoning)

Why do an assessment at this stage?	• To understand the existing microclimatic factors and the potential site constraints with respect to microclimate impacts. • Inform high level concepts such as street and block geometries that are responsive to urban heat mitigation, that are otherwise difficult to retrofit. • Inform passive urban heat responsive measures that provide less whole of life costs than other design measures.
Who should do them?	***Primary practitioners:*** Strategic planners, infrastructure planners
	Secondary contractors: Planning, environmental and GIS consultants and Universities.
What are the outcomes from the assessment?	• Understanding of the general microclimate conditions of the site. • Identify whether the site is in a hot spot. • Understanding of whether the existing building height and street geometry of the existing and surrounding precincts will affect the site.
Things to consider when doing the assessment	1. What are the hot and cool spots across the precinct and neighbouring areas? 2. Where does the prevailing wind come from during extreme heat or cold days? 3. Is this a green field or an intensification project? • Green fields – Is the site neighbouring a large natural area? Is it upwind or downwind from the site on extreme heat or cold days? • Intensification – Is the street layout fixed? What is the orientation of the streets? What are the building geometry characteristics? 4. Is there existing vegetation (particularly trees) at the site and in surrounding areas? Can it be retained? 5. Where are the main pedestrian routes? 6. How does water move across the site? Is water integrated into the landscape through irrigation or increased vegetation – green infrastructure?

How do you do them?	*Observational methods*	ACTmapi viewer ***Skills required: Urban design skills or experience desirable*** ***Access and cost: Free*** ***Outputs: Qualitative understanding of where hot and cool areas are surrounding your site for green-fields or intensification projects*** ***Limitations: This is an approximate qualitative method using satellite images, potentially resulting in missed analysis opportunities gained from a site visit or data analysis.*** ***Risks: The satellite data may not be up to date, resulting in the analysis being performed on out of date images.*** ACTmapi is the ACT Government's interactive mapping service that provides a convenient and fast way to analyse ACT spatial data. 1. Open ACTmapi and select basic map 2. Zoom to your site. 3. Observe the surrounding landscapes up to 1km around the site. Look for water bodies, urban areas, parks, forests, farmland, these can influence the microclimate of your site. Consider where your site fits in the landscape. Consider the existing vegetation at the site, particularly trees as they are microclimate moderators. Generally cooling effects from parks and water bodies can travel the width of the park with wind, where a 50m wide park could have a downwind cooling effect up to 50m away from the park. Conversely grasslands, industrial areas and large non-irrigated spaces are generally hotter during the day and may contribute to warming surrounding landscapes. If your site is undergoing urban intensification, skip to Step 5. If your site is a green-fields development, do Step 4. 4. Note in each direction around your site which areas are likely to be hotter (urban, impervious, dry, few trees) and colder (parks, water bodies, irrigated grass, many trees). These areas can have an influence on the microclimate of your site, particularly on extreme heat and cold days where wind can propagate the warmer and cooler air from surrounding areas into your site. To understand the direction of prevailing winds on extreme heat and cold days go to the **Data Analysis – Wind direction on extreme heat and cold days using Bureau of Meteorology sub-daily data** method. 5. Note which areas in the precinct are likely to be hottest and coolest. Hotter areas contain less vegetation, more impervious surfaces and densely packed buildings (image on the left). Cooler areas contain more and taller vegetation, more pervious surfaces and generally fewer buildings (image on the right).

6. Observe how the streets are oriented in surrounding precincts, do they run directly north south and east-west? Unshaded east-west streets are hotter than unshaded north-south streets as they are exposed to more sun throughout the day.
7. Observe how wide the streets are and whether they have much existing vegetation. Unshaded wide streets are hotter than thinner streets as they are exposed to more sun throughout the day.
8. Observe how tall the buildings are. Taller buildings create more shade at street level and are likely to result in cooler adjacent streets
9. Note which streets are likely to be hottest and coolest based on Steps 6–8. Use the table below to approximate which streets are likely to be hottest (red and yellow) and coldest (green and blue). Note that this table assumes zero current street tree cover.

Canyon width	Street tree prioritisation									Orientation
Very wide 40m	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	E-W
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	N-S
Wide 30 m	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.07	1.20	E-W
	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.07	1.20	N-S
Medium 20 m	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	E-W
	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	N-S
Narrow 10 m	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	E-W
	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	N-S
Canyon height	4 m	8 m	12 m	16 m	20 m	24 m	28 m	32 m	36 m	
	Low			Medium			High			

Table source: Norton et al. 2015 and CRC for Water Sensitive Cities

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Surface temperature monitoring campaign with drones
Skills required: GIS, drone flying, data analysis.
Access and cost: Technician with drone flying experience.
Outputs: Quantified map of observed average land surface temperatures of your site and surrounding areas
Limitations: If the weather is cloudy or windy during the observational campaign it may not produce useful maps of the land surface temperature, as cloudy days can reduce the magnitude of hot spots and windy days mixes the air so land surface temperature is not always an appropriate indicator of microclimate. Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.
Risks: Ensuring a consistent drone flight path and appropriate weather for the campaign can be difficult.
Fly a drone containing a thermal sensing camera across the site. This will create a picture of the land surface temperature across the site highlighting hot and cool spots.

Fly the drone once a day at approximately 3pm on the same trajectory during a two-week monitoring campaign taking thermal pictures of the site and surrounding areas.
Ensure the land surface temperature data is spatially consistent.
Average the land surface temperature for each day in the monitoring campaign.
Identify hot and cool spots across the site.

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<td>Data analysis</td>
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CSIRO land surface temperature and surface urban heat island data
Skills required: Basic GIS
Access and cost: Free from CSIRO data website.
Outputs: Quantified map of land surface temperature for your site and surrounding areas during an average summer day.
Limitations: Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.
Risks: This data is from summer 2015/16 and will become out of date as development continues in the ACT.
Land surface temperature and urban heat island data is available for the ACT based on observations from the Landsat8 satellite over summer 2015-16. The surface urban heat island data is based on the land surface temperature in urban areas compared to several comparison points in rural areas. The surface urban heat island is almost always larger than the urban heat island calculated using the air temperature.
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		1. Download data from CSIRO website. 2. Load into GIS software and find your site. 3. Determine whether your site of interest is in a hot spot compared to neighbouring areas in the ACT.
		Wind direction on extreme heat and cold days using Bureau of Meteorology sub-daily data ***Skills required: Microsoft Excel. If plotting a wind rose, then computer science programming is needed*** ***Access and cost: Bureau of Meteorology data available for a fee (~$100).*** ***Outputs: Quantified understanding of which direction the wind is most often coming from on an extreme heat or cold day. Histograms or wind roses of the wind direction on historical extreme heat or cold days. This informs the direction of prevailing winds at your site. Note that the Bureau of Meteorology data indicates the direction the wind is coming from. Wind direction of 360˚ means the wind is coming from the north and moving towards the south.*** ***Limitations: This is a general analysis into wind direction and cannot be used for detailed analysis between multiple buildings.*** ***Risks: In a highly urbanised area the wind direction recorded at a weather station may not reflect what is happening between buildings as they can affect wind flow.*** Air temperature, wind speed and direction, and other data can be requested from the Bureau of Meteorology for weather stations at 3 hourly or 30 minute time scales. Wind direction 1. Request data for the closest weather station to your site: • wind speed and direction • dry bulb temperature (air temperature). 2. Using the air temperature data filter for the hottest/coldest 5% of days during summer/winter. The 5% threshold can be found using the percentile function in excel. 3. Identify the most common wind speed and direction for the hottest/coldest 5% of days during summer and winter by plotting a histogram. OR 4. Plot a wind rose for the hottest/coldest 5% of days. A wind rose demonstrates the most common wind speed and direction in a visual format. 5. This gives information regarding the wind direction on the hottest/coldest days at your site, which is important if nearby areas are hotter or colder. The wind patterns can influence the temperature at your site.

A holistic prioritisation method for microclimate assessment and site selection (based on Norton et al. 2015)

Skills required: Basic GIS

Access and cost: Free

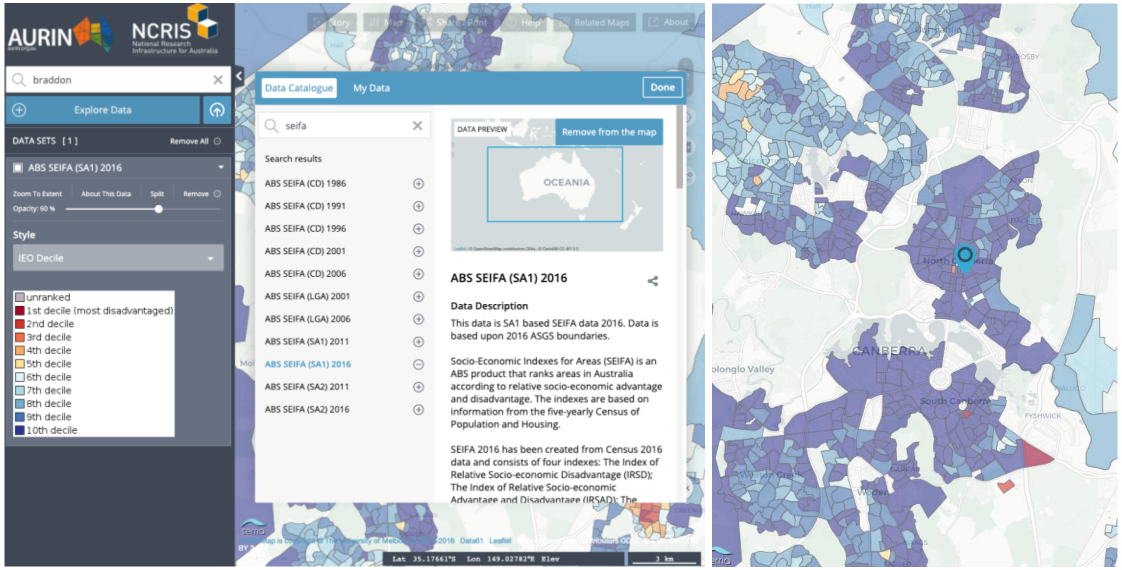
Outputs: Prioritised sites for development based on a quantified map of the land surface temperature of your site and surrounding areas, a quantified map of the socio-economic status of residents in your site or surrounding areas, and understanding of where vulnerable people are likely to congregate in your site or surrounding areas.

Limitations: This method works best when the user has an intimate knowledge of the site as it requires knowledge of where people congregate at the site.

Risks: There may be insufficient data for the site, especially if it is a green field site.

This framework combines microclimate assessment with assessment of human behaviours and vulnerability to prioritise locations for microclimate treatments.

1. Assess whether the site is in a hot or cold spot using the **CSIRO land surface temperature and surface urban heat island data** method
2. Assess the vulnerability of the current population if an intensification development, or surrounding population if greenfield. To do this access from the Australian Urban Research Infrastructure Network (AURIN) the Socio-Economic Indexes for Areas (SEIFA) data for your site. This can be done through Aurin Map by searching for your site by name, then selecting SEIFA in explore data (see images below). The SEIFA data is available for each Census period with SA1 data the highest resolution available. Other variables to consider that affect heat vulnerability include household incomes, health statistics and transport accessibility. Is your site more disadvantaged than surrounding areas? If so, residents are likely to be more vulnerable to extreme heat and extreme cold.



3. Assess whether your site and surrounding areas contains places where large numbers of vulnerable people will congregate such as aged care facilities, school, community centres and health centres. This is to understand where people are likely to be outdoors for prolonged periods of time. Some of this data is available through AURIN, though knowledge of the local area is sufficient. If your intensification site or greenfield site is near areas where vulnerable people congregate it is likely the people at the site will be more vulnerable to extreme heat and cold.
4. The intersection of places from the Steps 1-3 (land surface temperature, vulnerability and people congregating) demonstrates where should be prioritised for microclimate treatments.
5. Once a site is chosen, assess the existing vegetation and assess the built form noting street widths, street orientations and building heights as per **Observational methods – ACTmapi**.

Design and approval

(e.g. estate development plan approvals stage, which outlines areas designated for open space, street and block location/orientation/geometry – this applies to both urban intensification precincts and greenfield estates)

Why do an assessment at this stage?	• To mitigate threats to liveability outcomes in urban areas from urban heat and a warming climate, including those related to thermal comfort, energy efficiency and biodiversity, through improved precinct development plans and designs. • To help plan and design precinct infrastructure in such a way that reduces whole-of-lifecycle costs. • To ensure precinct plans and designs have adequately addressed and accounted for thermal comfort outcomes.
Who should do them?	***Primary responsibility:*** Public and private sector precinct and estate scale developers, planning consultants, capital infrastructure planners
	Secondary contractors: Landscape architects and urban design consultants.
What are the outcomes from the assessment?	• Understanding of hot spots and cool spots in the site design, and how human thermal comfort is affected. • Understanding of the prevailing winds and how they will interact with the site. • Understanding of whether the microclimate has been considered in the design of the site.
Things to consider when doing the assessment	1. What are the hot and cool spots across the precinct and neighbouring areas? 2. Where does the prevailing wind come from during extreme heat or cold days? 3. Is this a green field or an intensification project? • Green field – Is the site neighbouring a large natural area? Is it upwind or downwind from the site on extreme heat or cold days? • Intensification – Is the street layout fixed? What is the orientation of the streets? What are the building geometry characteristics? 4. Is there existing vegetation (particularly trees) at the site and in surrounding areas? Can it be retained? 5. Where are the main pedestrian routes? 6. How does water move across the site? Is water integrated into the landscape through irrigation or increased vegetation – green infrastructure?

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7. Does the design:

Harness the moderating effect of any surrounding natural environments?
Create hot and cool spots – and how can they be modified?
Enhance the microclimate of the area by providing a cool or warm refuge in summer and winter, respectively?
Meet tree canopy targets?

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<td>How do you do them?</td>
<td>Observational methods</td>
<td>
Principles of urban climate to qualitatively assess your site
Skills required: Urban design skills or experience desirable
Access and cost: Free
Outputs: Qualitative understanding of which parts of your design will be hotter or cooler. Quantified understanding of the shadow length of various buildings across the site
Limitations: This is a qualitative method that does not account for all specialist design options in a site that could affect the microclimate, such as green walls.
Risks: If the designs change this assessment may need to be repeated.

Look at the design of your site, understand which direction is north.
Look at the layout of the streets and in what directions they are running do they run directly north south and east-west? Unshaded east-west streets are hotter than unshaded north-south streets as they are exposed to more sun throughout the day.
Look at how wide the streets are and whether they have much existing vegetation. Unshaded wide streets are hotter than thinner streets as they are exposed to more sun throughout the day.
Look at how tall the designed buildings are. Taller buildings create more shade at street level and are likely to result in cooler adjacent streets
Note which streets in the design are likely to be hottest and coolest based on Steps 2–4. Use the table below to approximate which streets are likely to be hottest (red and yellow) and coldest (green and blue). Note that this table assumes zero current street tree cover.

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Canyon width	Street tree prioritisation									Orientation
Very wide 40m	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	E-W
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	N-S
Wide 30 m	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.07	1.20	E-W
	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.07	1.20	N-S
Medium 20 m	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	E-W
	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	N-S
Narrow 10 m	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	E-W
	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	N-S
Canyon height	4 m	8 m	12 m	16 m	20 m	24 m	28 m	32 m	36 m	
	Low			Medium			High			

Table source: Norton et al. 2015 and CRC for Water Sensitive Cities

6. Due to the position of the sun throughout the day sunlight is always shining onto north facing walls, and west facing walls during the afternoon.
7. Note which direction the walls of the building(s) are facing, labelling north and west facing falls as hotter and south and east facing walls as cooler. North and west facing walls are hotter, particularly in the afternoon, because they receive more sunlight throughout the day for north facing walls and during hottest times in the day for west facing walls. South or east facing walls are cooler because they are often in shadow or receive less incident sunlight throughout the day.
8. Consider whether there is planned or existing vegetation/structures/surfaces that could provide shading or cooling to the north and east facing walls, and the hottest streets.
9. Due to the position of the sun throughout the day, in the afternoon buildings will cast their shadows to the east, with a small shadow to the south.
10. To understand the length of shadows to the east of buildings use a shadow calculator. In the calculator type:
    - Object height: the height of your building
    - Date and time: any date of interest, though 3pm on the summer and winter solstice will produce the most extreme results
    - Latitude: 35˚ 16’ 55” S

		• Longitude: 149˚ 7’ 44” E • Time Zone: 10 (or 11 if during daylight savings) • E.g. At 3pm on the summer solstice during daylight savings in the ACT, a 5 m tall building will produce a shadow that is 2.7 m long. Therefore, at this time a 5m tall building would almost completely shade an east or south facing courtyard if it is smaller than 3m. If considering microclimate moderation look at temperature moderating treatments applicable at the precinct scale at the end of this section. Prioritise cooling options in the hot spots of your site. If using trees, consider deciduous trees to ensure adequate sunlight during winter.
	Data analysis	CSIRO land surface temperature and surface urban heat island data ***Skills required: Basic GIS*** ***Access and cost: Free from*** *CSIRO data website*. ***Outputs: Quantified map of land surface temperature for your site and surrounding areas during an average summer day.*** ***Limitations: Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.*** ***Risks: This data is from summer 2015/16 and will become out of date as development continues in the ACT.*** Land surface temperature and urban heat island data is available for the ACT based on observations from the Landsat8 satellite over summer 2015-16. The surface urban heat island data is based on the land surface temperature in urban areas compared to several comparison points in rural areas. The surface urban heat island is almost always larger than the urban heat island calculated using the air temperature. 1. Download data from CSIRO website. 2. Load into GIS software and find your site. 3. Determine whether your site is in a hot spot compared to neighbouring areas in the ACT. This helps set the context of the microclimate assessment by understanding the macro.
		Wind direction on extreme heat and cold days using Bureau of Meteorology sub-daily data ***Skills required: Microsoft Excel. If plotting a wind rose, then computer science programming is needed*** ***Access and cost: Bureau of Meteorology data available*** *for a fee (~$100)*. ***Outputs: Quantified understanding of which direction the wind is most often coming from on an extreme heat or cold day. Histograms or wind roses of the wind direction on historical extreme heat or cold days. This informs the direction of prevailing winds at your site. Note that the***

Bureau of Meteorology data indicates the direction the wind is coming from. Wind direction of 360˚ means the wind is coming from the north and moving towards the south.

Limitations: This is a general analysis into wind direction and cannot be used for detailed analysis between multiple buildings.

Risks: In a highly urbanised area the wind direction recorded at a weather station may not reflect what is happening between buildings as they can affect wind flow.

Air temperature, wind speed and direction, and other data can be requested from the Bureau of Meteorology for weather stations at 3 hourly or 30 minute time scales.

1. Request data for the closest weather station to your site:
   - wind speed and direction
   - dry bulb temperature (air temperature).
2. Using the air temperature data filter for the hottest/coldest 5% of days during summer/winter. The 5% threshold can be found using the percentile function in excel.
3. Identify the most common wind speed and direction for the hottest/coldest 5% of days during summer and winter by plotting a histogram.

   OR
4. Plot a wind rose for the hottest/coldest 5% of days. A wind rose demonstrates the most common wind speed and direction in a visual format.
5. This gives information regarding the wind direction on the hottest/coldest days at your site, which is important if nearby areas are hotter or colder. The wind patterns can influence the temperature at your site, and within your site design.

A holistic prioritisation method for microclimate assessment and site selection (based on Norton et al. 2015)

Skills required: Basic GIS

Access and cost: Free

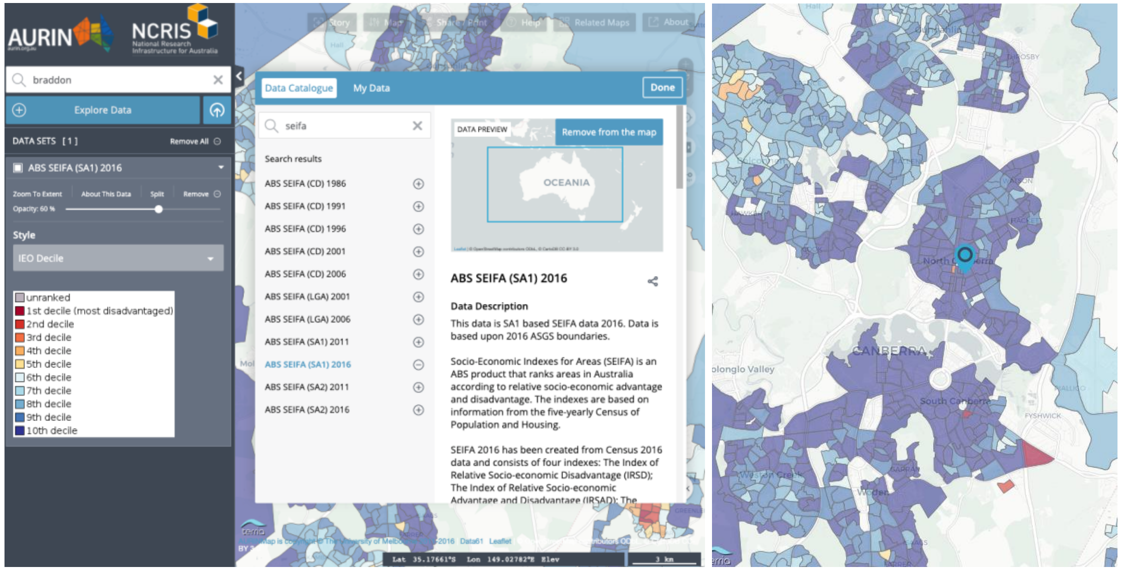
Outputs: Prioritised sites for development based on a quantified map of the land surface temperature of your site and surrounding areas, a quantified map of the socio-economic status of residents in your site or surrounding areas, and understanding of where vulnerable people are likely to congregate in your site or surrounding areas.

Limitations: This method works best when the user has an intimate knowledge of the site as it requires knowledge of where people congregate at the site.

Risks: There may be insufficient data for the site, especially if it is a green field site.

This framework combines microclimate assessment with assessment of human behaviours and vulnerability to prioritise locations for microclimate treatments.

1. Assess whether the site is in a hot or cold spot using the **CSIRO land surface temperature and surface urban heat island data** method
2. Assess the vulnerability of the current population if an intensification development, or surrounding population if greenfield. To do this access from the Australian Urban Research Infrastructure Network (AURIN) the Socio-Economic Indexes for Areas (SEIFA) data for your site. This can be done through Aurin Map by searching for your site by name, then selecting SEIFA in explore data (see images below). The SEIFA data is available for each Census period with SA1 data the highest resolution available. Other variables to consider that affect heat vulnerability include household incomes, health statistics and transport accessibility. Is your site more disadvantaged than surrounding areas? If so, residents are likely to be more vulnerable to extreme heat and extreme cold.



3. Assess whether your site and surrounding areas contains places where large numbers of vulnerable people will congregate such as aged care facilities, school, community centres and health centres. This is to understand where people are likely to be outdoors for prolonged periods of time. Some of this data is available through AURIN, though knowledge of the local area is sufficient. If your intensification site or greenfield site is near areas where vulnerable people congregate it is likely the people at the site will be more vulnerable to extreme heat and cold.

		4. The intersection of places from the Steps 1-3 (land surface temperature, vulnerability and people congregating) demonstrates where should be prioritised for microclimate treatments. 5. Once a site is chosen, assess the existing vegetation and assess the built form noting street widths, street orientations and building heights as per Observational methods – ACTmapi viewer
	Modelling methods	The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET), suitable for larger precincts up to 100 Ha in size *Skills required: GIS and computer science.* *Access and cost: TARGET model free from website, Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.* *Outputs: quantified maps of the air temperature and Universal Thermal Climate Index (UTCI) for the design of the site. If modelling microclimate treatments, outputs will also be maps of the air temperature and UTCI across the site incorporating microclimate treatments.* *Limitations: The model requires computer science skills to set up and run.* *Risks: The CRC for Water Sensitive Cities, the developers of TARGET, will end in 2021. There is doubt to whether further development of TARGET will occur.* The TARGET model calculates the air temperature, land surface temperature and outdoor human thermal comfort of an area of interest based on the land use design and meteorological data. It is best suited modelling at spatial resolutions of 20 m or larger, hence most appropriate for modelling larger precincts. 1. Identify using a bird's eye view of the site as many of the following features: • building outlines • building height • areas of dry grass • areas of irrigated grass • roads • trees • footpaths • water bodies.

2. Convert birds eye view perspective into the shapefile or raster format, which can be read by GIS programs. Alternatively, this land cover data can be purchased from data providers such as Geoscape for a fee.
3. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as people are most vulnerable during these times. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide.
4. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 3, as well as the day before and the day after. Variables to obtain are:
    - Air temperature.
    - Wind speed.
    - Relative humidity (can be derived from the dew point temperature).
    - Barometric pressure.
    - Incoming short wave radiation (download the variable Mean surface downward short wave radiation flux from the ERA5 data set.
    - Incoming long wave radiation (download the variable Mean surface downward long wave radiation flux from the ERA5 data set.
5. Use shapefile of design and meteorological data as inputs into the TARGET model.
6. Plot spatial maps of the air temperature and Universal Thermal Climate Index (UTCI) for different times of the day, paying particular attention to the afternoon, the hottest time of the day.
7. Look for hot spots and cool spots in the air temperature and UTCI maps.
8. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index.
    - Objectives: Outdoor Thermal Comfort (and others if desired).
    - Climate Regions: Canberra.
    - Urban Context: choose which best suits your area.
9. Consider the different microclimate moderation techniques that could work for your area to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects.

If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps.

10. Select which microclimate moderation technique will be used at the area and apply this to the GIS birds eye view raster or shapefile of the area defined in steps 1 and 2.
11. Rerun the TARGET model using the new area design inputs.
12. Compare to the original simulation and identify whether the hot or cold spots have been reduced.

ENVI-met

***Skills required:** GIS, urban climate science or microclimate assessment would be a benefit but is not essential.*

***Scale:** Suited from Block scale to smaller precincts up to 10 Ha*

***Access and cost:** Annual licence fee for ENVI-met (~$5000AUD), Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website*

***Outputs:** quantified maps of the air temperature and Universal Thermal Climate Index (UTCI) for the design of the site. If modelling microclimate treatments, outputs will also be maps of the air temperature and UTCI across the site incorporating microclimate treatments.*

***Limitations:** ENVI-met requires a significant investment in hardware (powerful computers to run the model), software (buying a licence to the program), expertise and time (to set up and run the model).*

***Risks:** The high costs associated with setting up and running ENVI-met may not be economical for a Block scale microclimate assessment.*

***Special notes:** ENVI-met is considered the best Simulation Tool at the Block scale, as it can simulate meteorological parameters such as sun and shade, wind, humidity and the interactions between blue and green infrastructure and the environment. However, ENVI-met is a time and resource intensive model to set up and run, and it requires detailed meteorological and site data. This is why the ENVI-met model is recommended for smaller precincts up to 10 Ha in size, as it becomes too resource intensive to set up and run the model at larger sizes. An annual licence is approximately $5000AUD and requires powerful desktop computers to run simulations, as well as specialist knowledge to set up and run the model. Additionally, it requires detailed designs and data.*

ENVI-met is a comprehensive microclimate model that combines an atmospheric model, a vegetation model and a building model to produce spatial maps of meteorological variables such as the air temperature, land surface temperature and outdoor human thermal comfort.

1. Obtain a bird's eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the raster or shapefile format, which can be read by GIS programs. Alternatively, this land cover data can be purchased from data providers such as Geoscape for a fee.
2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide.

		3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are: • Wind speed. • Wind direction • Air temperature. • Relative humidity. • Rainfall. 4. Use this shapefile of the design and meteorological information as inputs into the ENVI-met model. 5. Output spatial maps of the air temperature between 0 and 2m above the surface, the surface temperature and the UTCI for different times of the day. Pay special attention to the air temperature in the afternoon, the hottest time of the day if interested in extreme heat, and just before dawn if interested in extreme cold. 6. Look for hot spots and cool spots including areas that are shaded. 7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 7. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 8. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 9. Rerun the ENVI-MET model using the new site design inputs. 10. Compare to the original simulation and identify whether the hot or cold spots have been reduced. 11. Look for hot spots and cool spots including areas that are shaded.

Solar and LongWave Environmental Irradiance Geometry (SOLWEIG) model

Skills required: GIS

Scale: Suited from Block scale to smaller precincts up to 10 Ha

Access and cost: Free in UMEP plugin in QGIS, Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.

Outputs: quantified maps of the mean radiant temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments.

Limitations: The only temperature variable SOLWEIG outputs is the Mean Radiant Temperature, which is highly related to radiation, shadows and surface materials. This is not a standard meteorological variable and may be difficult for people to interpret.

Risks: SOLWEIG is an open source platform, which may not be appropriate for sensitive data.

Special notes: SOLWEIG is an easy to use Simulation tool that is well established and commonly used. SOLWEIG requires detailed information on the site including building dimensions to run. This is why the SOLWEIG model is recommended for smaller precincts up to 10 Ha in size, as it becomes too resource intensive to set up and run the model at larger sizes. SOLWEIG is an open source platform hosted on QGIS, another open source platform. Open source platforms are not always considered a safe space for recording sensitive data. The nature of open-source platforms is that they are not owned or managed by an individual or company meaning that updates to the platform occur through the input of individuals, another potential avenue for compromising sensitive information.

The SOLWEIG model uses the land surface, building geometry and the position of the sun to create spatial maps of the mean radiant temperature, a large determinant of outdoor human thermal comfort. The mean radiant temperature can be used as a proxy for the air temperature (though the scales are different) as the hot spots and cool spots would be very similar.

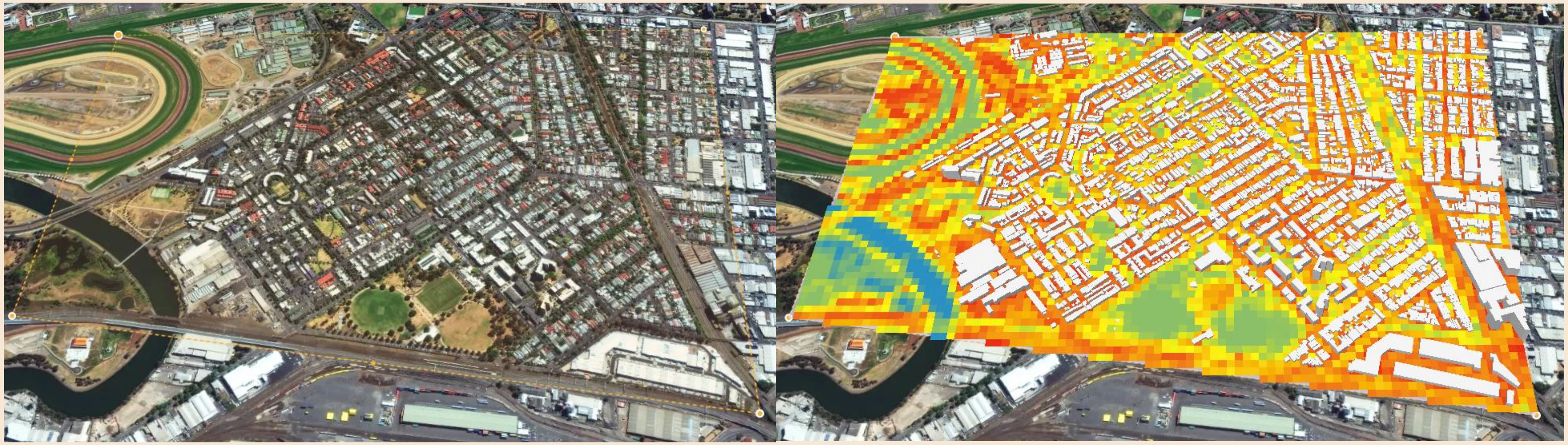
1. Obtain a bird's eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the raster or shapefile format, which can be read by GIS programs. Alternatively, this land cover data can be purchased from data providers such as Geoscape for a fee.
2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide.
3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are:
   - Incoming short wave radiation (if this cannot be found from the Bureau of Meteorology, download the variable Mean surface downward short wave radiation flux from the ERA5 data set.

		- Wind speed. - Air temperature. - Relative humidity. - Barometric pressure. - Rainfall. 4. Use this information as inputs into the SOLWEIG model. 5. Plot spatial maps of the mean radiant temperature for different times of the day, paying particular attention to the afternoon, the hottest time of the day. 6. Look for hot spots and cool spots including areas that are shaded. 7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. - Objectives: Outdoor Thermal Comfort (and others if desired). - Climate Regions: Canberra. - Urban Context: choose which best suits your site. 8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. 9. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 10. Select which microclimate moderation technique will be used at the site and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 11. Rerun the SOLWEIG model using the new site design inputs. 12. Compare to the original simulation and identify whether the hot or cold spots have been reduced.
		CRC for Water Sensitive Cities Scenario Tool *Skills required: GIS skills.* *Access and cost: Free if CRC for Water Sensitive Cities industry partner, CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.*

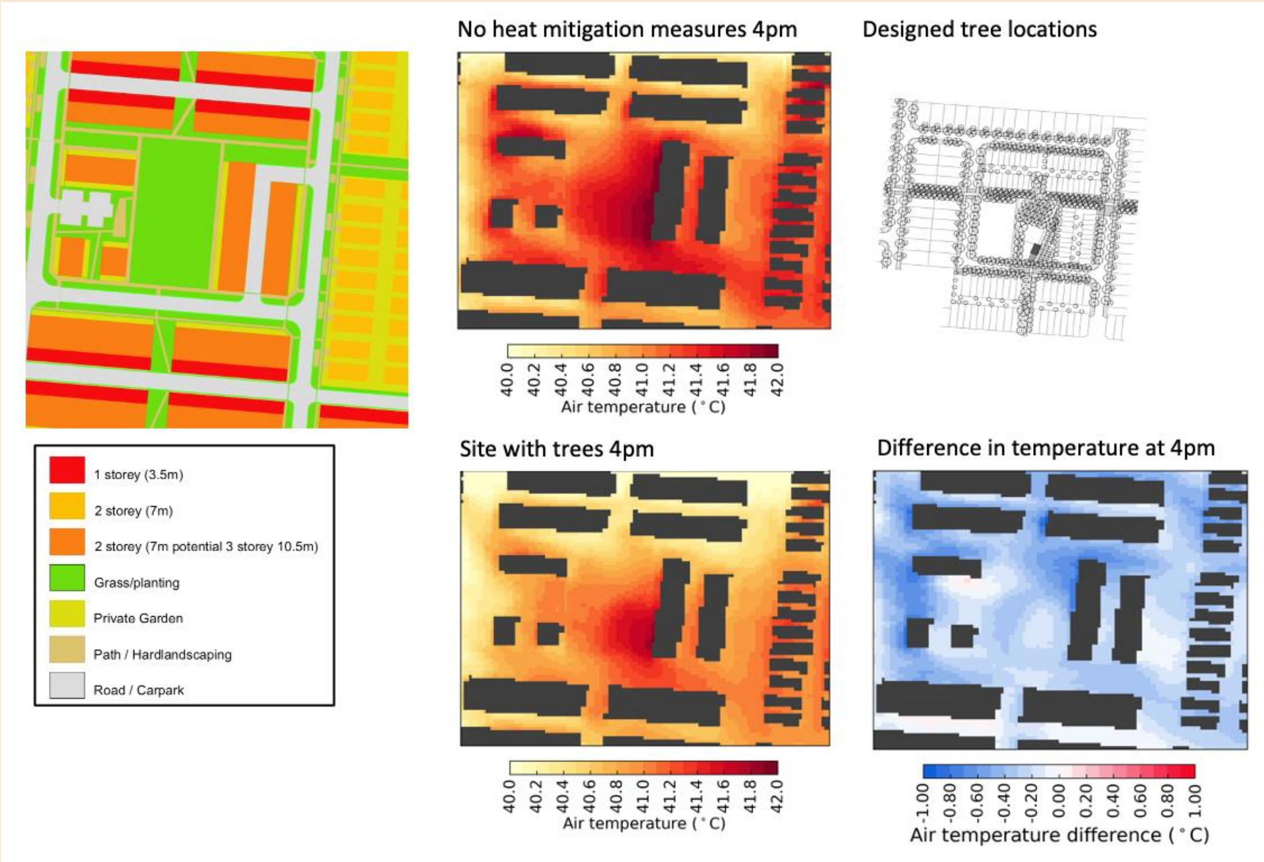
		Outputs: Quantified maps of the air temperature and land surface temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments and time series comparing the two simulations. *Limitations: The CRC Scenario Tool is best applied to larger areas rather than Block to building scale as the preferred resolution of the model is 20m.* *Risks: The CRC for Water Sensitive Cities will end in 2021 with the Water Sensitive Institute likely to commercialise the Tool with a subscription fee.* This online Tool, free for CRC for Water Sensitive Cities industry partners, enables users to quantify the air temperature, land surface temperature and human thermal comfort of a user defined region ranging from residential blocks up to the suburb area scale. 1. Select chosen area of interest in the Scenario Tool. 2. Add own surface cover data from design, such as building locations and where grass and roads are located. 3. Select Land Surface Temperature and TARGET Urban Heat Island assessment modules. 4. Select where your data is located. 5. By default, the Scenario Tool generates a map during extreme heat conditions. 6. Select weather module in the scenario builder to simulate an alternative date such as colder conditions. 7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from highly suited to less suited. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 9. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 10. Rerun the CRC for Water Sensitive Cities Scenario Tool using the new site design inputs.

		11. Compare to the original simulation and identify whether the hot or cold spots have been reduced.

Case Study – The CRC Scenario Tool: The tool was applied to parts of the suburb of Kensington in Melbourne where a map of the land surface temperature was generated highlighting the hot spots on an extreme heat day. An additional 30% of tree canopy cover was then added to the site resulting in a 4˚C reduction in land surface temperatures across the site. Credit: Mosaic Insights (2020).



Case study – proposed development in western Melbourne: A microclimate assessment was conducted on the proposed urban design of a new precinct in western Melbourne. Modelling with ENVI-met on an extreme heat day found that the air temperature was hottest near the north and west facing walls. North facing walls receive more direct sunlight throughout the day than south facing walls, making them hotter and causing them to emit more heat. West facing walls receive more direct sunlight during warmer times of the day when surfaces have been able to accumulate heat, resulting in them being hotter. This resulted in parts of the open space being some of the hottest in the precinct due to the heat coming from the west facing buildings and the fact the grass was not irrigated. The shadows to the east of the buildings cooled the air and were the coolest in the modelling area as they were shielded from the majority of the sunlight by the buildings. Trees were added to the design to reduce urban heat in the hot spots. These were then modelled with ENVI-met resulting in 1˚C of cooling in many places across the site. Credit: Mosaic Insights, Development Victoria, Tract and GBLA (2020)



Maintenance and renewal

(e.g. capital work upgrades to existing open spaces, town centres, retrofitting streets with cooling measures)

Why do an assessment at this stage?	• To establish whether there are opportunities to improve microclimates through infrastructure asset maintenance or renewal processes • To establish whether existing green or blue infrastructure is working to its full capacity as part of maintenance and renewal processes.
Who should do them?	***Primary responsibility:*** Infrastructure project managers.
	Secondary contractors: Landscape architects and urban asset maintenance contractors, consultants and universities.
What are the outcomes from the assessment?	• Qualitative understanding of the hot and cool spots across the site • If the site contains existing microclimate moderating infrastructure, determine whether the infrastructure is working correctly. • If the site is earmarked for microclimate moderation, determine where and what should be used at the site.
Things to consider when doing the assessment	1. What are the hot and cool spots across the precinct and neighbouring areas? 2. Where does the prevailing wind come from during extreme heat or cold days? 3. Is this a green field or an intensification project? o Green field – Is the site neighbouring a large natural area? Is it upwind or downwind from the site on extreme heat or cold days? o Intensification – Is the street layout fixed? What is the orientation of the streets? What are the building geometry characteristics? 4. Is there existing vegetation (particularly trees) at the site and in surrounding areas? Can it be retained? 5. Where are the main pedestrian routes? 6. How does water move across the site? Is water integrated into the landscape through irrigation or increased vegetation – green infrastructure? 7. Does the design: • Harness the moderating effect of any surrounding natural environments?

	• Create hot and cool spots – and how can they be modified? • Enhance the microclimate of the area by providing a cool or warm refuge in summer and winter, respectively? 8. Meet tree canopy targets? 9. Has this site been designed and constructed with microclimate in mind? • If yes, are the microclimate adaptations and features evident on site? Have you access to the plans? Proceed to Observational methods below • If no, use the questions and tools recommended in Precinct scale Design and Approval stage.	
How do you do them?	*Observational methods*	Observational microclimate checklist of the site and principles of urban climate to qualitatively assess your site. *Skills required: Urban design skills or experience desirable* *Access and cost: Free* *Outputs: Qualitative understanding of the hot and cool spots across the site based on a desktop inspection. Visual inspection of the site to check whether microclimate treatments are in working order.* *Limitations: This is a qualitative method that does not account for all specialist design options in a site that could affect the microclimate.* *Risks: If the designs change this assessment may need to be repeated.* 1. Review the design and implementation of the site. 2. Note which areas in the site are likely to be hottest and coolest. Hotter areas contain less vegetation, more impervious surfaces and densely packed buildings (image on the left). Cooler areas contain more and taller vegetation, more pervious surfaces and generally fewer buildings (image on the right). Both image examples are from Western Sydney.

3. Observe how the streets are oriented in surrounding precincts, do they run directly north south and east-west? Unshaded east-west streets are hotter than unshaded north-south streets as they are exposed to more sun throughout the day.
4. Observe how wide the streets are and whether they have much existing vegetation. Unshaded wide streets are hotter than thinner streets as they are exposed to more sun throughout the day.
5. Observe how tall the buildings are. Taller buildings create more shade at street level and are likely to result in cooler adjacent streets
6. Note which streets are likely to be hottest and coolest based on Steps 6–8. Use the table below to approximate which streets are likely to be hottest (red and yellow) and coldest (green and blue). Note that this table assumes zero current street tree cover.

Canyon width	Street tree prioritisation									Orientation
Very wide 40m	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	E-W
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	N-S
Wide 30 m	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.07	1.20	E-W
	0.13	0.27	0.40	0.53	0.67	0.80	0.93	1.07	1.20	N-S
Medium 20 m	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	E-W
	0.20	0.40	0.60	0.80	1.00	1.20	1.40	1.60	1.80	N-S
Narrow 10 m	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	E-W
	0.40	0.80	1.20	1.60	2.00	2.40	2.80	3.20	3.60	N-S
Canyon height	4 m	8 m	12 m	16 m	20 m	24 m	28 m	32 m	36 m	
	Low			Medium			High			

Table source: Norton et al. 2015 and CRC for Water Sensitive Cities

Review the designs and check for all microclimate features from the following list that apply to the site. Visit the site and determine:

Trees and vegetation

- Is vegetation at the site healthy and growing as expected? Is there enough water to sustain the vegetation?

Water

- Is the WSUD implemented according to the plan – are they functioning?
- Are irrigation systems installed and working correctly e.g. passive irrigation of street trees?
- Is there enough shading and sunlight at the site from trees?
    - Do the cool spots have adequate solar access?
    - Do the hot spots have adequate shade?

Building and landscape materials.

- Are the "cool" materials in use clean to maximise reflective abilities?
- Are shade structures in working order and providing shade where needed?
- Is solar access available as planned?

		Instantaneous surface temperature measurements with thermal imaging camera or spot thermometers *Skills required: None* *Access and cost: Thermal imaging cameras or thermometers need to be purchased. (Climate Change and Sustainability Division have access to this equipment)* *Outputs: Images of the surface temperature across the site which demonstrate whether areas with microclimate treatments are cooler than areas without microclimate treatments.* *Limitations: Ensuring observations are comparable can be difficult, particularly if background weather conditions can influence the surface temperature. Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.* *Risks: Monitoring is not conducted on a sufficient scale to consistently determine the hot and cool spots of the site.* These cameras can be used to produce thermal images of the surface temperature of a site. The surface temperature can be used as a proxy for air temperature, except on windy days. These cameras and thermometers can be obtained from many resources including Bunnings, Amazon and other sellers. Some cameras can become an attachment to mobile phones. 1. Plan where observations will be taken around the site. Consider sites that will measure the temperature of the north, south, east and west facing walls of buildings in the precinct, and various road typologies such as east-west oriented and north-south oriented, wide roads and thin roads. 2. Go to each site, adjust the site if necessary, to provide better imagery (e.g. if a tree is in the way of the original planned site). Geo locate the site. This can be done through dropping a pin on Google Maps, which records the latitude and longitude to seven decimal places. 3. Note the time of observation and meteorological conditions at your site: • Is it sunny or cloudy? • Is it windy or calm? • Is it raining? 4. Take photos with the thermal imaging camera or spot thermometer of your site. Note the height above the ground that you are taking the photos/recording the temperature. Record the observations. 5. When analysing data look for hot and cool spots across the site. The surface temperatures should be mitigated by the microclimate moderation technology. Repeat on days with similar meteorological conditions and at a similar time of day.

	Modelling methods	The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET) suitable for larger precincts up to 100 Ha in size *and* CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. *Skills required: GIS and computer science.* *Access and cost: TARGET model free from website, Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.* *Outputs: quantified maps of the air temperature and Universal Thermal Climate Index (UTCI) for the design of the site. If modelling microclimate treatments, outputs will also be maps of the air temperature and UTCI across the site incorporating microclimate treatments.* *Limitations: The model requires computer science skills to set up and run.* *Risks: The CRC for Water Sensitive Cities, the developers of TARGET, will end in 2021. There is doubt to whether further development of TARGET will occur.* The TARGET model calculates the air temperature, land surface temperature and outdoor human thermal comfort of an area of interest based on the land use design and meteorological data. It is best suited modelling at spatial resolutions of 20 m or larger, hence most appropriate for modelling larger precincts. 1. Identify using a bird's eye view of the site as many of the following features: • building outlines • building height • areas of dry grass • areas of irrigated grass • roads • trees • footpaths • water bodies. 2. Convert birds eye view perspective into the shapefile or raster format, which can be read by GIS programs. Alternatively, this land cover data can be purchased from data providers such as Geoscape for a fee. 3. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide.

		4. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 3, as well as the day before and the day after. Variables to obtain are: • Air temperature. • Wind speed. • Relative humidity (can be derived from the dew point temperature). • Barometric pressure. • Incoming short wave radiation (download the variable Mean surface downward short wave radiation flux from the ERA5 data set. • Incoming long wave radiation (download the variable Mean surface downward long wave radiation flux from the ERA5 data set. 5. Use shapefile of design and meteorological data as inputs into the TARGET model. 6. Plot spatial maps of the air temperature and Universal Thermal Climate Index (UTCI) for different times of the day, paying particular attention to the afternoon, the hottest time of the day. 7. Look for hot spots and cool spots in the air temperature and UTCI maps. 8. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 9. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 10. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 11. Rerun the TARGET model using the new site design inputs. 12. Compare to the original simulation and identify whether the hot or cold spots have been reduced.

		ENVI-met ***Skills required: GIS, urban climate science or microclimate assessment would be a benefit but is not essential.*** ***Scale: Suited from Block scale to smaller precincts up to 10 Ha*** ***Access and cost: Annual licence fee for ENVI-met (~$5000AUD), Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website*** ***Outputs: quantified maps of the air temperature and Universal Thermal Climate Index (UTCI) for the design of the site. If modelling microclimate treatments, outputs will also be maps of the air temperature and UTCI across the site incorporating microclimate treatments.*** ***Limitations: ENVI-met requires a significant investment in hardware (powerful computers to run the model), software (buying a licence to the program), expertise and time (to set up and run the model).*** ***Risks: The high costs associated with setting up and running ENVI-met may not be economical for a Block scale microclimate assessment.*** ***Special notes: ENVI-met is considered the best Simulation Tool at the Block scale, as it can simulate meteorological parameters such as sun and shade, wind, humidity and the interactions between blue and green infrastructure and the environment. However, ENVI-met is a time and resource intensive model to set up and run, and it requires detailed meteorological and site data. This is why the ENVI-met model is recommended for smaller precincts up to 10 Ha in size, as it becomes too resource intensive to set up and run the model at larger sizes. An annual licence is approximately $5000AUD and requires powerful desktop computers to run simulations, as well as specialist knowledge to set up and run the model. Additionally, it requires detailed designs and data.*** ENVI-met is a comprehensive microclimate model that combines an atmospheric model, a vegetation model and a building model to produce spatial maps of meteorological variables such as the air temperature, land surface temperature and outdoor human thermal comfort. 1. Obtain birds eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the raster or shapefile format, which can be read by GIS programs. Alternatively, this land cover data can be purchased from data providers such as Geoscape for a fee. 2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide. 3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are: • Wind speed. • Wind direction • Air temperature.

		• Relative humidity. • Rainfall. 4. Use this shapefile of the design and meteorological information as inputs into the ENVI-met model. 5. Output spatial maps of the air temperature between 0 and 2m above the surface, the surface temperature and the UTCI for different times of the day. Pay special attention to the air temperature in the afternoon, the hottest time of the day if interested in extreme heat, and just before dawn if interested in extreme cold. 6. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 7. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 8. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 9. Rerun the ENVI-MET model using the new site design inputs. 10. Compare to the original simulation and identify whether the hot or cold spots have been reduced. 11. Look for hot spots and cool spots including areas that are shaded.
		Solar and LongWave Environmental Irradiance Geometry (SOLWEIG) model *Skills required: GIS* *Scale: Suited from Block scale to smaller precincts up to 10 Ha* *Access and cost: Free in UMEP plugin in QGIS, Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.*

Outputs: quantified maps of the mean radiant temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments.

Limitations: The only temperature variable SOLWEIG outputs is the Mean Radiant Temperature, which is highly related to radiation, shadows and surface materials. This is not a standard meteorological variable and may be difficult for people to interpret.

Risks: SOLWEIG is an open source platform, which may not be appropriate for sensitive data.

Special notes: SOLWEIG is an easy to use Simulation tool that is well established and commonly used. SOLWEIG requires detailed information on the site including building dimensions to run. This is why the SOLWEIG model is recommended for smaller precincts up to 10 Ha in size, as it becomes too resource intensive to set up and run the model at larger sizes. SOLWEIG is an open source platform hosted on QGIS, another open source platform. Open source platforms are not always considered a safe space for recording sensitive data. The nature of open-source platforms is that they are not owned or managed by an individual or company meaning that updates to the platform occur through the input of individuals, another potential avenue for compromising sensitive information.

The SOLWEIG model uses the land surface, building geometry and the position of the sun to create spatial maps of the mean radiant temperature, a large determinant of outdoor human thermal comfort. The mean radiant temperature can be used as a proxy for the air temperature (though the scales are different) as the hot spots and cool spots would be very similar.

1. Obtain birds eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the raster or shapefile format, which can be read by GIS programs. Alternatively, this land cover data can be purchased from data providers such as Geoscape for a fee.
2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide.
3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are:
    - Incoming short wave radiation (if this cannot be found from the Bureau of Meteorology, download the variable Mean surface downward short wave radiation flux from the ERA5 data set.
    - Wind speed.
    - Air temperature.
    - Relative humidity.
    - Barometric pressure.
    - Rainfall.

		4. Use this information as inputs into the SOLWEIG model. 5. Plot spatial maps of the mean radiant temperature for different times of the day, paying particular attention to the afternoon, the hottest time of the day. 6. Look for hot spots and cool spots including areas that are shaded. 7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 9. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 10. Rerun the SOLWEIG model using the new site design inputs. 11. Compare to the original simulation and identify whether the hot or cold spots have been reduced.
		CRC for Water Sensitive Cities Scenario Tool *Skills required: GIS skills.* *Access and cost: Free if CRC for Water Sensitive Cities industry partner, CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.* *Outputs: Quantified maps of the air temperature and land surface temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments and time series comparing the two simulations.* *Limitations: The CRC Scenario Tool is best applied to larger areas rather than Block to building scale as the preferred resolution of the model is 20m.* *Risks: The CRC for Water Sensitive Cities will end in 2021 with the Water Sensitive Institute likely to commercialise the Tool with a subscription fee.*

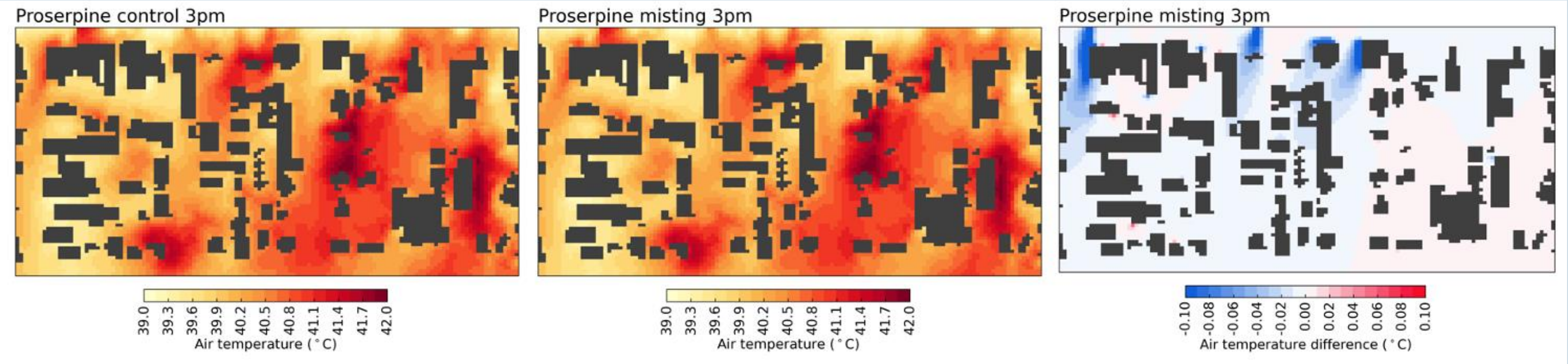
This online Tool, free for CRC for Water Sensitive Cities industry partners, enables users to quantify the air temperature, land surface temperature and human thermal comfort of a user defined region ranging from residential blocks up to the suburb area scale.

1. Select chosen area of interest in the Scenario Tool.
2. Add own surface cover data from design, such as building locations and where grass and roads are located.
3. Select Land Surface Temperature and TARGET Urban Heat Island assessment modules.
4. Select where your data is located.
5. By default, the Scenario Tool generates a map during extreme heat conditions.
6. Select weather module in the scenario builder to simulate an alternative date such as colder conditions.
7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index.
   - Objectives: Outdoor Thermal Comfort (and others if desired).
   - Climate Regions: Canberra.
   - Urban Context: choose which best suits your site.
8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from *highly suited* to *less suited*. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects.

If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps.

9. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2.
10. Rerun the CRC for Water Sensitive Cities Scenario Tool using the new site design inputs.
11. Compare to the original simulation and identify whether the hot or cold spots have been reduced.

Proserpine heat reduction case study: A microclimate assessment was conducted on the town of Proserpine, QLD. A combination of Geoscape spatial data, Bureau of Meteorology sub-daily data and the TARGET model was conducted to identify the hottest areas of the town on an extreme heat day (top row). The hottest pedestrian heavy areas were identified as Main St. ENVI-met modelling was then used to conduct high resolution modelling (area marked by purple box) tests of numerous cooling options on Main St and in the areas to the south of the street. In the example (bottom row) five misters were set up on street corners on Main St providing cooling of up to 0.6 ˚C. Credit: Mosaic Insights and Whitsunday Regional Council (2020).



Evaluation

(e.g. positive findings may help to support the development of future business cases)

Why do an assessment at this stage?	To evaluate the performance of precinct plans and policies aimed at reducing climate risks and infrastructure lifecycle costs by improving urban microclimates and delivering on thermal comfort and liveability outcomes.	
Who should do them?	***Primary responsibility:*** Government planning, health and environmental agency staff.	
	Secondary contractors: Universities and policy evaluation and liveability consultants.	
What are the outcomes from the assessment?	• Comparable and quantifiable indicators of the temperature across the site. • Comparable liveability indicators for the site.	
Things to consider when doing the assessment	Evaluation could include: 1. Inspections 2. Interviews, online surveys 3. Heat related hospital admissions data and ambulance call outs to determine any correlation with areas with poor microclimates 4. Any temperature change in urban heat maps 5. Locations of heat refuges and cool oases	
How do you do them?	*Observational methods*	★ Site monitoring checklist *Skills required: Horticultural or engineering skills.* *Access and cost: Free*

		Outputs: Qualitative understanding of whether the microclimate is being considered at the site and whether treatment options are working to their full capacity. ***Limitations: This method helps to highlight whether infrastructure is working correctly but relies heavily on an individual's existing skills.*** ***Risks: If the site inspections are too far apart, crucial observations may be missed.*** Immediately post construction handover, undertake site visits and inspections of infrastructure. After 12 months, 2 years, 5 years, 10 years: *Trees and vegetation.* • Is vegetation at the site healthy and growing as expected? Is there enough water to sustain the vegetation? *Water.* • Is the WSUD implemented according to the plan – are they functioning? • Are irrigation systems installed and working correctly e.g. passive irrigation of street trees? • Is there enough shading and sunlight at the site from trees? o Do the cool spots have adequate solar access? o Do the hot spots have adequate shade? *Building and landscape materials.* • Are the "cool" materials in use clean to maximise reflective abilities? • Are shade structures in working order and providing shade where needed? • Is solar access available as planned?
		Meteorological monitoring campaign with weather stations ***Skills required: GIS, weather station installation expertise.*** ***Access and cost: Weather stations and equipment need to be purchased. Each weather station usually costs more than $100*** ***Outputs: Time series and maps of the average air temperature across the site, highlighting the hot and cool spots. These measurements will form a baseline from before construction, which can be compared with measurements taken during a monitoring and evaluation period.*** ***Limitations: A sufficient spatial and temporal coverage of weather stations is required to properly assess the microclimate of the site***

Risks: The location of the weather stations may need to change once the site design is complete.

Immediately post construction place a minimum of four weather stations around the site. Weather stations can be procured from this website, though cheaper options are available. All weather stations should be the same make and brand. The weather station would ideally measure air temperature, relative humidity, wind speed and radiant temperature. They would also have Wi-Fi capability so that data is directly stored on a cloud server.

1. Place the weather stations a consistent height above the ground, make sure the weather station has full access to the wind from all directions. Ensure an even spread of weather stations across the site, though areas previously identified as hot or cool spots, or flagged for microclimate moderation can have more weather stations.
2. Throughout the monitoring period record the air temperature, relative humidity, wind speed and radiant temperature
3. Select the hottest or coldest 5% of days within the most recent complete season of summer or winter for each weather station.
4. Calculate the average of the hottest or coldest 5% for each weather station.
5. Interpolate the weather station data spatially across the site using GIS software.
6. Plot the spatial average temperature across the site.
7. Look for hot spots and cool spots.
8. Repeat steps 3-7 for each monitoring period.

Surface temperature monitoring campaign with drones

Skills required: GIS, drone flying, data analysis.

Access and cost: Technician with drone flying experience.

Outputs: Quantified map of observed average land surface temperatures of your site and surrounding areas for each monitoring period.

Limitations: If the weather is cloudy or windy during the observational campaign it may not produce useful maps of the land surface temperature, as cloudy days can reduce the magnitude of hot spots and windy days mixes the air so land surface temperature is not always an appropriate indicator of microclimate. Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.

Risks: Ensuring a consistent drone flight path and appropriate weather for the campaign can be difficult.

Immediately post construction fly a drone containing a thermal sensing camera across the site. This will create a picture of the land surface temperature across the site.

1. Fly the drone once a day at approximately 3pm on the same trajectory during a two-week monitoring campaign taking thermal pictures of the site.

		2. Ensure the land surface temperature data is spatially consistent. 3. Average the land surface temperature for each day in the monitoring campaign. 4. Identify hot and cool spots across the site. 5. Repeat steps 1-4 for each monitoring period.
		Survey precinct residents and workers *Skills required: Social science, survey design.* *Access and cost: Ethics approval.* *Outputs: Understanding of whether people have noticed changes in the microclimate of the precinct.* *Limitations: Answers to survey questions will be subjective and the survey would need a large number of respondents for significant results* *Risks: There are too few people to answer the survey.* The aim of this survey is to determine whether people who live or work or visit the precinct receive the microclimate moderation benefits. Survey questions could include: 1. Where in the precinct do you feel hottest and coldest? 2. Have you noticed more people walking in this neighbourhood than others? 3. How do your electricity bills during summer and winter compare to other locations?
	Data analysis	Landsat8 land surface temperature *Skills required: GIS.* *Access and cost: Data is free from Remote Sensing Lab Landsat Land Surface Temperature webpage.* *Outputs: Quantitative maps of the land surface temperature for your area during summer or winter* *Limitations: Observations are limited to the Landsat8 flight path, reaching the ACT every two weeks. The satellite needs clear skies for observations to take place. Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.* *Risks: The satellite needs clear skies for observations to take place.*

		The Landsat8 satellite passes over the ACT every 14 days monitoring the land surface temperature at a high resolution of 25m. It creates one snapshot of the land surface temperature per flyover. This data can help to capture the land surface temperature across your area and demonstrate how it changes over time. 1. Create a KML file of your area of interest. 2. Navigate to the Landsat Land Surface Temperature webpage run by the Remote Sensing Lab. 3. Input date selection. Ideally, you should look at the most recent and complete dataset for the season you are interested in. • For summer, this is from December 1 to February 28/29 • For winter, this is from June 1 to August 31. Other dates of interest can be included too. • Select Landsat: Landsat 8, the mostly widely used for land surface temperature calculations. • Select Emissivity: MODIS. This emissivity setting is best suited when analysing the land surface temperature for urban areas. 4. Upload the KML and select Calculate LST. Depending on the size of your site multiple KMLs may need to be created and the resulting rasters stitched together. 5. Download all the available data for the selected dates. 6. Using a raster calculator in a GIS program calculate the average land surface temperature for your season of interest. 7. Note the season average land surface temperature at your area and how it compares to neighbouring areas. Repeat these steps at later monitoring intervals to determine any variation in the land surface temperature at the area. This method could be used to provide updated urban heat maps for the ACT.
	Modelling methods	**The Air-temperature Response to Green/blue-infrastructure Evaluation Tool (TARGET) suitable for larger precincts up to 100 Ha in size *and* CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index.** ***Skills required: GIS and computer science. Access and cost: TARGET model free from website, Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.*** ***Outputs: quantified maps of the air temperature and Universal Thermal Climate Index (UTCI) for the design of the site. If modelling microclimate treatments, outputs will also be maps of the air temperature and UTCI across the site incorporating microclimate treatments.*** ***Limitations: The model requires computer science skills to set up and run.*** ***Risks: The CRC for Water Sensitive Cities, the developers of TARGET, will end in 2021. There is doubt to whether further development of TARGET will occur.***

		The TARGET model calculates the air temperature, land surface temperature and outdoor human thermal comfort of an area of interest based on the land use design and meteorological data. It is best suited modelling at spatial resolutions of 20 m or larger, hence most appropriate for modelling larger precincts. 1. Identify using a bird's eye view of the site as many of the following features: • building outlines • building height • areas of dry grass • areas of irrigated grass • roads • trees • footpaths • water bodies. 2. Convert birds eye view perspective into the shapefile or raster format, which can be read by GIS programs. Alternatively, this land cover data can be purchased from data providers such as Geoscape for a fee. 3. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide. 4. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 3, as well as the day before and the day after. Variables to obtain are: • Air temperature. • Wind speed. • Relative humidity (can be derived from the dew point temperature). • Barometric pressure. • Incoming short wave radiation (download the variable Mean surface downward short wave radiation flux from the ERA5 data set. • Incoming long wave radiation (download the variable Mean surface downward long wave radiation flux from the ERA5 data set. 5. Use shapefile of design and meteorological data as inputs into the TARGET model.

		6. Plot spatial maps of the air temperature and Universal Thermal Climate Index (UTCI) for different times of the day, paying particular attention to the afternoon, the hottest time of the day. 7. Look for hot spots and cool spots in the air temperature and UTCI maps. 8. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 9. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from highly suited to less suited. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 10. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 11. Rerun the TARGET model using the new site design inputs. Compare to the original simulation and identify whether the hot or cold spots have been reduced.
		ENVI-met *Skills required: GIS, urban climate science or microclimate assessment would be a benefit but is not essential.* *Scale: Suited from Block scale to smaller precincts up to 10 Ha* *Access and cost: Annual licence fee for ENVI-met (~$5000AUD), Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website* *Outputs: quantified maps of the air temperature and Universal Thermal Climate Index (UTCI) for the design of the site. If modelling microclimate treatments, outputs will also be maps of the air temperature and UTCI across the site incorporating microclimate treatments.* *Limitations: ENVI-met requires a significant investment in hardware (powerful computers to run the model), software (buying a licence to the program), expertise and time (to set up and run the model).* *Risks: The high costs associated with setting up and running ENVI-met may not be economical for a Block scale microclimate assessment.*

		Special notes: ENVI-met is considered the best Simulation Tool at the Block scale, as it can simulate meteorological parameters such as sun and shade, wind, humidity and the interactions between blue and green infrastructure and the environment. However, ENVI-met is a time and resource intensive model to set up and run, and it requires detailed meteorological and site data. This is why the ENVI-met model is recommended for smaller precincts up to 10 Ha in size, as it becomes too resource intensive to set up and run the model at larger sizes. An annual licence is approximately $5000AUD and requires powerful desktop computers to run simulations, as well as specialist knowledge to set up and run the model. Additionally, it requires detailed designs and data. ENVI-met is a comprehensive microclimate model that combines an atmospheric model, a vegetation model and a building model to produce spatial maps of meteorological variables such as the air temperature, land surface temperature and outdoor human thermal comfort. 1. Obtain birds eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the raster or shapefile format, which can be read by GIS programs. Alternatively, this land cover data can be purchased from data providers such as Geoscape for a fee. 2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide. 3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are: • Wind speed. • Wind direction • Air temperature. • Relative humidity. • Rainfall. 4. Use this shapefile of the design and meteorological information as inputs into the ENVI-met model. 5. Output spatial maps of the air temperature between 0 and 2m above the surface, the surface temperature and the UTCI for different times of the day. Pay special attention to the air temperature in the afternoon, the hottest time of the day if interested in extreme heat, and just before dawn if interested in extreme cold. 6. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra.

- Urban Context: choose which best suits your site.

7. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from highly suited to less suited. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects.

If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps.

8. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2.
9. Rerun the ENVI-MET model using the new site design inputs.
10. Compare to the original simulation and identify whether the hot or cold spots have been reduced.

Look for hot spots and cool spots including areas that are shaded.

Solar and LongWave Environmental Irradiance Geometry (SOLWEIG) model, suitable for smaller precincts up to 10 Ha in size

Skills required: GIS

Scale: Suited from Block scale to smaller precincts up to 10 Ha

Access and cost: Free in UMEP plugin in QGIS, Bureau of Meteorology data available for a fee (~$100), CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.

Outputs: quantified maps of the mean radiant temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments.

Limitations: The only temperature variable SOLWEIG outputs is the Mean Radiant Temperature, which is highly related to radiation, shadows and surface materials. This is not a standard meteorological variable and may be difficult for people to interpret.

Risks: SOLWEIG is an open source platform, which may not be appropriate for sensitive data.

Special notes: SOLWEIG is an easy to use Simulation tool that is well established and commonly used. SOLWEIG requires detailed information on the site including building dimensions to run. This is why the SOLWEIG model is recommended for smaller precincts up to 10 Ha in size, as it becomes too resource intensive to set up and run the model at larger sizes. SOLWEIG is an open source platform hosted on QGIS, another open source platform. Open source platforms are not always considered a safe space for recording sensitive data. The nature of open-source platforms is that they are not owned or managed by an individual or company meaning that updates to the platform occur through the input of individuals, another potential avenue for compromising sensitive information.

		The SOLWEIG model uses the land surface, building geometry and the position of the sun to create spatial maps of the mean radiant temperature, a large determinant of outdoor human thermal comfort. The mean radiant temperature can be used as a proxy for the air temperature (though the scales are different) as the hot spots and cool spots would be very similar. 1. Obtain birds eye view of the design specifying building outlines and building height. Additional details can be added if available such as: grassed areas, roads, trees and footpaths. Convert into the raster or shapefile format, which can be read by GIS programs. Alternatively, this land cover data can be purchased from data providers such as Geoscape for a fee. 2. Decide what type of weather you would like to model, extreme heat, extreme cold or anything in between. Extreme heat and cold are usually used for a microclimate assessment as this is when people are most vulnerable. Use the Bureau Climate Data Online website to find the closest weather station to the site, and search for an appropriate date using maximum and minimum temperatures as a guide. 3. Meteorological data is required to run the model and can be purchased from the Bureau of Meteorology observational database. Request half hourly data for your date chosen in Step 2, as well as the day before and the day after. Variables to obtain are: • Incoming short wave radiation (if this cannot be found from the Bureau of Meteorology, download the variable Mean surface downward short wave radiation flux from the ERA5 data set. • Wind speed. • Air temperature. • Relative humidity. • Barometric pressure. • Rainfall. 4. Use this information as inputs into the SOLWEIG model. 5. Plot spatial maps of the mean radiant temperature for different times of the day, paying particular attention to the afternoon, the hottest time of the day. 6. Look for hot spots and cool spots including areas that are shaded. 7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site.

8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from highly suited to less suited. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects.

If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps.

9. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2.
10. Rerun the SOLWEIG model using the new site design inputs.

Compare to the original simulation and identify whether the hot or cold spots have been reduced.

CRC for Water Sensitive Cities Scenario Tool, suitable for precincts up to 100 Ha in size

Skills required: GIS skills.

Access and cost: Free if CRC for Water Sensitive Cities industry partner, CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index available for free from website.

Outputs: Quantified maps of the air temperature and land surface temperature for the design of the site. If modelling microclimate treatments, outputs will also be maps of the mean radiant temperature across the site incorporating microclimate treatments and time series comparing the two simulations.

Limitations: The CRC Scenario Tool is best applied to larger areas rather than Block to building scale as the preferred resolution of the model is 20m.

Risks: The CRC for Water Sensitive Cities will end in 2021 with the Water Sensitive Institute likely to commercialise the Tool with a subscription fee.

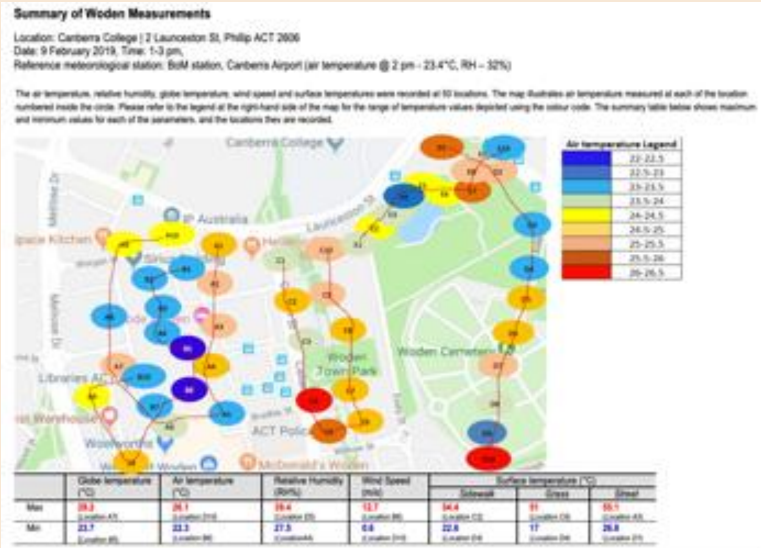
This online Tool, free for CRC for Water Sensitive Cities industry partners, enables users to quantify the air temperature, land surface temperature and human thermal comfort of a user defined region ranging from residential blocks up to the suburb area scale.

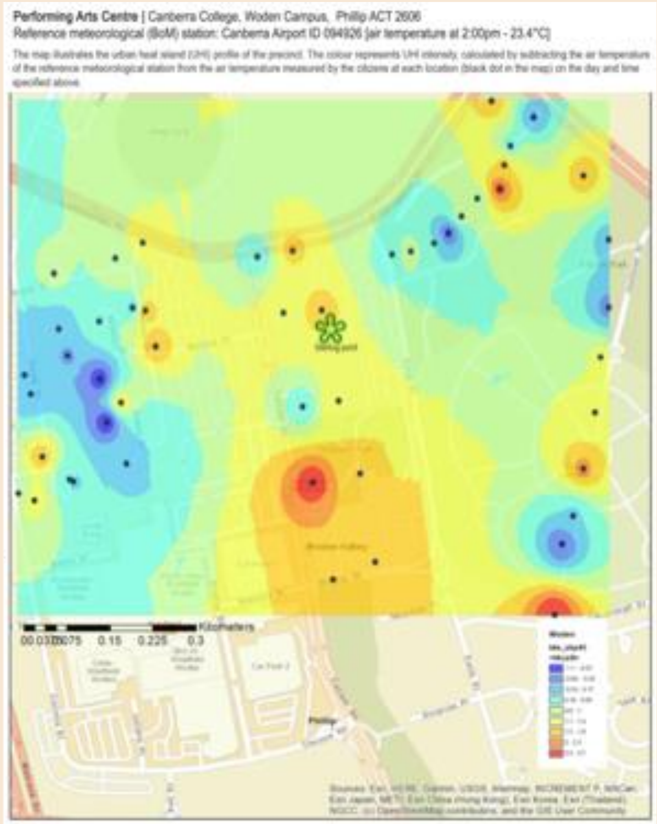
1. Select chosen area of interest in the Scenario Tool.
2. Add own surface cover data from design, such as building locations and where grass and roads are located.
3. Select Land Surface Temperature and TARGET Urban Heat Island assessment modules.
4. Select where your data is located.
5. By default, the Scenario Tool generates a map during extreme heat conditions.
6. Select weather module in the scenario builder to simulate an alternative date such as colder conditions.

		7. Open the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index. • Objectives: Outdoor Thermal Comfort (and others if desired). • Climate Regions: Canberra. • Urban Context: choose which best suits your site. 8. Consider the different microclimate moderation techniques that could work for your site to reduce the hot or cool spots noting the strategies are ranked from highly suited to less suited. Click on the information icon next to each strategy for implementation options and quantification from the literature of the microclimate moderation effects. If you would like to model the microclimate moderation techniques from the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index continue to the next steps. 9. Select which microclimate moderation technique will be used at the site, and apply this to the GIS birds eye view raster or shapefile of the site defined in steps 1 and 2. 10. Rerun the CRC for Water Sensitive Cities Scenario Tool using the new site design inputs. Compare to the original simulation and identify whether the hot or cold spots have been reduced.

Case study, Meteorological monitoring campaign with weather stations method – Canberra College Performing Arts Centre

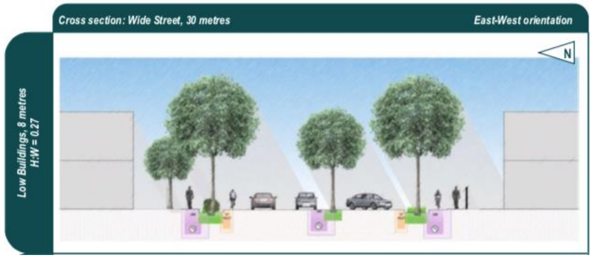
As part of their Citizen Science Project people took measurements at various sites around Australian cities. Meteorological measurements were captured at various sites across the ACT including measurements at 50 locations in Woden. The first map demonstrates the air temperature measured at each site while the second map shows the interpolated temperatures and the urban heat island through comparing the temperature map to a reference weather station, in this case Canberra Airport. Credit: RMIT Citizen Science Project (https://citizenscienceproject.org.au/participant-registration/act/)





Temperature moderating treatments applicable at the precinct scale

The purpose of these treatments is to create a more comfortable and moderate microclimate throughout the year in the ACT, improving human thermal comfort. The treatment measures are effective as they reduce the amount of solar radiation reaching or being absorbed by impervious and pervious surfaces, generally through shading. As such, impervious surfaces such as buildings and roads become cooler and moderate the microclimate. Increasing vegetation also has a moderating effect on microclimate through increasing shade but also creating an insulation effect in winter.

Strategy	Suitability	Description	Retrofit and design considerations
Height width ratio (H:W) for shading prioritisation	Highly suited	The height width ratio (height of building divided by the street width; H:W) can greatly affect the urban microclimate, as tall buildings increase shading at street level. Understanding the H:W is important for prioritising which streets would benefit most from shade. Research has shown that the thermal comfort during heat occurs when a building is three times higher than the width of the street (e.g. a 30m high building on a 10m wide street) (Yang et al. 2015). This is because the building shades the street and negates the need for additional shading from trees at street level. If the H:W is lower than three, trees will be an effective heat mitigator at street level. The principles of urban microclimate indicate that wide streets with short buildings are most in need of microclimate treatment, while narrow streets with tall buildings are a low priority as they are often self-shading. **Advantages:** Effective at urban cooling, helps prioritise where street level shading is required **Disadvantages:** Not always feasible due to zoning plans, can contribute to a 'concrete jungle' city if only shading from buildings is achieved	• Depending on the stage of development, it is easier to adjust the height of a building than the width of the street. This is particularly true with retrofitting precincts. The H:W ratio can be used to prioritise which streets and what side of the street would benefit most from microclimate treatment. • On narrow streets with low buildings (H:W = 0.8), street trees are only required on the southern side of the street.  • Conversely, wide streets with low buildings will likely require multiple trees to provide adequate shading for pedestrians. 

Strategy	Suitability	Description	Retrofit and design considerations
			• Additional H:W ratio scenarios and design considerations including plan view tree placement options, can be found in the CRC for Water Sensitive Cities Trees for a Cool City: Guidelines for optimised tree placement.
Street orientation	Highly suited	When streets run in a north-south and east-west grid they are susceptible to having very different solar exposures and microclimates. An east-west oriented street is always exposed as the sun moves overhead. A north-south oriented street receives morning sun on the western side of the street and afternoon sun on the eastern side of the street. As a result, an east-west oriented street usually has a warmer microclimate. Understanding street orientation can help determine which streets should be prioritised with ground level shading such as from trees. **Advantages:** Creates more equitable shade distribution, helps prioritise where street level shading is required **Disadvantages:** Cannot retrofit to an existing urban area	• Altering street orientation for microclimate treatment is not possible in the retrofit context as it would involve completely demolishing and redesigning the street layouts. • For a greenfield development knowledge of the street orientation will help prioritise where microclimate treatment is needed on which streets. Generally, wide east-west oriented streets will require shading from street trees. • North-south streets experience sun on the west side of the street in the morning and on the east side of the street in the afternoon. On wide north-south oriented streets it is advised that trees or shading devices are placed in the centre of the street to provide shade throughout the day, though if this is not possible, prioritise placing shade on the eastern side of the street to provide shade in the hotter afternoon.
Cool and permeable pavements	Highly suited	Pavements made from materials that are highly reflective and light coloured as well as pavements that are permeable and retain water decreasing temperatures through evaporation. Permeable pavements can help retain water and vegetation in the urban landscape, increasing the cooling effect. **Advantages:** Reduce the surface temperature of the pavement and air temperature above the pavement, reduced stormwater runoff for permeable pavements **Disadvantages:** Can increase glare for pedestrians, decreasing their human thermal comfort. Permeable pavements with large gaps can negatively affect accessibility	• Can be applied to new or retrofitted precincts • Cool pavements should be designed to minimise glare for pedestrians in the public realm • For additional information into the ideal material properties for cool and permeable pavements see the CRC for Low Carbon Living Urban Heat Island Mitigation Performance Index Tool
Street trees and planting	Highly suited	Reduce the temperature and improve human thermal comfort at street level through shading and evapotranspiration. Their	• Can be applied to new or retrofitted precincts

Strategy	Suitability	Description	Retrofit and design considerations
		effectiveness can be maximised through considering microclimate elements such as the street orientation, building setbacks from the street and ideal plant species. They can be prioritised through understanding the microclimate elements as well as level of pedestrian activity, character and use of the street. For more information including resources on appropriate species and establishing a hierarchy of streets see the CRC for Low Carbon Living Heat Mitigation Performance Index. **Advantages:** Reduced air temperature and improved thermal comfort, enhanced biodiversity, amenity, human health, social cohesion, energy savings and air quality **Disadvantages:** Deciduous trees can cause leaf litter	• The arrangement of street trees can be prioritised based on the orientation of the streets, the height of buildings in the precinct and the width of the streets. • Detailed information including into can be found in the CRC for Water Sensitive Cities Trees for a Cool City: Guidelines for optimised tree placement.
Green Open Spaces	Highly suited	Parks with grasses, shrubs trees and minimal impervious surfaces are very effective at improving the urban microclimate, particularly when irrigated. This is regardless of the size of the park. However, the cooling effect from a park travels further for larger parks while smaller parks have a more localised cooling effect. Further information can be found in the CRC for Low Carbon Living Heat Mitigation Performance Index. **Advantages:** Reduced temperature, improved thermal comfort, enhanced, biodiversity, amenity, human health, social cohesion, air quality. **Disadvantages:** Irrigation and maintenance required for peak performance	• Can be applied to new or retrofitted precincts • Green open spaces should have more vegetated surfaces than impervious surfaces • A variety of tree species and tree arrangements will produce the best outcomes for microclimate as well as for the open space • Borders between open and forested areas can be created to ensure sun, shade and shelter are available in close vicinity • If highly paved areas exist (such as a public square), ensure there are trees with large crowns to provide adequate shade • Irrigation, including passive irrigation will help the success of the open space, particularly during hot and dry summers.
Water features and evaporative cooling	Highly suited	Water features such as fountains, misting systems, lakes, rivers, ponds, the ocean, marshes, and wetlands etc. are effective at reducing surface temperatures during the day, where larger water bodies have a larger cooling effect. In winter, water can create a small relative warming effect at night as it has a higher heat capacity and can hold heat more than land (Santamouris et al. 2017). Ideally features like fountains and misting systems are strategically placed	• Can be applied to new or retrofitted precincts • Water bodies accompanied by greenery helps keep them clean (e.g. constructed wetlands) • Larger and deeper water features provide a greater cooling effect

Strategy	Suitability	Description	Retrofit and design considerations
		in public spaces to maximise their cooling benefit and amenity values in the case of fountains, as their cooling effects can dissipate quickly. Watering impervious pavement watering is also an effective heat mitigator **Advantages:** Reduced temperature, increased amenity, can provide relative heating at night (desirable in winter) **Disadvantages:** Water fountains and misters require potable water and have a localised cooling effect	• In new precincts, low-lying areas in developments should be designated for constructive wetlands • Increased evaporative cooling should be placed strategically across the precinct with passive (fountains, lakes, ponds etc.) and active systems (misting fans)
Public space shading structures	Highly suited	Shading structures help reduce the temperature and are most effective when planned for highly used public spaces or those particularly susceptible to heat. These can include wide streets with short buildings, and plazas/squares. **Advantages:** Reduced temperature, particularly in areas of high pedestrian exposure. **Disadvantages:** Need to be specially designed to cut off radiation from the sun while still allowing light through	• Shading should be prioritised in wide pedestrian heavy streets and open spaces such as plazas, squares, parks and playgrounds • Use light coloured, highly reflective materials for the shading device, though be aware of glare • Generally, avoid fully glazed and instead use partially glazed materials • Cooling technologies such as misters can be integrated into the shading system

Water sensitive urban design (WSUD) technologies	Somewhat suited	WSUD components such as water filtration, harvesting and treatment systems can reduce urban heat through evaporative cooling of the water itself or evapotranspiration through the vegetation. The water captured can also be used for irrigation, further increasing the cooling. WSUD options include raingardens, bio swales and constructed wetlands.
		
		Advantages: Reduced temperature, increased amenity, reduced stormwater run-off
		
		Disadvantages: Need to be specially designed and maintained
			• Raingardens can be constructed in:
			  o Roadsides
			  o Median strips
			  o Courtyards
			  o Green spaces
			  o Traffic islands
			  o Roundabouts
			  o Carparks
			• Ensure species with strong nutrient and pollutant removal properties are chosen, and that they can withstand periods of drought or inundation

7 District to city-scale climate assessments (> 100 Ha)

Climate assessments at the district to city-scale can help to

- Identify hot spots and help to inform a strategic approach to managing urban heat mitigation across the city
- Identify potential urban growth areas with more desirable microclimates
- Inform more detailed assessments at the precinct and estate scale

Assessments at this scale are most effective at the early strategic planning stage and are quite high level. They require a high-level understanding of the area of interest, general characteristics of the surrounding areas, such as geography, weather and climate. This includes understanding the topography of the region, prevailing winds, and climate, such as how cold are the winters and how hot are the summers. Understanding these factors in district to city-scale climate assessments ensures that the city is appropriately and equitably planned and designed to improve thermal comfort, creating a more liveable and enjoyable environment.

Examples of district to city-scale activities where a climate assessment could be used include:

- High level strategic planning stage where future urban areas and areas for intensification are identified
- For program and policy performance evaluation they help to assess long-term change and can provide possible indicators of success

Following a District to city scale climate assessment, a more detailed microclimate assessment can be undertaken using methods from the Block or Precinct scales sections. These could be applied to:

- Hot spots that have been identified
- A green field development

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Early planning

Why do an assessment at this stage?	• Support high level baseline measures for future comparison. • Identify priority hot spots and inform strategic prioritisation of climate moderation projects • Improve decision-making regarding urban expansion and urban infill. • To understand climate-related growth constraints and target problem areas for improvement with respect to new suburbs and urban infill and renewal programs.
Who should do them?	***Primary users:*** Strategic planners and policy-makers.
	Secondary contractors: Planning, environmental and GIS consultants.
What are the outcomes from the assessment?	• Knowledge of the landscape of surrounding areas, and how they can affect the site's climate • Quantification of the air temperature of the area compared to nearby urban, rural or natural areas. • Understanding of where the wind comes from on extremely hot and cold days.
Things to consider when doing the assessment	1. What are the hot and cool spots across the district to city scale area and neighbouring regions? 2. Where does the prevailing wind come from during extreme heat or cold days? 3. What is the area surrounding the region of interest? • Built up • Rural • Natural environment 4. What is the topography and geomorphology of the area? Particularly the location of valleys and hills. 5. Is there existing vegetation (particularly trees) at the area and in surrounding regions? Can it be retained?

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<td colspan="2">6. What are the intended development outcomes, such as land uses – low density residential, high density residential, commercial, community facilities, open space, industry, other?</td>
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<td>How do you do them?</td>
<td>Observational methods</td>
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ACTmapi viewer
Skills required: Natural resource management skills desirable
Access and cost: Free
Outputs: Qualitative understanding of the site including where hot and cool areas are likely to be based on vegetation, topography and geomorphology
Limitations: This is an approximate qualitative method using satellite images and Lidar, potentially resulting in missed analysis opportunities gained from a site visit or data analysis.
Risks: The data accessed may not be up to date, resulting in the analysis being performed on out of date images.
ACTmapi is the ACT Government's interactive mapping service that provides a convenient and fast way to analyse ACT spatial data. All steps need to be completed.

Explore the subject area by:

Open ACTmapi and select basic map
Zoom to your site.
Look for water bodies, urban areas, national parks, forests, farmland in a 5km radius surrounding your area. A park can moderate the climate of an area up to the width of the park away, based on the wind direction (Motazedian 2017). If there is a 100m wide water body to the west of the area, when winds come from the west the 100m closest to the water body is likely to experience cooling effects.
Note in each direction around your site which areas are likely to be hotter (urban, impervious, dry, few trees) and colder (parks, water bodies, irrigated grass, many trees). These areas can have an influence on the climate of your site, particularly on extreme heat and cold days where wind can propagate the warmer and cooler air from surrounding areas into your site. To understand the direction of prevailing winds on extreme heat and cold days go to the Data Analysis – Wind direction on extreme heat and cold days using Bureau of Meteorology sub-daily data method.

Explore topography data by:

Select Access to data → Geospatial Data catalogue, Search: Lidar.
Select 2015 5m Contours. Zoom in until the contour lines appear. Click Create Map. Example map below.

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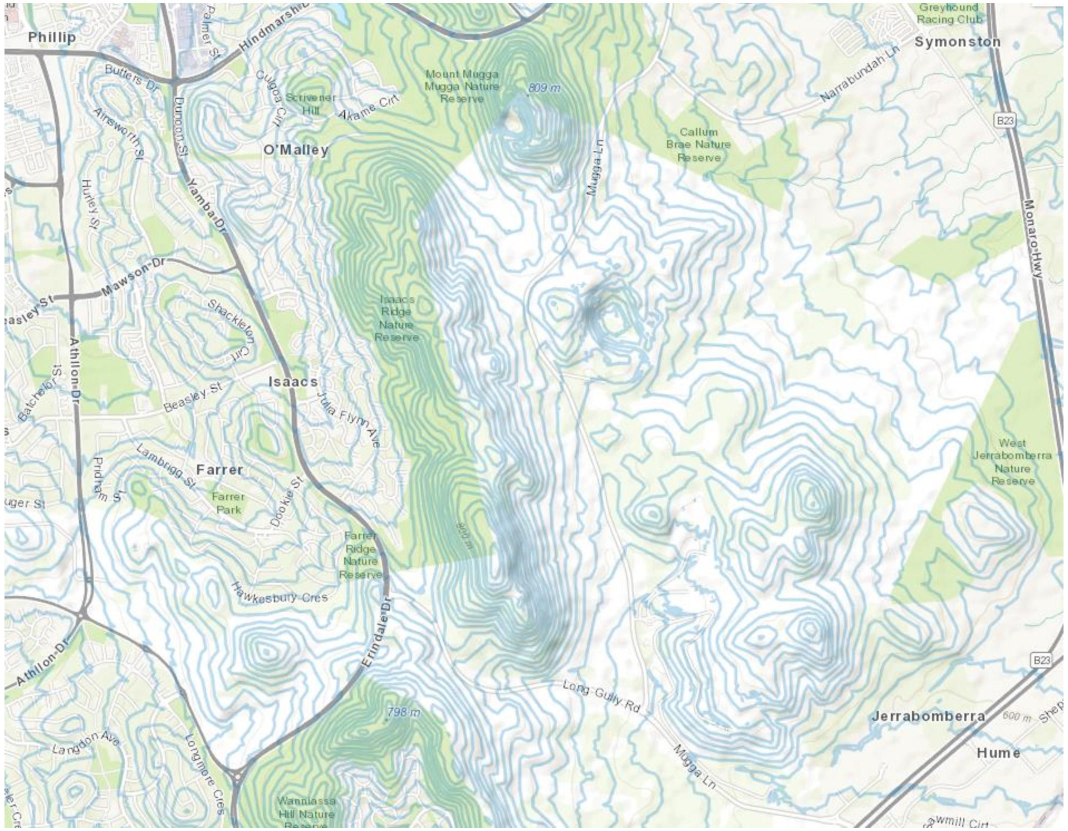


- Areas on the north and west side of hills are more exposed to solar radiation, whereas the south side of hills are less exposed
- Cold air pools in valleys as cold air is denser than warm air and sinks (Trewin 2005).
- Label hills that are north and west facing as warmer, and hills that are south and east facing as cooler. Label valleys as cooler.
- This Lidar data can be downloaded and used in a GIS program.

3. Explore Canberra Vegetation Structure data by:

- Select Access to data → Geospatial Data catalogue, Search: Vegetation.

		• Select ACT Vegetation Map 2018. Zoom in until the contour lines appear. Click Create Map. Example map below. • Map the canopy cover percentage for your area and adjacent regions, up to 5km from your area. The taller and higher percentage canopy cover the vegetation is, the larger cooling effect it is likely to have. This can influence the climate of your area if the vegetation is upwind from your area on an extreme heat day.
		Surface temperature monitoring campaign with drones *Skills required: GIS, drone flying, data analysis.* *Access and cost: Technician with drone flying experience.* *Outputs: Quantified map of observed average land surface temperatures of your site and surrounding areas for each monitoring period.* *Limitations: If the weather is cloudy or windy during the observational campaign it may not produce useful maps of the land surface temperature, as cloudy days can reduce the magnitude of hot spots and windy days mixes the air so land surface temperature is not always an appropriate indicator of climate. Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.* *Risks: Ensuring a consistent drone flight path and appropriate weather for the campaign can be difficult.* Immediately post construction fly a drone containing a thermal sensing camera across the site. This will create a picture of the land surface temperature across the site. 1. Fly the drone once a day at approximately 3pm on the same trajectory during a two-week monitoring campaign taking thermal pictures of the site. 2. Ensure the land surface temperature data is spatially consistent. 3. Average the land surface temperature for each day in the monitoring campaign. 4. Identify hot and cool spots across the site.
	Data analysis	CSIRO land surface temperature and surface urban heat island data *Skills required: Basic GIS* *Access and cost: Free from CSIRO data website.* *Outputs: Quantified map of land surface temperature for your site and surrounding areas during an average summer day.* *Limitations: Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.*

		Risks: This data is from summer 2015/16 and will become out of date as development continues in the ACT. Land surface temperature and urban heat island data is available for the ACT based on observations from the Landsat8 satellite over summer 2015-16. The surface urban heat island data is based on the land surface temperature in urban areas compared to several comparison points in rural areas. The surface urban heat island is almost always larger than the urban heat island calculated using the air temperature. 4. Download data from CSIRO website. 5. Load into GIS software and find your site. Determine whether your site of interest is in a hot spot compared to neighbouring areas in the ACT.
		Global air temperature and outdoor human thermal comfort (ERA5 dataset) ***Skills required: Advanced GIS skills, or spatial computer science skills.*** *Access and cost: Free with a user registration* ***Outputs: Spatial maps of the hottest and coldest days at your site for the air temperature, Universal Thermal Climate Index (UTCI) and the wind speed and direction on those days.*** ***Limitations: This data has a 30km spatial resolution so is only applicable for analysing very large areas.*** ***Risks: The large spatial resolution of the data means that extracting information for specific locations in the ACT would be difficult.*** This global dataset of meteorological variables includes wind speed and direction, surface temperature, air temperature and a measure of human thermal comfort called the Universal Thermal Climate Index (UTCI). It is available for every hour of the day from 1981 to present at a 30km spatial resolution. Due to this resolution, this data is only useful at the city scale. 1. Navigate to the website to download ERA5-Land hourly data from 1981 to present. 2. Meteorological variables to download. • 2m temperature. • Skin temperature (this is the surface temperature). • 10m u-component of wind. • 10m v-component of wind. 3. Year: Select the last 10 years. While the whole available time period can be selected, the dataset is extremely large, and a reduced set of years will suffice. 4. Month: Select either December, January, February if interested in extreme heat, or June, July, August if interested in extreme cold.

		5. Days: Select all days in the month. 6. Time: Select all hours of the day if interested, or just 05:00 and 19:00. This is Greenwich Mean Time (GMT), so 00:00 GMT is 10am in the ACT, 05:00 is 3pm and 19:00 is 5am. 7. Geographical area: The default is for ERA5 to download the entire globe. Instead, choose a smaller area with your site in the centre. This is based on latitude and longitude degrees (e.g.) • North: –33. • East: 151. • South: –37. • West: 147. 8. Format: NetCDF. 9. Download the data. 10. In your downloaded data identify the point closest to your area of interest. 11. Using the 2m temperature data and Skin temperature data identify the hottest or coldest 5% of days in your dataset, depending on whether you have a summer or winter interest. 12. Take an average of the hottest or coldest 5% of days. 13. Plot a map for the average of the hottest or coldest 5% of days, 2m temperature at 3pm local time (05:00 GMT) for extreme heat or 5am (19:00 GMT) for extreme cold. 3pm is the hottest time of day and can be used as a proxy for the maximum temperature. Just before sunrise is generally the coldest time of the day and can be a proxy for the minimum temperature. 14. Plot a map for the average of the hottest or coldest 5% of days, skin (surface) temperature at 3pm local time (05:00 GMT) for extreme heat or 5am (19:00 GMT) for extreme cold. 15. Plot a map of wind vectors on top of the 2m temperature for the average of the hottest or coldest 5% of days. This demonstrates the direction and magnitude of the wind near your area during extreme heat or cold days. 16. Download the Universal Thermal Climate Index (UTCI), a popular measure of human thermal comfort for the hottest and/or coldest 5% of days identified in Step 11 at 05:00 GMT and 19:00 GMT. As of September 2020, the UTCI download does not currently let users specify their geographical area and defaults to downloading the entire globe. This results in a larger download. 17. Plot a map for the average of the hottest or coldest 5% of days, Universal thermal climate index, which demonstrates the heat or cold stress level at your region of interest, compared to surrounding areas

		18. This data analysis gives an overview of the extreme temperatures across the ACT including human thermal comfort, and the prevailing wind direction which can influence the climate of an area.
		Bureau of meteorology spatial maximum and minimum temperature, Australian Water Availability Project (AWAP) *Skills required: Microsoft Excel, GIS.* *Access and cost: Free* ***Output: Spatial map of the average maximum and minimum temperature across the area on the hottest days, and coldest days*** ***Limitations: This data has a 5km spatial resolution so is only applicable for analysing very large areas.*** ***Risks: The large spatial resolution of the data means that extracting information for specific locations in the ACT would be difficult.*** The Bureau of Meteorology has daily spatial maximum and minimum air temperature data available nationwide and for NSW/ACT at a 5km spatial resolution. 1. Log into Bureau Climate Data Online website. 2. Download all years of data for the maximum temperature data for the closest weather stations to your area. 3. Identify the hottest or coldest 5% of days at the weather station closest to your area, based on the maximum temperature. 4. Repeat these steps for the minimum temperature. 5. Navigate to the Bureau's climate map daily temperature webpage Archive. 6. Select Map: Mean maximum. 7. Period: 1 day. 8. Area: Australia. 9. Year/Month/Day: Select one of the hottest or coldest 5% of days identified using the *Bureau of Meteorology maximum and minimum air temperature at weather stations.* 10. Download the data (click Download the daily grid). Repeat until all hottest/coldest 5% of days are downloaded. 11. Using a raster calculator in a GIS program calculate the average maximum temperature of your 5% of hottest/coldest days. 12. Look for how the temperature at your area compares with the 10km radius surrounding your area of interest. 13. Repeat with the minimum temperature.

Wind direction on extreme heat and cold days using Bureau of Meteorology sub-daily data

Skills required: Microsoft Excel. If plotting a wind rose, then computer science programming is needed

Access and cost: Bureau of Meteorology data available for a fee (~$100).

Outputs: Quantified understanding of which direction the wind is most often coming from on an extreme heat or cold day. Histograms or wind roses of the wind direction on historical extreme heat or cold days. This informs the direction of prevailing winds at your site. Note that the Bureau of Meteorology data indicates the direction the wind is coming from. Wind direction of 360˚ means the wind is coming from the north and moving towards the south.

Limitations: This is a general analysis into wind direction and cannot be used for detailed analysis between multiple buildings.

Risks: In a highly urbanised area the wind direction recorded at a weather station may not reflect what is happening between buildings as they can affect wind flow.

Air temperature, wind speed and direction, and other data can be requested from the Bureau of Meteorology for weather stations at 3 hourly or 30 minute time scales.

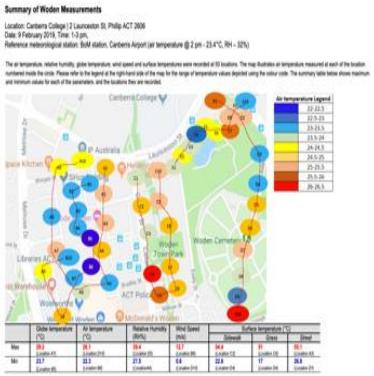
1. Request data for the closest weather station to your area:
   - wind speed and direction.
   - dry bulb temperature (air temperature).
2. Using the air temperature data filter for the hottest/coldest 5% of days during summer/winter. The 5% threshold can be found using the percentile function in excel.
3. Identify the most common wind speed and direction for the hottest/coldest 5% of days during summer and winter by plotting a histogram.

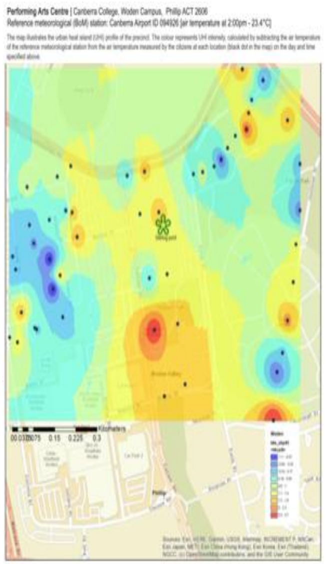
   OR
4. Plot a wind rose for the hottest/coldest 5% of days. A wind rose demonstrates the most common wind speed and direction in a visual format.
5. This gives information regarding the wind direction on the hottest/coldest days at your area. The wind patterns can influence the temperature at your area, particularly if your area is neighbouring a warmer (e.g. dense urban area) or cooler (e.g. water body, thick forest) landscape.

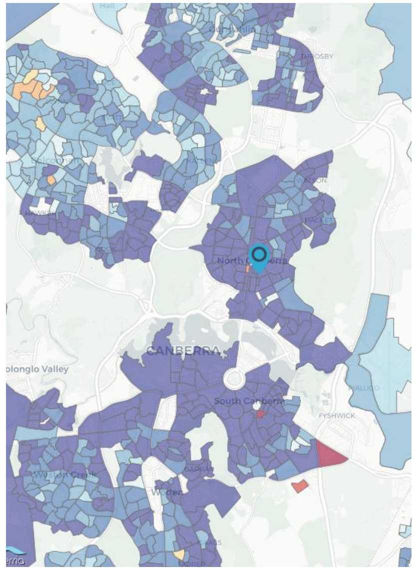
A holistic prioritisation method for climate assessment and site selection (based on Norton et al. 2015)

Skills required: Basic GIS

		Access and cost: Free *Outputs: Prioritised sites for development based on a quantified map of the land surface temperature of your site and surrounding areas, a quantified map of the socio-economic status of residents in your site or surrounding areas, and understanding of where vulnerable people are likely to congregate in your site or surrounding areas.* *Limitations: This method works best when the user has an intimate knowledge of the site as it requires knowledge of where people congregate at the site.* *Risks: There may be insufficient data for the site, especially if it is a green field site.* This framework combines climate assessment with assessment of human behaviours and vulnerability to prioritise locations for microclimate treatments. 1. Assess whether the site is in a hot or cold spot using the **CSIRO land surface temperature and surface urban heat island data** method 2. Assess the vulnerability of the current population if an intensification development, or surrounding population if greenfield. To do this access from the Australian Urban Research Infrastructure Network (AURIN) the Socio-Economic Indexes for Areas (SEIFA) data for your site. This can be done through Aurin Map by searching for your site by name, then selecting SEIFA in explore data (see images below). The SEIFA data is available for each Census period with SA1 data the highest resolution available. Other variables to consider that affect heat vulnerability include household incomes, health statistics and transport accessibility. Is your site more disadvantaged than surrounding areas? If so, residents are likely to be more vulnerable to extreme heat and extreme cold.



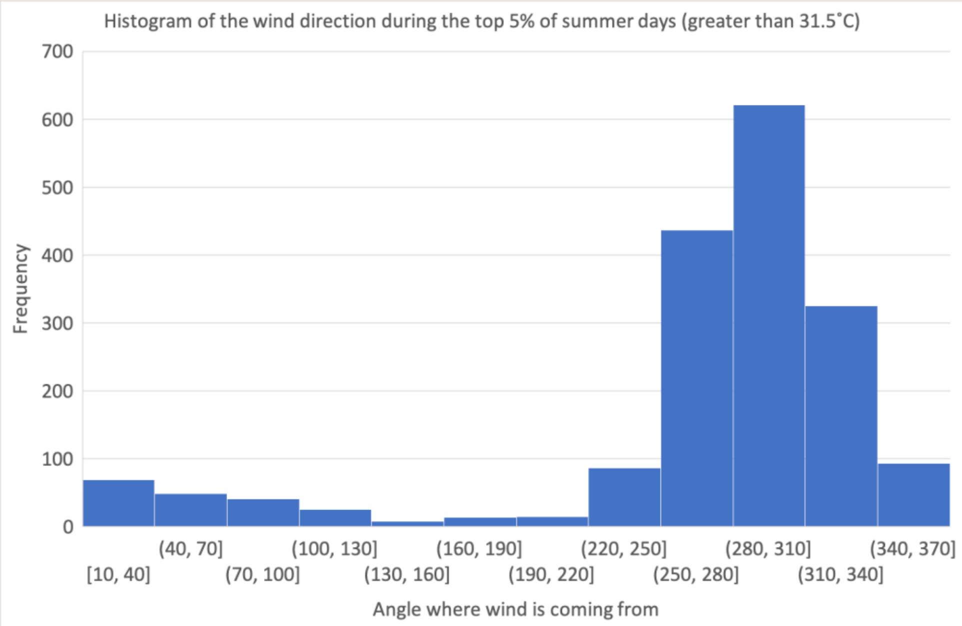


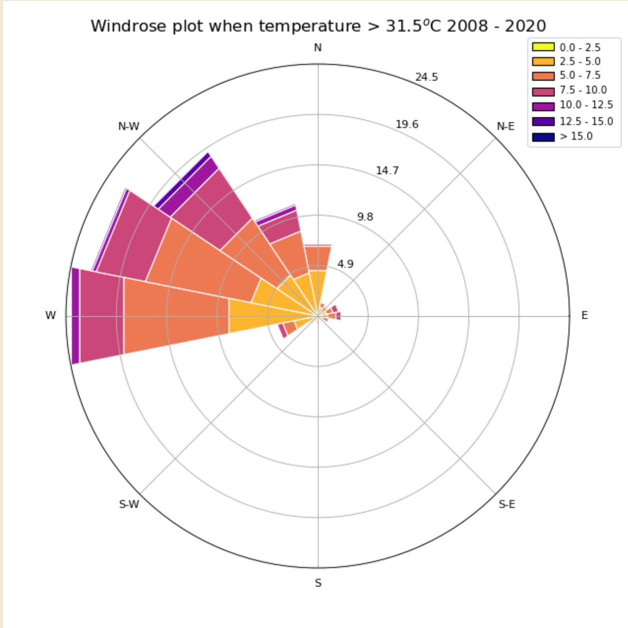


3. Assess whether your site and surrounding areas contains places where large numbers of vulnerable people will congregate such as aged care facilities, school, community centres and health centres. This is to understand where people are likely to be outdoors for prolonged periods of time. Some of this data is available through AURIN or ACTmapi, though knowledge of the local area is sufficient. If your intensification site or greenfield site is near areas where vulnerable people congregate it is likely the people at the site will be more vulnerable to extreme heat and cold.
4. The intersection of places from the Steps 1-3 (land surface temperature, vulnerability and people congregating) demonstrates where should be prioritised for microclimate treatments.

Once a site is chosen, assess the existing vegetation and assess the built form noting street widths, street orientations and building heights as per **Observational methods – ACTmapi viewer**

Case study: The **Wind direction on extreme heat and cold days using Bureau of Meteorology sub-daily data method** was applied to Canberra Airport weather station. Half-hourly data was sourced for the length of the dataset, 2008 to present. The data was first filtered for summer temperatures only looking at the months of December, January and February in the dataset. Then, the percentile function in excel was used to determine the threshold for the top 5% of summer temperatures, which was found to be 31.5˚C. All the corresponding wind direction for any time when the temperature exceeded 31.5˚C were then used to create a histogram of the wind direction during hot days. The wind direction data from the Bureau of Meteorology is based on where the wind is coming from. For example, a wind direction of 270 indicates that the wind is coming from the west and travelling towards the east. The histogram shows that the significant majority of winds on the hottest days come from the west, and to a smaller extent WNW. This is further demonstrated in the wind rose that was created using Python programming language. Additionally, the wind rose shows that the fastest wind speeds on these hot days generally come from the NW. Credit: Mosaic Insights (2020).





Evaluation

<table>
<tr><td>Why do an assessment at this stage?</td><td colspan="2">Support ongoing strategic management of urban heat mitigation.
Help to inform high level indicators of success.</td></tr>
<tr><td rowspan="2">Who should do them?</td><td colspan="2">Primary responsibility: Strategic planners, GIS specialists and policymakers.</td></tr>
<tr><td colspan="2">Secondary contractors: Universities and policy evaluation and liveability consultants.</td></tr>
<tr><td>What are the outcomes from the assessment?</td><td colspan="2">Comparable and quantifiable indicators of the air and land surface temperature across the area.
Comparable health indicators for the area.</td></tr>
<tr><td>Things to consider when doing the assessment</td><td colspan="2">Evaluation could include:
Inspections
Interviews, online surveys
Heat related hospital admissions data and ambulance call outs to determine any correlation with areas with poor microclimates
Any temperature change in urban heat maps
Locations of heat refuges and cool oases</td></tr>
<tr><td>How do you do them?</td><td>Data analysis</td><td>Landsat8 land surface temperature
Skills required: GIS.
Access and cost: Data is free from <u>Remote Sensing Lab Landsat Land Surface Temperature webpage</u>.
Outputs: Quantitative maps of the land surface temperature for your area during summer or winter</td></tr>
</table>

Limitations: Observations are limited to the Landsat8 flight path, reaching the ACT every two weeks. The satellite needs clear skies for observations to take place. Note that the surface temperature is heavily influenced by the relationship between materials and heat. Hence, understanding the location of a hot or cool spot will then require further investigation into the underlying cause of the hot or cool spot.

Risks: The satellite needs clear skies for observations to take place.

The Landsat8 satellite passes over the ACT every 14 days monitoring the land surface temperature at a high resolution of 25m. It creates one snapshot of the land surface temperature per flyover. This data can help to capture the land surface temperature across your area and demonstrate how it changes over time.

1. Create a KML file of your area of interest.
2. Navigate to the Landsat Land Surface Temperature webpage run by the Remote Sensing Lab.
3. Input date selection. Ideally, you should look at the most recent and complete dataset for the season you are interested in.
    - For summer, this is from December 1 to February 28/29
    - For winter, this is from June 1 to August 31. Other dates of interest can be included too.
    - Select Landsat: Landsat 8, the mostly widely used for land surface temperature calculations.
    - Select Emissivity: MODIS. This emissivity setting is best suited when analysing the land surface temperature for urban areas.
4. Upload the KML and select Calculate LST. Depending on the size of your site multiple KMLs may need to be created and the resulting rasters stitched together.
5. Download all the available data for the selected dates.
6. Using a raster calculator in a GIS program calculate the average land surface temperature for your season of interest.
7. Note the season average land surface temperature at your area and how it compares to neighbouring areas.
8. Repeat these steps at later monitoring intervals to determine any variation in the land surface temperature at the area. This method could be used to provide updated urban heat maps for the ACT.

Hospital admissions, ambulance call outs and mortality data relating to extreme heat and cold

Skills required: Public health expertise

Access: Ethics approval, health data can be difficult to obtain

Outputs: Quantitative data for hospital admissions throughout the site monitoring period

Limitations: This method requires public health expertise and would likely need collaboration with a university.

		Risks: The available health data may not have an appropriate resolution to determine how it is affected by climate. Hospital admissions and emergency call out data can be used to quantify the number of people presenting to hospital with symptoms of hypothermia or hyperthermia and other heat related health issues. While there may be various factors that contribute to heat related admissions, such as poor indoor thermal comfort, poor outdoor thermal comfort due to undesirable climate conditions can also play a role. Any data analysis should include a breakdown of admissions and callouts at the suburb and/or district scale.

8 Where can I get more information?

8.1 Guides and reports

A multi-scale assessment of urban heating in Melbourne during an extreme heat event: policy approaches for adaptation
A report detailing an observational campaign and microclimate assessment of the City of Melbourne and City of Port Phillip local government areas using scientific flights.

CRC for Low Carbon Living Guide to Urban Cooling Strategies
Details the causes and implications of the urban heat island while also detailing numerous heat mitigation options and identifying which are most appropriate for many Australian cities including Canberra.

Growing Green Guide
A guide for implementing green roofs and green walls including details on their design, construction and maintenance.

Mapping surface urban heat in Canberra
Report and results from CSIRO mapping of vegetation and the land surface temperature of the ACT satellite data.

Quebec Urban Heat Island Mitigation Strategies (Giguere 2009)
An extensive literature review into urban heat mitigation strategies for Quebec, Canada. Details measures for various scales and lists the co-benefits of different strategies and their expected longevity with appropriate maintenance.

RMIT Citizen Science project
Details the method and findings of urban microclimate observations taken by volunteers.

Trees for a cool city: Guidelines for optimised tree placement
Guide defines many principles of urban climate and gives specific detail and design guidelines for where to prioritise trees in urban streetscapes.

Trees for Cooler and Greener Streetscapes
Guidance for how to integrate trees into different streetscapes such as suburban streets, major thoroughfares and commercial streets.

8.2 Academic literature

Green roof retrofit
Academic literature review on green roofs including information on how they mitigate the urban heat island, engineering issues, stormwater management, plant selection and biodiversity.

Microclimate assessment method for urban design – a case study in subarctic climate
An academic study describing a microclimate assessment of a town in Sweden to quantify the wind speed around buildings and the solar load through shading throughout the year.

Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes
Academic article that details a flexible framework that is applicable across multiple scales for prioritising sites for microclimate treatment. A case study from the City of Port Phillip is used to demonstrate the framework.

8.3 Datasets, tools and modelling

ACTmapi (ACT Government, 2020)
ACT Government website displaying spatial data and resource for data

Australian Urban Research Infrastructure Network (AURIN) (Sinnott et al. 2015)
Data portal containing thousands of multidisciplinary spatial data sets from sources such as researchers, government and the private sector

Bureau of Meteorology spatial data (Bureau of Meteorology, 2020)
Spatial data of the daily maximum and minimum air temperature across Australia at a 5km resolution from 1910 to present.

Bureau of Meteorology weather station data (Bureau of Meteorology, 2020)
Resource where users can purchase weather station data and all available observed meteorological variables

Climate Chip (Climate Chip, 2020)
Online resource to track historical climate change and future climate change in Australia

CRC for Low Carbon Living Microclimate and Urban Heat Island Mitigation Decision Support Tool (Ding 2019; Ding et al. 2020)
Online tool detailing various heat mitigation strategies including implementation options and prioritisation for different cities and purposes

CRC for Water Sensitive Cities Scenario Tool (Ulrich 2020a, 2020b)
Online tool that calculates the air temperature and land surface temperature for different cities across Australia

ENVI-met (Bruse and Fleer, 1998)
Complex physical urban microclimate model aimed at smaller blocks and precincts

ERA5 data (Copernicus Climate Change Service, 2017)
Global dataset of meteorological observations at a 30km spatial resolution

NARCliM (Evans et al. 2014)
High resolution climate model data for the current and future climate for southeastern Australia.

Remote Sensing Lab Landsat Land Surface Temperature (Parastatidis et al. 2017)
Online source of high-resolution land surface temperature observed by the Landsat satellites

SOLWEIG (Lindberg et al. 2008)
Urban microclimate model for calculating the mean radiant temperature

TARGET (Broadbent et al. 2019)
Urban microclimate model for calculating the air temperature across large precincts.

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