COOL SUBURBS

USER GUIDE AND SCIENCE RATIONALE

2022

WSROC

TURN DOWN THE HEAT

Cool Suburbs is a heat resilience rating and assessment tool for urban planning and development.

Visit **coolsuburbs.com.au** for more information

The need for the Cool Suburbs Tool was identified as a priority action under the *Turn Down the Heat Strategy and Action Plan* (2018). The Turn Down the Heat Strategy was developed by 55 organisations across greater Sydney to create cooler, more resilient communities.

Cool Suburbs is also a flagship action under the *Resilient Sydney Strategy* (2018).

The Cool Suburbs project is a collaboration between WSROC, Resilient Sydney and the Greater Sydney Commission.

Cool Suburbs has been developed by Edge Environment in collaboration with the CRC for Water Sensitive Cities, Hydrology and Risk Consulting (HARC) and Kinesis. The project was supported by an expert science panel, consisting of: Monash University, Melbourne University, University of NSW, Western Sydney University.

This project has been assisted by the New South Wales Government and supported by Local Government NSW.

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WSROC acknowledges Aboriginal and Torres Strait Islander peoples as the traditional custodians of the lands and waters of this place we now call Metropolitan Sydney. We pay our respect to Elders past, present and future of the Eora, Dharawal (Tharawal), Gundungurra, Dharug (Darug) and Guringai (Kuring-gai) peoples.

Park in Western Sydney. The combination of water, greening and light materials help to cool these spaces.

EXECUTIVE SUMMARY

Cool Suburbs is a heat resilience rating and assessment tool for urban planning and development. This user guide outlines key concepts, describes the credits and criteria, and provides the scientific basis and references for the Tool. The Cool Suburbs Tool can be accessed via **coolsuburbs.com.au**.

Heat (urban heat, extreme heat and heatwave) is acknowledged to have cumulative and cascading impacts on our community, economy and ecosystems (1). Already, heat is placing significant strain on essential infrastructure including energy grids, hospitals and transport networks (2), and it is Australia's most deadly natural hazard causing more fatalities than all other natural hazards combined (3).

IMPACTS OF HEAT

6%

Higher heat-related mortality risks for residents living in warm neighbourhoods

100%

Increase in peak electricity demand when temperatures increase from 20 °C to 40 °C

Unmeasured

Impacts on flora and fauna. Mass deaths of flying foxes are one indicator of the scale of this impact

$6.9 billion

In lost productivity due to heat stress, annually Australia wide

Figure 2. Heatwave impacts (modified based on WSROC 2018, p.15)

These impacts are expected to increase in future as extreme heat becomes more common, and heatwaves become more frequent and intense under climate change (4). As a result, heat resilience is a significant and growing challenge for NSW.

Greater Western Sydney (GWS) bears an undue proportion of heat-related impacts (due to historical climate trends, combined with its socio-economic and demographic profile) and these are expected to increase in future. Projections indicate temperatures in Western Sydney will increase at a faster rate than other parts of the city (5). At the same time, Western Sydney's rapid urban development is exacerbating an already hot climate via the urban heat island effect (6). With an additional one million people expected to settle in the region in the next 20 years, more people will be at risk of adverse impacts of heat (7). Many organisations have recognised this unique risk profile (e.g., NSW OEH (5), Sydney Water & UNSW (6), Resilient Sydney (4), WSROC (8)).

Given the extensive awareness of extreme heat impacts in Western Sydney, attention has turned to measures that can reduce risk to heat and build resilience. Despite a significant body of knowledge to inform the management of heat, much of this science has not been translated into practical tools that can help guide on-ground decision making at multiple scales.

This document provides user guidance on the Cool Suburbs Tool (CST), a voluntary, industry-based performance (ratings) tool to assess place-based urban heat resilience. The CST has been designed for use by both developers and government, with the goal of supporting improved resilience outcomes. The design and development of the tool followed the process outlined in Figure 2.

The CST is intended to inform and guide planning and development decisions by providing a synthesis of urban heat science in an easy-to-use platform.

The CST's objectives include:

- Setting out a broad range of measures (represented by credits in the CST) that guide improved place-based urban heat resilience.
- Identifying specific measures that should be considered at different stages of the development process; supporting the Tool's use in early stages of planning and design.
- Scoring (via a rating system) the urban heat resilience of a range of developments from precinct to lot scale.
- Providing guidance for the assessment of urban heat resilience in existing, transforming, and new suburbs.

The development of the CST was supported by an expert science panel and extensive government and industry engagement. This User Guide provides a summary of the key concepts that have been considered in developing the CST and a description of how the CST has been structured to integrate across key influences on urban heat.

This User Guide presents:

- Background on key concepts, including how resilience has been embedded into the design of the CST (Section 2).
- Description of the credits and criteria and how ratings are calculated (Section 3).
- Science rationale, describing the scientific basis and references for the credits and criteria (Appendix A).

CST CLIMATE ZONES

The CST has been designed to enable operation across the eight climate zones that have been defined by the Building Code of Australia, supporting potential use across the country in future. However, the current version of the tool has been configured for Western Sydney, which is classed as falling in Zone 5 which is "Warm temperate".

To enable the CST to be used for other climate zones, at least four credits will need to be tailored based on local geography:

- UD1 - Wind paths
- UD2 - Wind buffering
- CB1 – Site coverage
- CB2 – Site shade

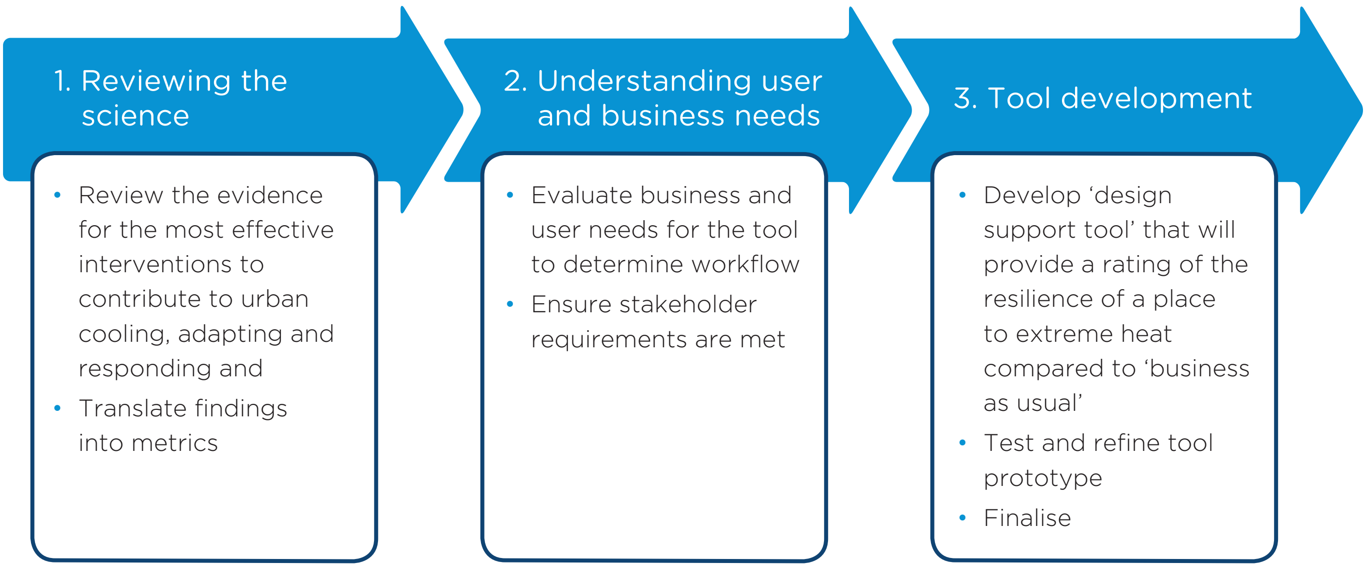


Figure 2. Summary of the CST development process.

CONTENTS

GLOSSARY OF TERMS

Term	Definition	Reference
Adaptation	Projects and programs designed to reduce risk and help residents and organisations better cope with the impacts of heat.	(8)
Albedo	Albedo is the fraction of solar radiation reflected from a material's surface.	(9)
Awareness	Involves assessing the physical conditions in the area, and the vulnerability of residents and urban infrastructure to heat.	(8)
Urban Heat Island effect	The Urban Heat Island Effect (UHI) is a local climate change phenomenon whereby urban areas present higher air temperatures than their rural proximities. The difference is often 3-4°C, but higher peak differences can reach 10°C.	(8)
Heatwave	The Bureau of Meteorology states a heatwave occurs when the maximum and the minimum temperatures are unusually hot over a three-day period at a location. This is considered in relation to the local climate and past weather at the location.	(10)
Hot days	Defined by the Climate Council as days between 30°C and 35°C.	(8)
Very hot days	Defined by the Climate Council as days between 35°C and 40°C.	(8)
Extremely hot days	Defined by the Climate Council as temperatures 40°C and over.	(8)
City resilience	City resilience is the capacity of individuals, communities, businesses and systems within a city to survive, adapt and thrive no matter what kinds of chronic stresses and acute shocks they experience.	(4)
Cool refuge	Shaded outdoor spaces and cooled indoor spaces.	(8)
Urban heat mitigation	Projects and interventions that seek to reduce the root cause of urban heat (and therefore the temperature) through either an increase in green canopy, use of more building and paving reflective materials, use of irrigation and water features.	(8)
Climate hazard	Climatic hazards are climate-related events or phenomena that may pose risks to human settlements or the environment.	(11)
Reduce	Involves reducing average ambient temperatures in the built environment as much as possible.	(8)
Response	There will still be residual heat-related risk in extreme events, and therefore we also need emergency preparedness and response measures, particularly to help the most vulnerable people in the community.	(8)
Solar Reflectance Index (SRI)	Solar reflectance Index (SRI) is a composite measure that accounts for a surface's solar reflectance and emittance. To calculate the SRI, the material or product's emittance values and total solar reflectance must be known.	(12)

SECTION 1

INTRODUCTION

1 INTRODUCTION

1.1 WHY IS HEAT AN ISSUE?

Extreme heat has significant and cascading effects on the function of both city systems and ecosystems. This includes impacts on community, infrastructure, economy and the natural environment. Heat is a major driver of mortality and morbidity in Australia, accounting for more deaths than all other natural hazards combined (3). The economic impacts of extreme heat can be profound, ranging from reduced workforce productivity, health and safety impacts through to impacts on the built environment and higher energy costs (6).

The impacts of heat can be more pronounced in cities than in natural or less developed landscapes due to the qualities of urban environments. Urbanisation is driven by population growth and is a process of both urban expansion and intensification, including:

- More established areas within cities becoming more densely occupied, which reduces green space in the public and private realm.
- The continued development of green field sites from what is often agricultural or forested land into hard surfaces such as housing and community infrastructure.

In built-up, urbanised areas, impervious materials with high thermal mass facilitate the absorption and storage of heat from the sun and anthropogenic sources (e.g. industrial activity, air conditioning and transportation). Beyond material selection, patterns of wind movement, building orientation, and local topography can also contribute to heat accumulation. The accumulation of heat in urban areas is called the urban heat island (UHI) effect.

It is well established that the impacts of urban heat will be compounded by global climate change and that mitigating UHI is vital to mitigating heat-related risks urban residents will face in the future.

As demonstrated in Figure 3, minimum, average and maximum temperatures will increase under climate change. This means more heat accumulation in cities on average across the year as well as more record hot weather. Further, hotter and drier conditions may have flow-on effects for reducing the quality of green space if additional sources of irrigation are not found.

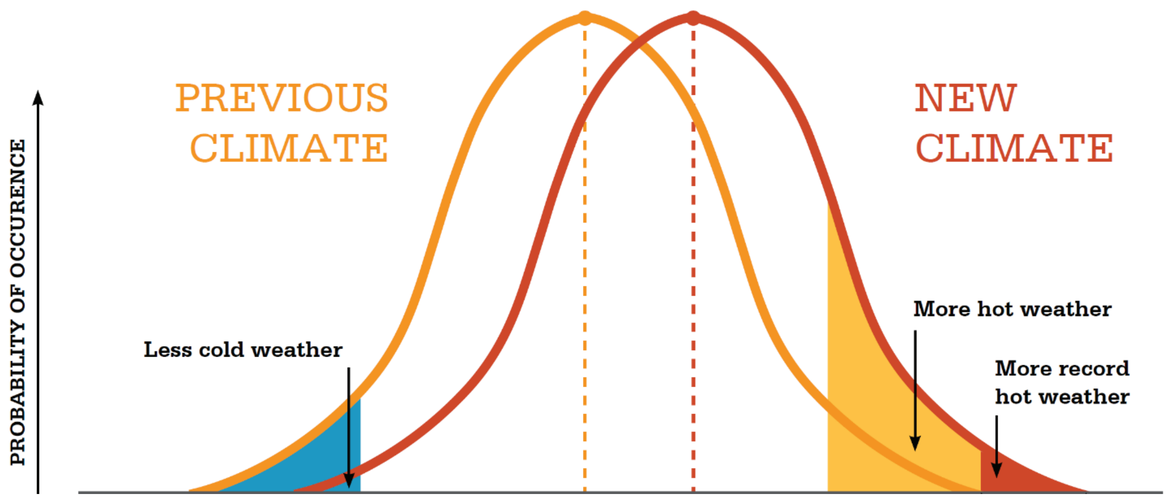


Figure 3. Overview of how as the climate warms, there will be significantly hotter weather and heatwaves. Source: Climate Council (13).

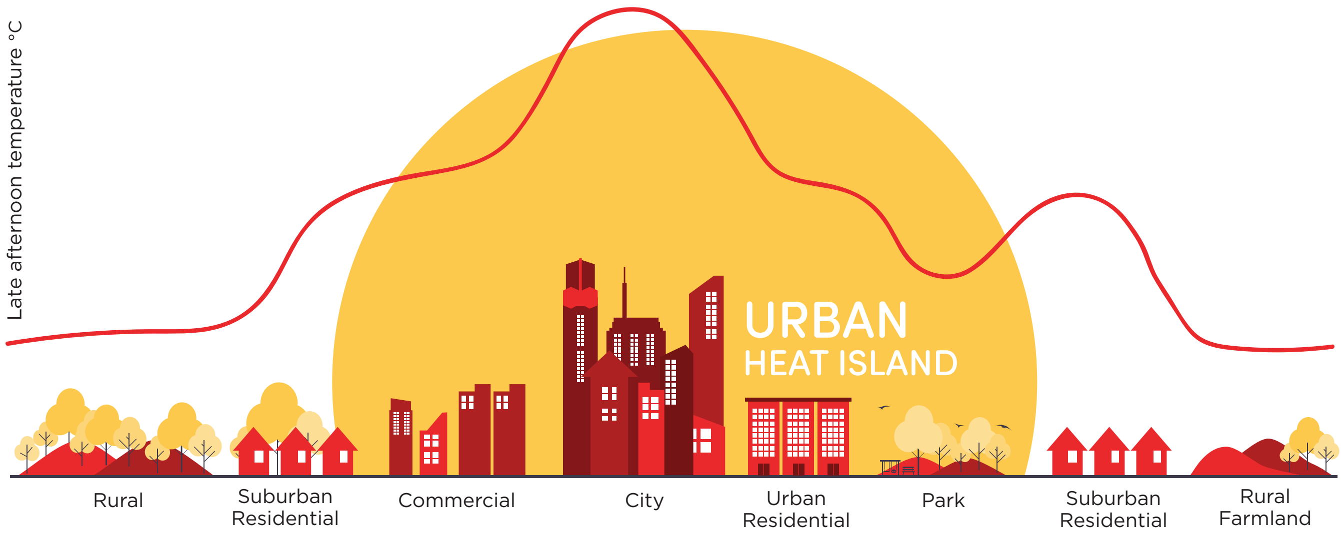


Figure 4. Urban heat island effect in cities.

1.2 THE IMPACT OF URBAN HEAT IN WESTERN SYDNEY

The Greater Western Sydney region covers over 8,948 square kilometres, ranging from densely populated metropolitan areas such as Parramatta and Liverpool, to rural lands of the Hawkesbury and Wollondilly and the World Heritage Area of the Blue Mountains. Greater Western Sydney is one of the most rapidly growing urban areas in Australia. The region's current population is 2.3 million and is expected to increase by almost one million by 2036 (7).

Urban heat is not unique to Western Sydney, but it does have a particularly significant impact due to the region's unique climatic conditions, its large residential population, socio-economic factors, and ongoing urban development. The west of the city has always been hotter than the east because coastal breezes do not penetrate past Parramatta, and in summer, the region is subject to hot airmasses from central Australia. As such, the classical urban heat island effect diagram (Figure 4), showing cooler areas on the fringe of a city and hotter areas in the centre, does not apply in the Greater Sydney context.

Nevertheless, when considering Western Sydney in isolation, the difference between urban areas and surrounding rural zones is stark. Recent research has found that temperature differences between urban and natural areas can range between 6-10°C (14). It was also found that the UHI effect is non-uniform across the city, and its intensity is strongly influenced by weather conditions and the built environment.

Within the region, Western Sydney University's Benchmarking Heat studies have found significant temporal and spatial temperature variations exist between suburbs within each local government area (LGA) and even between adjoining streets (refer to (15) (16) (17) (18)). Importantly, they found that the number of days where air temperature reached above 35°C was much greater in some locations than others (e.g., 47 days above 35°C compared to 10-25 days at two locations in Western Sydney near Parramatta). Figure 5 demonstrates the vulnerability (defined as exposure to heat and relative socio-economic vulnerability) of communities to urban heat and the significant concentration in Sydney's west.

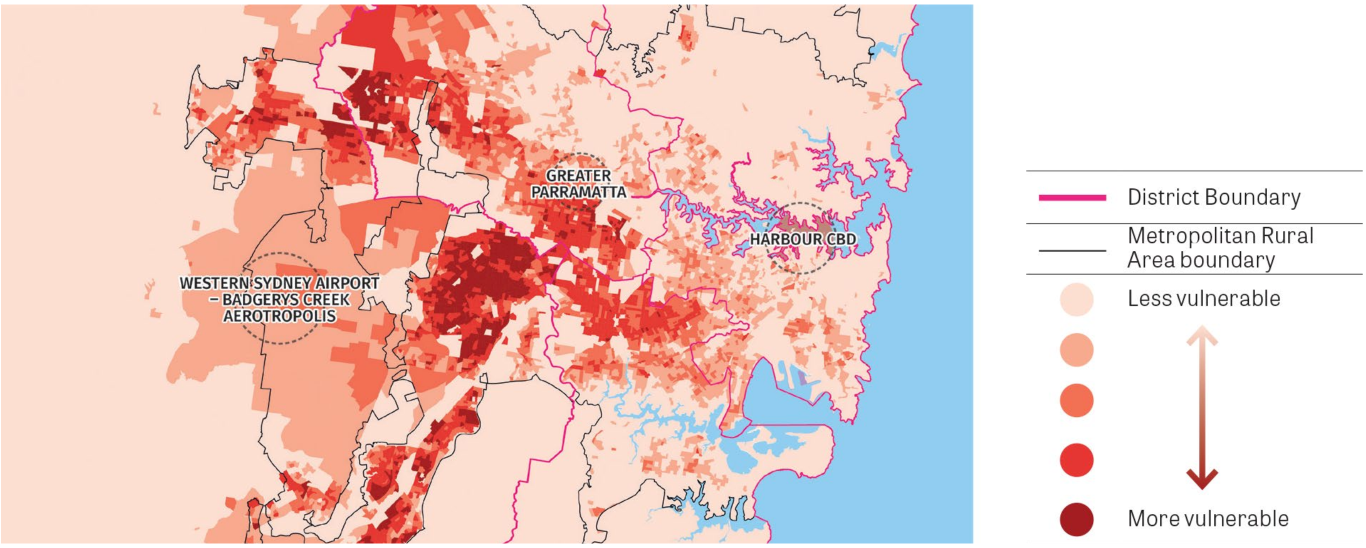


Figure 5. Urban heat vulnerability map (summarising exposure to heat plus relative socio-economic vulnerability) shows that areas of Western Sydney are highly vulnerable to heat (19).

As Greater Sydney grows, there is an expectation that the city will expand westward. Figure 6 outlines the Greater Sydney Commission's Metropolis of Three Cities Plan, which identifies significant population and economic growth in the Western Parkland City and Central River City over the next 15 years. This pattern of growth – which will see large numbers of people and significant urban development in the hottest part of Sydney – will have impacts for human health and city functions if heat is not considered as an integral part of planning and design for new development. Research suggests that converting areas in the north-west and south-west of Sydney from forest and grasslands to new urban development will more than double the temperature changes projected to occur due to climate change (20).

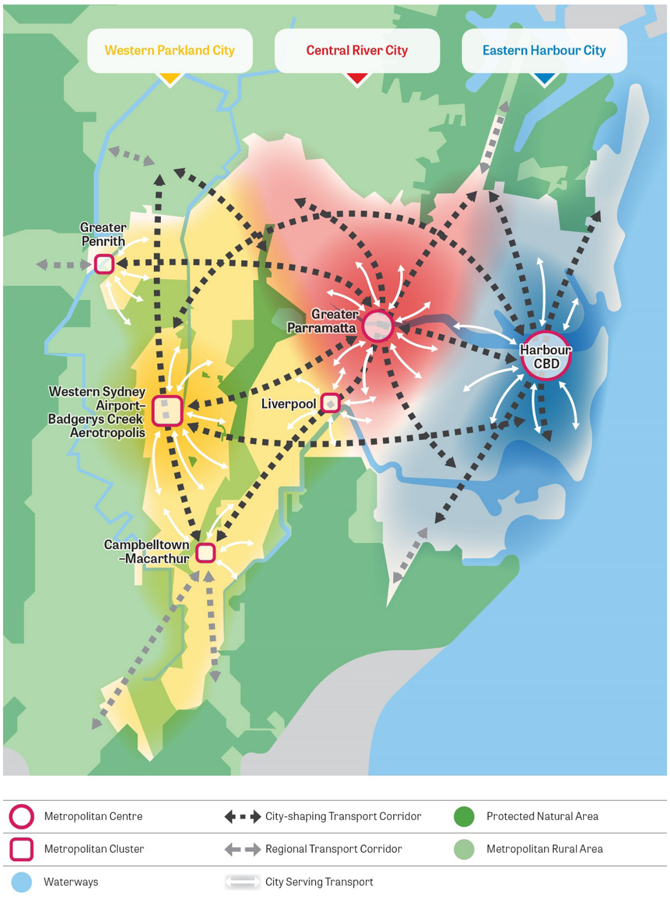


Figure 6. Metropolis of Three Cities Plan reprinted from the Greater Sydney Commission.

Fortunately, heat has been recognised as a priority issue by national, state and local organisations including:

- **NSW Government:** Adapt NSW and Premier's Priorities
- **WSROC:** Turn Down the Heat Strategy and Action Plan 2018 (8)
- **Resilient Sydney:** A Strategy for City Resilience 2018 (4)
- **Greater Sydney Commission:** Greater Sydney Region Plan (19) and the Western and Central District Plans
- **NSW Treasury:** 2021 Intergenerational Report (21)

Specifically, the Greater Sydney Region Plan includes the following objectives relating to urban heat mitigation and climate adaptation:

- *Objective 36:* People and places adapt to climate change and future shocks and stresses
- *Objective 37:* Exposure to natural and urban hazards is reduced
- *Objective 38:* Heatwaves and extreme heat are managed

1.3 BUILDING RESILIENCE TO HEAT IN WESTERN SYDNEY

The need for the Cool Suburbs Tool was identified under the Turn Down the Heat Strategy; a collaborative, multi-sector approach to tackling urban heat in Western Sydney. Launched in 2018, the Strategy lays out a five-year plan for a cooler, more liveable and resilient future.

A range of projects are being implemented under the Turn Down the Heat Strategy. Two projects that relate to the Cool Suburbs Tool (CST), include:

- **Urban Heat Planning Toolkit:** Developed to help local councils strengthen local planning provisions to reduce the impacts of heat. It focuses on strategies that can be implemented in both new development and redevelopment contexts, to reduce urban heat and adapt to a changing climate.
- **Heat Smart Western Sydney:** Identifies what processes and structures are needed for the city to respond to extreme heat and heatwaves. The project has assessed our current approach to heatwave emergency management and developed a Heat Smart Resilience Framework that outlines recommendations for improving resilience to extreme heat.

Cool Suburbs is also a flagship action under the Resilient Sydney Strategy (4).

1.4 LIMITATIONS OF PAST APPROACHES TO MITIGATING URBAN HEAT

Mitigating urban heat has been an objective for decision makers in cities around the world for several decades. Efforts have accelerated in recent years as the impacts of urban heat combined with climate change become both more apparent and better understood.

Policies developed to mitigate urban heat have often focused on single drivers. For example, cool roof initiatives have successfully reduced the temperature of buildings, investment in tree planting provides localised cooling solutions, and greater irrigation of open space can provide neighbourhood cooling effects. However, research shows that focussing on single solutions or generic approaches is insufficient to support precinct-scale cooling outcomes. Furthermore, approaches that focus only on urban heat island mitigation (reducing surface temperatures and lowering ambient temperature) will not prevent large-scale extreme weather events such as heatwaves, or protect communities from such events.

To successfully address this complex issue, an integrated approach is required that considers a range of factors contributing to heat exacerbation including:

- The local climate context (including the effects of climate change)
- Development site condition (e.g. greenfield or brownfield sites)
- Development scale (e.g. masterplan)
- Development typology (e.g. building, residential home or park)

By considering this broad range of influences on urban heat, a more integrated approach can be developed that can be applied at multiple scales and be tailored to the local climatic context.

1.5 THE COOL SUBURBS TOOL

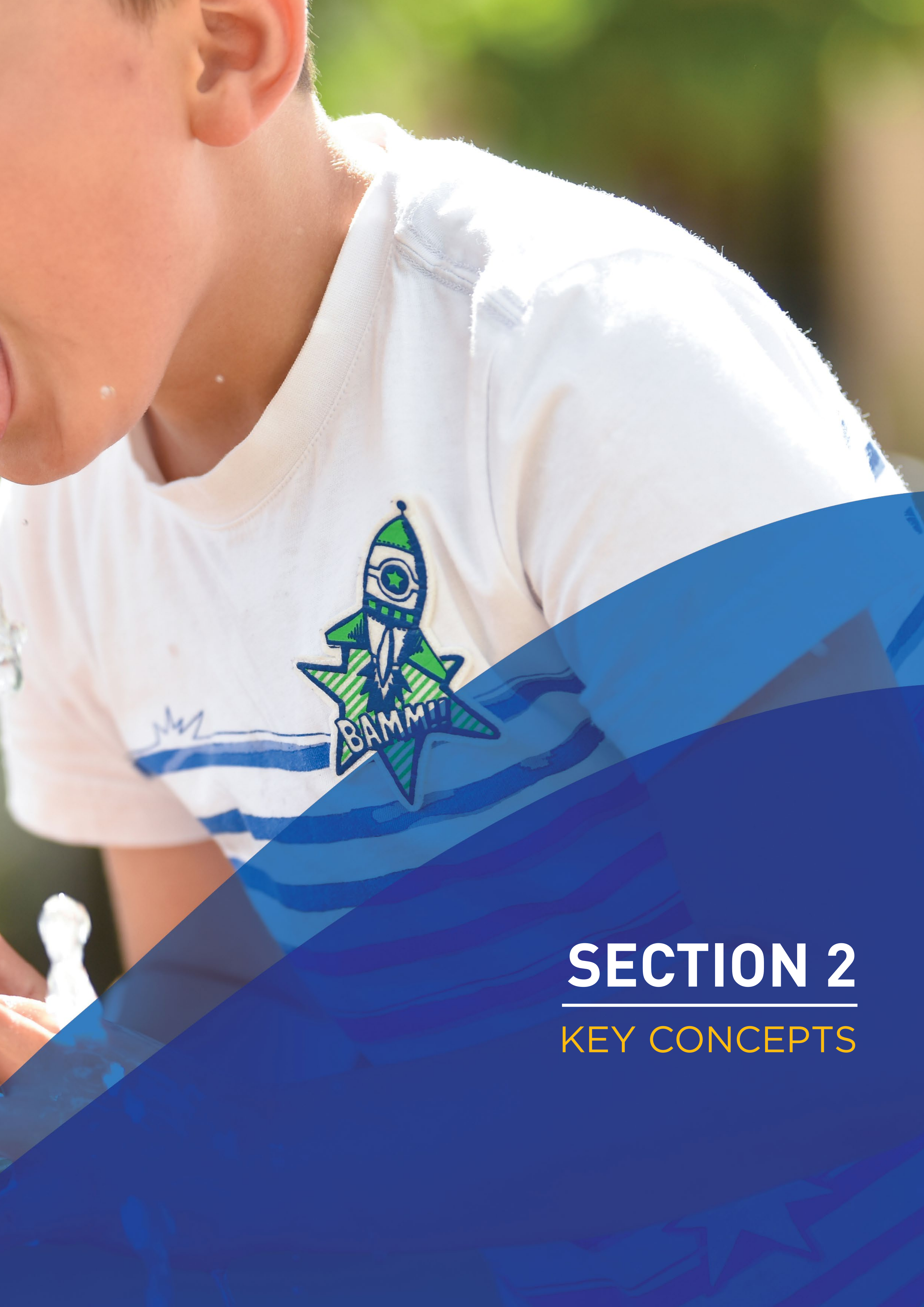
The Cool Suburbs Tool (CST) is a voluntary, industry-based performance (ratings) tool for place-based heat resilience. The CST has been designed for use by both developers and government, with the goal of supporting improved heat-mitigation outcomes.

The CST is intended to inform and guide planning and development decisions by providing a synthesis of urban heat science in an easy-to-use platform.

The CST's objectives include:

- Setting out a broad range of measures (represented by credits in the CST) that guide improved place-based urban heat resilience.
- Identifying specific measures that should be considered at different stages of the development process; supporting the Tool's use in early stages of planning and design.
- Scoring (via a rating system) the urban heat resilience of a range of developments from precinct to lot scale.
- Providing guidance for the assessment of urban heat resilience in existing, transforming, and new suburbs.

To support the development of the CST, a science translation task was undertaken with guidance from an expert science panel to identify the most effective urban heat resilience measures for Western Sydney. Government and industry engagement was then undertaken to help translate findings into an easy-to-use rating tool for a place (building, street, precinct or suburb). This User Guide provides a summary of the key concepts that have been considered in developing the CST and a description of how the CST has been structured to integrate across key influences on urban heat. Appendix A summarises the science rationale that has been used to inform each of the CST's Credits.



SECTION 2

KEY CONCEPTS

2 KEY CONCEPTS

2.1 A RESILIENCE APPROACH TO URBAN COOLING

Given significant historic temperature extremes as well as projected increases under a changing climate, the impacts of heat on the community cannot be eliminated just by reducing the average (ambient) temperature.

Ensuring people have the capacity to adapt to higher and extreme temperatures, and that both community and emergency services are in place to support the most vulnerable when all else fails, is essential. As such, a resilience approach is required, based on strategies that minimise the impacts of intense shocks such as heatwaves and the ongoing stress of frequent hot and very hot weather.

This project takes a resilience approach to address heat. Urban resilience is defined by Resilient Sydney as the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience (4).

Therefore, an intervention that successfully improves community resilience to heat must include measures in the built environment that:

- Mitigate urban heat (e.g., greening, high albedo roofs etc.)
- Allow people and infrastructure to adapt to a hotter climate (e.g., development of energy efficient buildings, inclusion of PV and energy storage).
- Provide appropriate social infrastructure, including designated heat refuges (e.g., pools, air-conditioned libraries etc.) and response approaches to heat-stress (e.g., provisions for emergency services, ambulances etc.).

WSROC has developed a resilience framework for heat, which includes four steps, as shown in Figure 7 and summarised below:

1. **Awareness:** Involves assessing the physical conditions in the area, and the vulnerability of residents and urban infrastructure to heat.
2. **Reduce:** Involves reducing average ambient temperatures in the built environment as much as possible (e.g. via mitigation of climate change and urban heat islands).
3. **Adapt:** At most, we can reduce ambient temperatures at the city scale by approximately 2°C (6), so it is also important to design to help people thrive in hotter conditions and survive heatwaves. At smaller scales within the urban environment (e.g., within streets, parks, courtyards) it is possible to reduce site-specific temperatures to a much greater degree.
4. **Respond:** There will still be residual heat-related risk in extreme events, and therefore emergency preparedness and response measures are required; particularly to help communities most at-risk.

Within each element of resilience are approaches to mitigate urban heat and help people adapt to a warmer future climate. Examples of these approaches are provided in Figure 8.

Figure 7. Urban heat resilience framework. Source: (22)

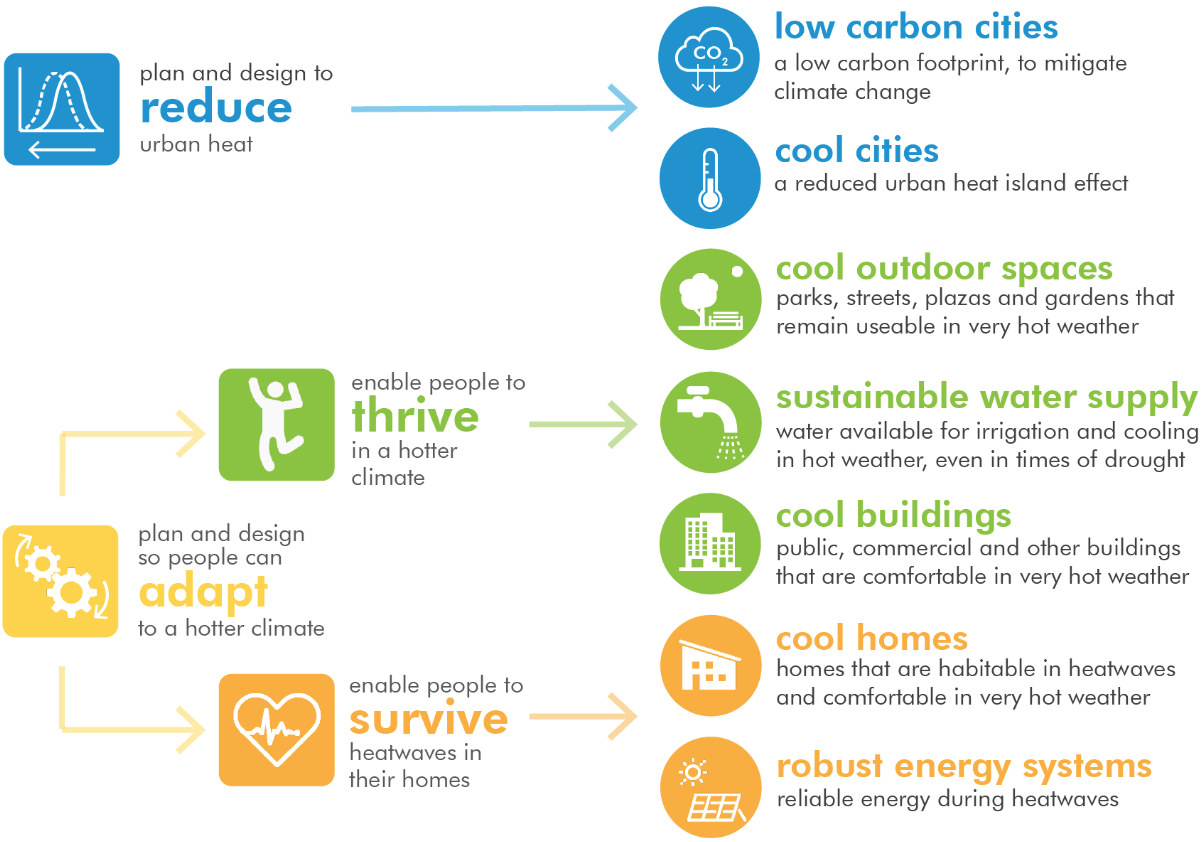


Figure 8. Urban planning and design approaches to reduce urban heat and help people adapt to urban heat. Source: (22)

2.2 RESILIENCE IN THE COOL SUBURBS TOOL

The CST has been developed to describe the performance of a proposed development as it relates to resilience criteria for “Reduce”, “Adapt” and “Respond”. “Recovery” is also often included as a step in a resilience framework. However, the focus of the CST is on measures to reduce heat and to help people adapt to heat. It is in these areas that urban planning, and design can play the greatest role.

By combining the elements of resilience, a more thorough approach to responding to and managing the impacts of heat now and under future climate change can be developed.

The types of measures associated with each of the resilience elements is illustrated in Figure 9. The CST has a focus on the “reduce” and “adapt” aspects of a resilience approach due to the leading role urban planning and design plays in these elements of resilience. It should be noted that developing cool cities will also require work with other stakeholders to ensure that the broader range of awareness raising and respond measures are implemented in current and new developments.

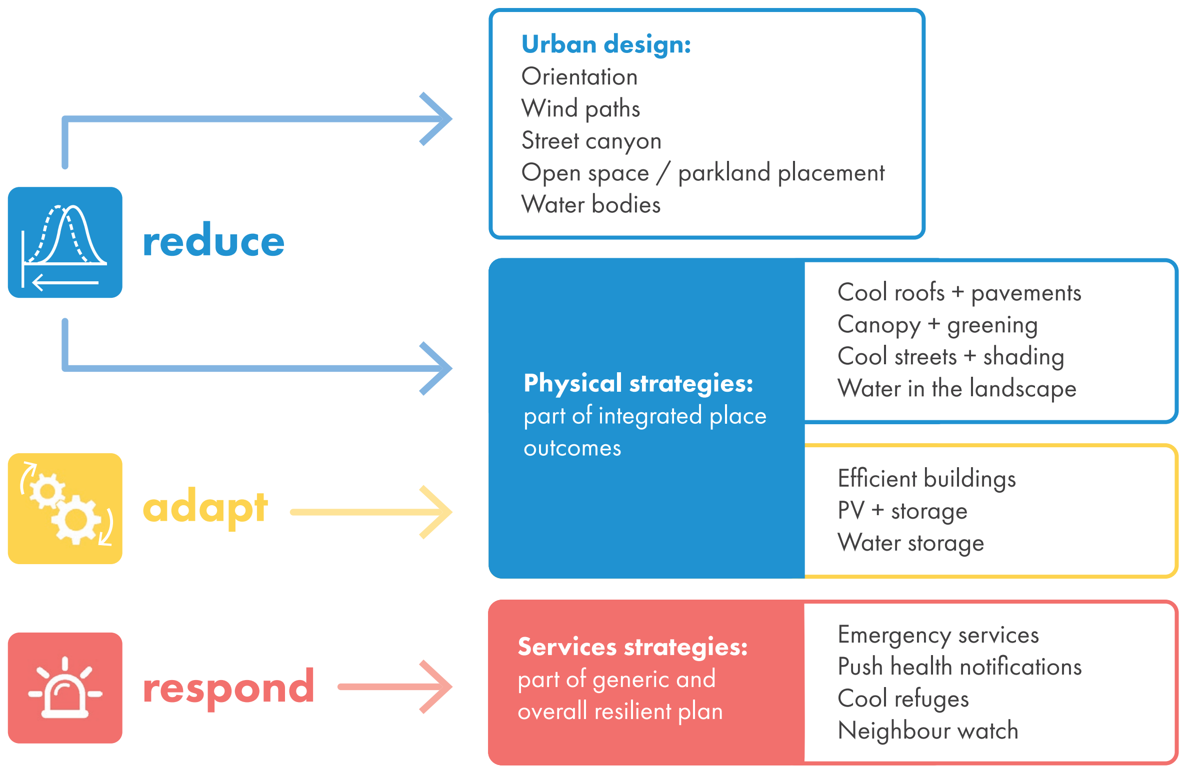


Figure 9. The resilience framework as applied to the urban heat mitigation context.

2.3 CHANGING HOW WE DEAL WITH PLACE-BASED HEAT

Through the planning and development process, a range of decisions impact upon who manages which aspects of reducing heat impacts, what is required and how this is achieved. This includes:

- **Government decision-making:** Strategic decisions that guide the requirements and performance of a development or community (e.g. regulatory landscapes and their enforcement)
- **Developer decision-making:** Operational decisions that reflect changes in market demands, regulatory requirements, or economic outcomes.

These decision-making contexts are both dynamic and interdependent. Government (regulatory) and developer (market) decision-making interact to produce place-based design outcomes that determine base levels of urban heat risk. Where place-based design outcomes exacerbate urban heat islands, local communities are left to manage the legacy of residual risk either through proactive house upgrades, risk avoidance or increased emergency services (health).

Due to the dynamic nature of both regulatory and market environments, the Cool Suburbs Tool focuses on measures to reducing residual risk (outcomes) as opposed to linking directly with current planning processes or regulatory environments.

The resilience approach used to develop CST facilitates place-based assessment that recognises the challenges of urban heat as they play out in a community across a range of scales. The ability to specify local conditions (including the climate region and the physical composition) means that the measures recommended through the CST assessment will remain relevant and effective at addressing urban heat, regardless of the local policy context. This place-based logic was central to the development of the CST, helping to facilitate the flow of evidence-based measures to address urban heat throughout the planning and development process.

In NSW, there are a number of ways for new developments to progress through state and local government planning processes. The CST is particularly relevant to development application and assessment. Examples of intervention points relevant to the CST are summarised in Table 1.

Table 1. Examples of intervention points where the CST can be applied.

DEVELOPMENT PHASE	PLANNING PROCESS INTERVENTION POINT	RELEVANT CREDIT CATEGORIES
Development control	Masterplans & precinct plans	Category 1: Urban design Category 2: Cool streets Category 4: Cool Homes Category 5: Cool Buildings (Non-Residential)
Development application and assessment	Public domain	Category 1: Urban design Category 2: Cool streets
	Buildings	Category 5: Cool Buildings (Non-Residential)
	Dwellings	Category 4: Cool Homes
	Public parks	Category 3: Cool Parks

2.4 RELATIONSHIP BETWEEN RATING METHODOLOGY AND RISK

The CST demonstrates that there are opportunities to address elements of heat impacts across multiple development scales. In a traditional development process, where no mandated consideration or control for heat risk is required, communities and residents ultimately bear the long-term responsibility for maintaining resilience to heat impacts (either through proactive house upgrades or risk avoidance). In this way, historic planning and design decisions determine the long-term risk exposure of communities, which will be further exacerbated by the effects of climate change.

As decisions are made through the planning process, heat risk should be, where possible, effectively mitigated through targeted initiatives, with the aim being that the long-term residual risk at the community or household level is reduced (Figure 10 summarises this concept).

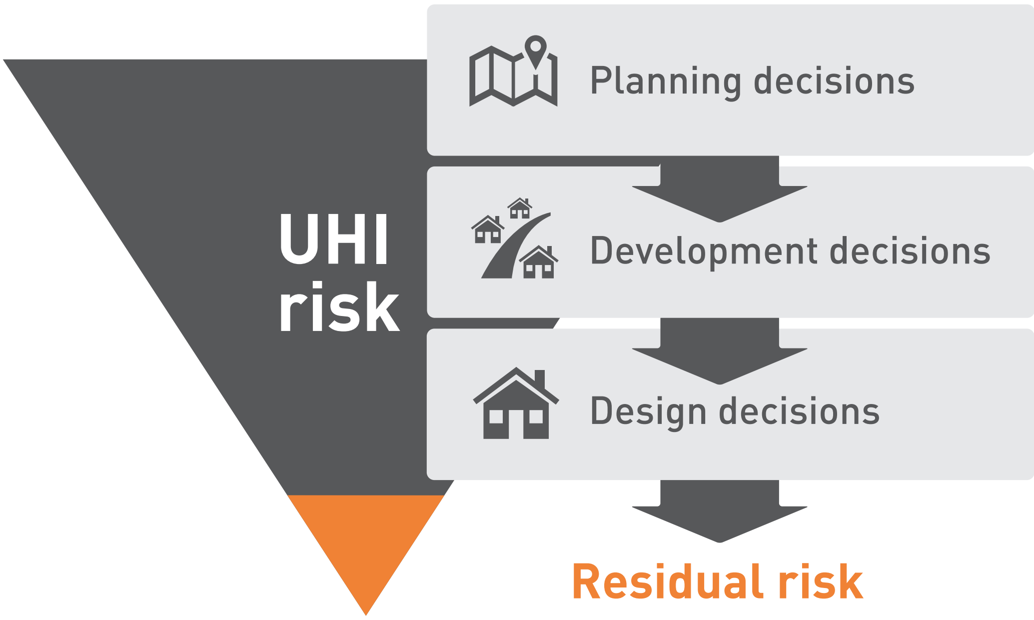


Figure 10. Heat risk can be address across the planning and development process.

2.5 SCIENCE BASED APPROACH

Urban and extreme heat science is an evolving field with a rapidly expanding body of evidence to guide policy and strategic action on urban heat resilience.

The CST is underpinned by a robust science translation task by a panel of urban heat scientists (the Expert Panel) from leading research institutions familiar with the climatic and place-based context of Western Sydney. The Expert Panel included those summarised in Table 2 below.

The science translation task was not intended to identify gaps in the current science for further research but to draw pertinent aspects from the body of published urban heat research to guide the development of the CST and selection of the urban heat resilience measures (called Credits) to be included.

The science translation process involved a series of four deliberative workshops between the CST development team and the Expert Panel. The process was to firstly identify the headline issues for heat resilience in Western Sydney and then drill down into the specific measures best suited to the Western Sydney context. The Expert Panel provided advice on the best approach to rate (or score) each measure having regard to co-dependencies and the non-linearity of urban heat performance of bundled measures.

The Expert Panel identified the following headline heat resilience considerations for Western Sydney:

- **Extreme heat conditions (heat waves) –** Extreme heat conditions across Western Sydney are driven by macro-scale synoptic weather patterns that cause hot air from central Australia to shift eastward across the Great Dividing Range and settle over the eastern seaboard for up to several days. Local measures to mitigate and adapt to heat will have minimal impact on air temperature at the urban scale during heat wave conditions, thereby reinforcing the importance of a resilience approach to living with extreme heat in Western Sydney.
- **Climate change –** Climate change is increasing the frequency, duration and severity of extreme heat events across Western Sydney with the new normal hot summer day temperatures likely to be close to 50°C by 2050; highlighting the importance of planning now for this likely future.
- **Ventilation –** Design of the urban morphology and individual buildings for effective ventilation is paramount. This includes measures to displace stagnant hot air and to circulate cooler air from "cool islands" to areas of high heat vulnerability.
- **Shade –** Provision of shade to exposed hard surfaces is essential for human thermal comfort on extreme heat days.
- **Ratio of soft (green and permeable) to hard (grey/black and typically impermeable) surfaces –** Empirical evidence collected from Western Sydney indicates a ratio > 6:4 is needed to avoid the creation of urban heat islands.
- **Water supply and security –** Maintaining soil moisture during extreme heat conditions when centralised supplies of town water may be restricted is critical to ensure the survival and health of landscapes providing shade and amenity. Secure, alternative water sources are therefore essential as is Water Sensitive Urban Design (WSUD).
- **Energy supply security –** Maintaining access to a secure and adequate energy supply to mechanically cooled "cool zones" within private dwellings and in public buildings during extreme heat conditions is critical to ensuring public health is protected, particularly for at-risk individuals.
- **Urban heat metrics to measure impact –** The impact of local urban heat resilience actions can be measured at range of scales (e.g., neighbourhood to local street/allotment) using different metrics (e.g., land surface temperature, air temperature, and thermal comfort).

The urban heat resilience measures (linked to the resilience framework) listed in Table 2 were included in the CST based on their appropriateness for Western Sydney.

Table 2. Expert panel members

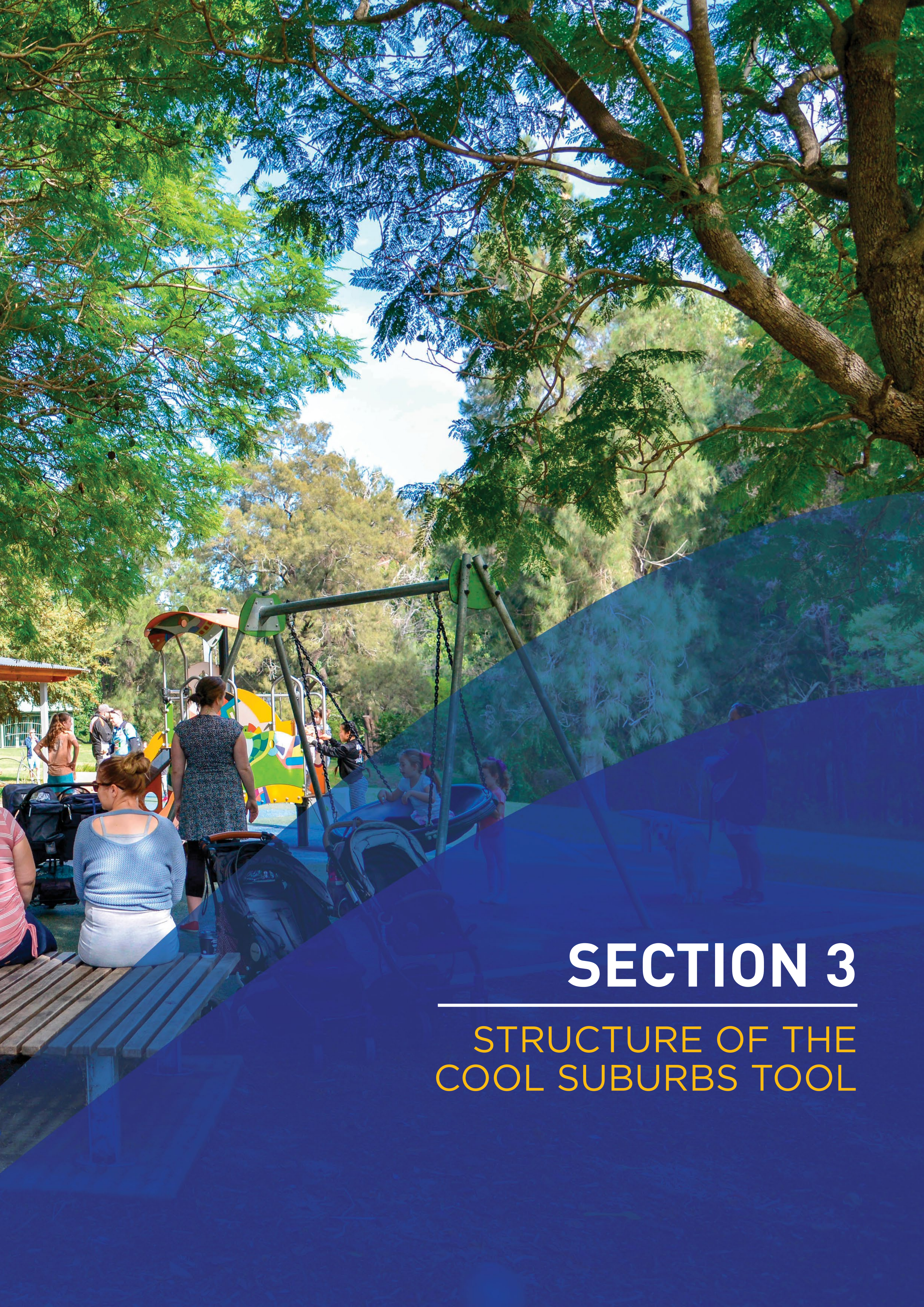
NAME	DISCIPLINE	ORGANISATION
Professor Nigel Tapper	Urban climate	Monash University
Dr Kerry Nice	Urban heat and water sensitive urban design	University of Melbourne
Dr. Negin Nazarian	Urban climate	University of NSW
Dr Sebastian Pfautsch	Urban heat mitigation	Western Sydney University

Table 3. Credits and their relationship to the resilience framework.

MEASURES (CREDITS)	REDUCE	ADAPT		RESPOND
		THRIVE	SURVIVE	
Category 1: Urban Design				
UD1: Wind paths	X	X	–	–
UD2: Wind buffering/filtering	X	X	–	–
UD3: Street canyons	X	X	–	–
UD4: Green and blue open space	X	X	–	–
UD5: Retention of existing tree canopy	X	X	–	–
UD6: Water sensitive urban design	X	X	–	–
Category 2: Cool Streets				
CS1: Shade	X	X	–	–
CS2: Irrigation	X	X	–	–
CS3: Cool and/or porous pavements	X	X	–	–
Category 3: Cool Parks				
CP1: Shade	X	X	–	–
CP2: Irrigation	X	X	–	–
CP3: Cool and/or porous pavements	X	X	–	–
Category 4: Cool Homes				
CH1: Site coverage	X	X	–	–
CH2: Site shade	X	X	–	–
CH3: Site irrigation	X	X	–	–
CH4: Passive cooling	-	X	–	–
CH5: Cool roofs	X	X	–	–
CH6: Cool and/or porous pavements	X	X	–	–
CH7: Alternative energy supply	–	X	X	–
Category 5: Cool Buildings (Non-Residential)				
CB1: Site coverage	X	X	–	–
CB2: Site shade	X	X	–	–
CB3: Site irrigation	X	X	–	–
CB4: Passive design	–	X	–	–
CB5: Cool roofs, green roofs and green walls	X	X	–	–
CB6: Cool and/or porous pavements	X	X	–	–
CB7: Alternative energy supply	–	X	X	–
Category 6: Innovative New Technology				
INV1: New technologies	X	X	–	–
INV2: Data collection	–	X	–	X
Response Checklist				X

Detailed descriptions of each of the urban heat resilience measures (Credits) is provided in Appendix A.

White roof in Western Sydney.
Light colours can reduce heat impacts.



SECTION 3

STRUCTURE OF THE COOL SUBURBS TOOL

3 STRUCTURE OF THE COOL SUBURBS TOOL

3.1 CREDITS AND CRITERIA

The CST provides an assessment of the performance of an actual or potential project by generating a rating. The rating is produced by synthesising scores against a range of criteria that have been developed based on urban heat mitigation measures that relate to the different elements of the resilience framework.

The measures (called Credits in the CST) are grouped under six categories, as presented in Section 2.5, with each Credit individually structured in the tool as follows:

- **Outcome of a Credit:** Outlines the desired outcomes of the credit.
- **Credit criteria:** Explains requirements that must be met.
- **Guidance:** Provides general guidance to support development/design of compliant solutions.
- **Science rationale:** Provides relevant references drawn from the scientific literature to support the Credit criteria.
- **Related Credits:** Lists other Credits in the CST that are complementary.

The CST includes some "mandatory" Credits that **must** be satisfied to qualify for a "cool suburbs" rating. The mandatory Credits are listed in Table 4. Details on the compliance criteria for these mandatory credits is provided in Appendix A.

Table 4. Summary of credit categories and mandatory credits

CREDIT CATEGORY	MANDATORY CREDITS	CREDIT CODE
Urban Design	Retention of existing tree canopy	**UD5**
	Water sensitive urban design	**UD6**
Cool Parks	Shade	**CP1**
	Irrigation	**CP2**
Cool Streets	Shade	**CS1**
	Irrigation	**CS2**
Cool Homes	Passive cooling	**CH4**
	Cool roofs	**CH5**
	Alternative energy supply	**CH7**
Cool Buildings	Passive design	**CB4**
	Cool roofs, green roofs, green walls	**CB5**
	Alternative energy supply	**CB7**

The six categories of Credits are as follows:

3.1.1 CATEGORY 1 - URBAN DESIGN (UD) CREDITS

Urban design shapes our neighbourhoods and suburbs creating an enduring urban pattern and form (Urban Morphology). Decisions on urban grid orientation, the placement and size of parkland and open spaces, waterbodies and treed areas, and the distribution of building typologies impacts the urban heat performance at neighbourhood as well as local scales.

The Urban Design Credits aim to ensure urban morphology responds to the prevailing and future climatic conditions and enables passive cooling of the local environment by removing heat from the environment through increased effective ventilation and vegetation cover and reducing radiant temperatures to enhance Human Thermal Comfort.

The Urban Design Credits establish an urban morphology that optimises the urban heat benefits available from the other categories of credits listed in the CST.

3.1.2 CATEGORY 2 - COOL STREETS (CS) CREDITS

Streets constitute a large proportion of our urban areas and with private open space diminishing in our suburbs, streets have an increasingly important role in providing amenity and recreation opportunities in addition to traditional transport functions. Streets are also predominantly in public ownership making it possible for state and local governments to program street rejuvenation projects at scale where improvements to tree canopy cover, passive irrigation of soft landscapes and cool pavement technologies can be strategically implemented to create "cool lines" within the urban landscape allowing residents and workers to move and recreate outdoors in a warming climate.

However, trees cannot be just 'squeezed in' to traditional road designs. Integration of healthy trees that will deliver many benefits over a long life requires prioritising space for trees amongst what is often a crowded ground-level and underground environment with many competing elements. This re-prioritisation is a challenge, and effort and action is needed across a range of land use types and by different land managers, including government and the community.

Cooling streets not only improves local thermal comfort, but it also reduces local ambient air temperatures, particularly if streets have also been aligned to channel prevailing breezes, which can reduce active cooling (air conditioning) for local buildings with commensurate energy cost savings, reduced greenhouse gas emissions and reduced anthropogenic heating from lower usage of air-conditioning units.

The Cool Streets Credits promote provision of shade and retention of soil moisture as a priority with optimal urban cooling outcomes achieved at the local precinct and neighbourhood scales when applied in concert with the Urban Design Credits.

3.1.3 CATEGORY 3 - COOL PARKS (CP) CREDITS

Outdoor spaces are experienced at a human scale, where temperature variations are more pronounced than those measured at a city or precinct scale. Within the urban environment, temperatures experienced at a human scale can vary significantly from place to place at the local level. For example, the microclimate in a well irrigated landscape under a shady tree will be different to the microclimate in a paved area with no shade and surrounding heat-reflective surfaces.

While only modest reductions can be achieved in ambient air temperatures at the city-scale, smaller scale variability in temperatures in the urban environment mean that it is possible to create a mosaic of cool outdoor spaces that enable people to spend time outdoors even in a warming climate.

Cool Park Credits promote provision of shade and retention of soil moisture as a priority with optimal urban cooling outcomes achieved at the local precinct and neighbourhood scales when applied in concert with the Urban Design Credits.

3.1.4 CATEGORY 4 - COOL HOMES (CH) CREDITS

Thermally safe environments – places that remain within a temperature range that protect us from injury or death (due to either overheating or over-cooling) – are critical to human health and wellbeing.

Unlike most other building types, our homes have a fundamental requirement to provide us with safety at all hours of the day and night, under all circumstances. By day, some people have the option of seeking shelter from the heat in cooler public places; shady parks, swimming pools or rivers, or inside air-conditioned buildings like libraries and shopping centres. But many people, especially the elderly or those with mobility limitations, have no choice but to shelter at home. At present, there is an inherent assumption in our current planning system and construction codes that a home has air-conditioning to maintain a safe indoor temperature during heatwaves. However, not all homes have functional air-conditioning, not all residents can afford the associated energy costs, and air-conditioning availability depends on reliable power, which can fail in extreme heat conditions.

The Cool Homes Credits promote passive design principles to make homes more resilient to high outdoor ambient air temperatures, and potential electricity network failure during extreme heat events.

The Cool Homes Credits are focused on protecting human health and wellbeing. Avoiding heat related mortality is the primary goal. Notwithstanding, the Cool Homes Credits will also contribute to local outdoor thermal comfort and modest reductions to local ambient outdoor air temperatures which, if applied at scale, together with the other categories of Credits in the CST, will reduce the overall urban heat island effect.

3.1.5 CATEGORY 5 - COOL BUILDINGS (NON-RESIDENTIAL) CREDITS

The Cool Buildings Credits (non-residential) focus on places of work and community hubs such as public shopping centres (malls), libraries, transport hubs (bus/rail stations) and places of worship where people who are able can congregate during very hot conditions for respite. As with the Cool Homes Credits, the Cool Buildings Credits promote passive design principles to make buildings more resilient to high outdoor ambient air temperatures and potential energy grid failure during extreme heat events.

3.1.6 CATEGORY 6 - INNOVATIVE NEW TECHNOLOGIES CREDITS

The Innovative New Technologies Credits have been included in the CST to recognise and promote development seeking to push the envelope on urban heat performance by collaborating with research institutions to develop and/or pilot new technologies, for example through new smart digital solutions or new cool materials. These Credits are the “icing on the cake” and allow a development to achieve the highest possible Cool Suburbs rating if all other categories of Credits have also been satisfied.

3.2 SCORECARD

The CST Scorecard identifies all of the Cool Suburbs requirements to help project teams ensure they have considered all conditions and performance pathways.

The rating score is generated by providing information about a development in relation to the following key steps:

- **Step 1 – Details:**
  Provide details of the project, including a contextual description, the project location and the relevant Local Government Area.
- **Step 2 – Define:**
  Calibrating the tool assessment scorecard via the following parameters:
  - *Australian Climate Region:* The local climate influences the type of response that will be effective at a given location. The CST has been designed to enable operation across the eight climate zones defined by the Building Code of Australia. However, the current version of the tool has been configured for Western Sydney, which falls in Zone 5 "Warm temperate".
  - *Development Site Condition:* A development is described as greenfield, (land previously undeveloped) or brownfield (previously developed land that is not currently in use or land that is available for redevelopment).
  - *Development Scale:* The CST considers the scale of development and can cater for precinct through to lot scale projects. The development scale options are:
    - Large Precinct - Masterplan Community (>1000 Lots)
    - Medium Precinct (101 - 1000 Lots)
    - Small Precinct (11-100 Lots)
    - Local (2-10 Lots)
    - Single Lot
  - *Zones/Typologies:* In Western Sydney there are a broad range of development zones and within these, development types. To cater for these, the following zone and typology combinations have been developed:
    - Residential High Density
    - Residential - Medium Density
    - Residential - Low-Medium Density
    - Residential - Low Density
    - Commercial - Local Centre
    - Commercial - Commercial Centre
    - Industrial - Heavy Industry
    - Industrial - Medium Industry
    - Industrial - Light Industry
    - Open Space - Parks and Reserves
    - Streets (All)

    To calibrate the tool, the relative percentage of each development zone within the development boundary must be defined. For example, a large-scale development may have 15% open space, 40% street reserves, 30% low density residential, 10% medium density residential, and 5% local centre.
- **Step 3 – Assess**:
  - Determine compliance with the Credit criteria relevant to the development type (Step 2) by referring to the guidance and science rationale provided in the CST for each Credit.
- **Step 4 – Response Checklist:**
  - Undertake the Respond Checklist (included as Step 4 in the CST)

After completing the above steps, the CST generates a Cool Suburbs Rating for the development.

3.3 CALCULATING THE RATING

The CST uses a point scoring system that reflects each Credit's relative impact on the following urban heat metrics (having regard to both day and night-time impacts):

- Neighbourhood air temperature;
- Street /allotment air temperature; and
- Street /allotment scale thermal comfort

Credit points and impact scores for each Credit are shown in Table 5.

Table 5. Summary of credits and available points and impact scores.

CATEGORY / CREDITS	CREDIT POINTS	* IMPACT SCORES 0 = NO IMPACT; 3 = HIGHEST IMPACT						*TEMPORAL IMPACT SCORES 0 = NO IMPACT; 3 = HIGHEST IMPACT		
		NEIGHBOURHOOD AIR TEMP.		LOCAL AIR TEMP.		LOCAL THERMAL COMFORT		SHORT-TERM (0-10YRS)	MID-TERM (10-20 YRS)	LONG-TERM (20+ YRS)
		DAY	NIGHT	DAY	NIGHT	DAY	NIGHT			
Urban Design Credits:										
UD1: Wind paths	3	1	1	1	1	3	3	2	2	2
UD2: Wind buffering/filtering	2	1	1	1	1	2	2	1	2	2
UD3: Street canyons	4	3	3	3	3	2	2	2	2	2
UD4: Green and blue open space	8	3	3	3	3	2	2	2	2	2
UD5: Retention of existing tree canopy	7	3	3	3	3	3	1	2	2	2
UD6: Water sensitive urban design	6	2	2	2	1	2	1	1	2	1
Cool Streets Credits:										
CS1: Shade	6	3	0	3	1	3	0	1	2	2
CS2: Irrigation	4	2	1	2	1	2	0	1	2	2
CS3: Cool and/or porous pavements	5	2	1	3	1	2	1	2	1	1
Cool Parks Credits:										
CP1: Shade	6	3	1	3	1	3	0	2	2	2
CP2: Irrigation	6	3	1	3	1	2	1	1	2	2
CP3: Cool and/or porous pavements	3	2	1	2	1	2	1	2	1	1
Cool Homes Credits:										
CH1: Site coverage	2	2	1	2	1	2	1	2	2	2
CH2: Site shade	3	2	1	3	2	3	1	2	2	2
CH3: Site irrigation	1	2	1	1	1	2	1	2	2	2
CH4: Passive cooling	2	0	0	0	0	3	2	2	2	2
CH5: Cool Roofs, green roofs and green Walls	3	2	2	2	1	0	0	2	2	2
CH6: Cool and/or porous pavements	1	1	0	2	0	2	0	2	2	2
CH7: Alternative energy supply	3	0	0	0	0	3	3	2	2	2
Cool Buildings Credits:										
CB1: Site coverage	3	2	1	2	1	2	1	2	2	2
CB2: Site shade	3	2	1	3	2	3	2	2	2	2
CB3: Site irrigation	1	2	0	1	0	2	1	2	2	2
CB4: Passive design	2	0	0	0	0	3	2	2	2	2
CB5: Cool envelope (including green roofs/walls)	2	3	3	2	2	2	2	2	2	2
CB6: Cool and/or porous pavements	1	2	1	2	1	2	1	2	2	2
CB7: Alternative energy supply	3	0	0	0	0	3	3	2	2	2
Innovative New Technology Credits:										
INV1: New technologies	5	2	2	2	2	2	2	2	2	2
INV2: Data collection	5	2	2	2	2	2	2	2	2	2

* Impact scores are for regular hot summer conditions (max day temperature < 37°C) and not for extreme heat conditions (max day temperature >37°C)

An important aspect of the CST's point scoring system is the weightings applied to the six categories of Credits. The weightings reflect the relative priority (importance) of each category of Credits in achieving the best overall urban heat resilience outcomes. The weightings are defined in the CST by the total quantum of Credit points available to each of the six category of Credits, as shown in Table 6.

Table 6. Summary of default tool category weightings and total available points per category.

CATEGORY	RELATIVE WEIGHTING OF CATEGORY	TOTAL CREDIT POINTS ALLOCATED TO CREDITS IN CATEGORY
Urban Design	30%	30
Cool Parks	15%	15
Cool Streets	15%	15
Cool Homes	15%	15
Cool Buildings	15%	15
Innovative New Technologies	10%	10
TOTAL	**100%**	**100 points**

As an example, a large-scale master planned community with design controls over the full development cycle would be in a position to implement urban heat resilience Credits across all of the six categories of Credits. If the project team decides not to implement any of the Urban Design Credits, the development would forgo 30 points (out of a possible total of 100). It is not possible for the development to "do more" in other categories to compensate. This approach reflects the high relative importance given in the CST to a well-designed urban morphology to achieve the best possible urban heat resilience outcomes for larger scale developments.

Additionally, to account for variable land use cover within a development the CST applies a weighting adjustment to the calculated performance (impact) of each Credit to reflect the relative spatial cover of land use(s) to which the Credit applies. For example, if street reserves cover 40% of the total development area, the relative performance (impact) of the Cool Streets Credits needs to be adjusted (factored up) from the default weighting of 15% in Table 5, which assumes the spatial cover of Cool Streets, Cool Parks, Cool Homes and Cool Buildings within a development are all equal. Note, this factoring only applies to the calculated Credit performance (impact) and not to the value of the Credit Points earned, the former being used by the CST to derive the Cool Suburbs Rating as described later.

The CST also considers development type and scale as a key determinant of the urban heat resilience Credits that can be directly influenced by the development and therefore which Credits should be used to rate the development.

Table 7 outlines the relationship between the development type/scale and the urban heat resilience Credits used for rating the development.

Table 7. Relationship between development type/scale and the urban heat resilience Credits used for rating the development.

DEVELOPMENT SCALE	APPLICABLE CREDIT CATEGORIES
Large precinct (>1000 lots)	All
Medium precinct (100-1000 lots)	All
Small precinct (10-100 lots)	All (except Urban Design Category)
Local (1-10 lots)	All (except Urban Design Category and Innovative New Technologies Category)
Single lot (Residential)	Cool Homes only
Single lot (Non-residential)	Cool Buildings only
Local street	Cool Streets only
Local park	Cool Parks only

The CST calculates an overall performance for a development based on the Credits satisfied, the relative points and weightings assigned in the CST to those Credits, and the impact scores associated with those Credits. A development's overall Cool Suburbs rating is determined by comparing its calculated performance to that of an ideal development of the same type/scale that satisfies all the applicable Credits. In this way, the Cool Suburbs rating generated by the CST reflects a development's level of performance scaled from ideal rather than from an arbitrary benchmark of current practice.

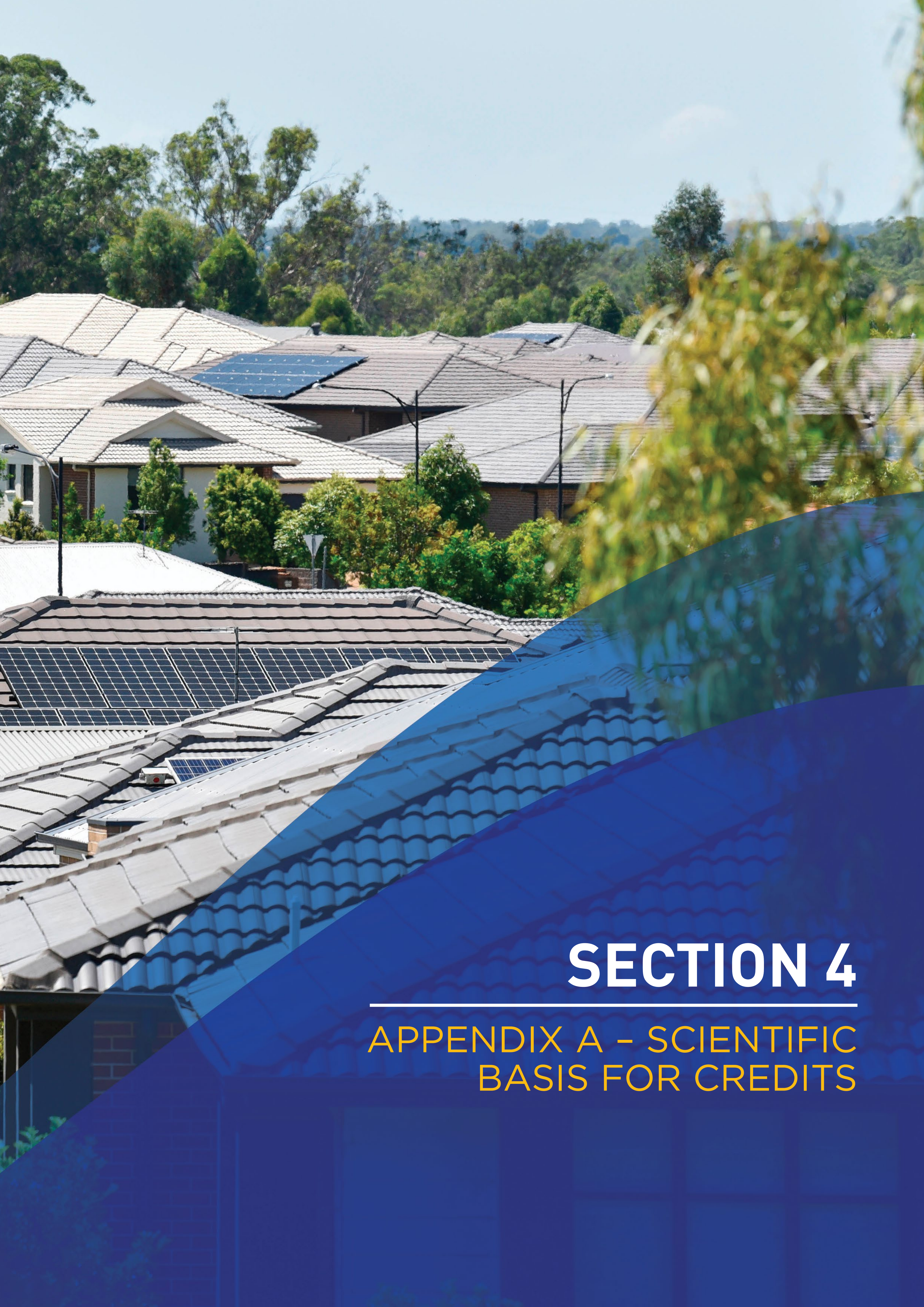
3.4 COOL SUBURBS RESPONSE CHECKLIST

In addition to the assessment criteria described above in Section 3.1, the CST features a Response Checklist (Step 4) that covers key elements of what should be included in a development to ensure that the residual risk from acute heat events is managed appropriately, particularly in relation to vulnerable communities. These initiatives are provided for guidance only and will not have any implication on the overall CST score developed under the Step 2 assessment. The key response elements, outcomes, criteria and guidance are provided in Table 8 below.

Table 8 – Response checklist criteria.

RESPOND ELEMENTS	OUTCOME	CRITERIA	GUIDANCE	REFERENCE
RES1: Vulnerability mapping (for existing communities only)	Improved understanding of the distribution of at-risk members of the community to guide investment in heat mitigation measures.	Spatial vulnerability mapping undertaken using ABS statistics such as the SEIFA index. In large greenfield developments, consideration should be given to SEIFA index of surrounding communities.	Vulnerable members of the community are most at risk from extreme heat due to a range of socio-economic or physiological factors. Mitigation measures such as cool spaces should be readily accessible in areas with higher levels of vulnerable groups (e.g., low-income, over 65, young children).	(23) (24)
RES2: Community awareness and decision support	Provide information that supports the community to make safe decisions that reduce their heat risk, with a focus on extreme conditions.	Integration of design elements that inform communities about local climate conditions and encourages actions to reduce risk. For example, the installation of temperature or UV displays in public spaces, signage promoting hydration in hot weather, or alerting to the likelihood of hot metal play equipment at certain temperatures.	Low awareness of extreme heat and its health impacts can result in individuals not taking action to protect themselves or their families. The aim of this element is to use technology to provide the community information on the severity of place-based conditions.	(25) (26)

RESPOND ELEMENTS	OUTCOME	CRITERIA	GUIDANCE	REFERENCE
RES3: Drinking water access	Ensure that the community has access to fresh drinking water in all public spaces in order to reduce likelihood of heat-related illness.	Provision of safe drinking water in all public parks and spaces.	Hydration is essential for maintaining health in extreme heat. Water is essential for the body's primary cooling mechanism (sweating), for supporting kidney function, and can be used by first responders to assist individuals experiencing heat-related illness via drinking or wetting the skin.	(27)
RES4: Heat shelters/refuges centres	Designated heat refuges or cool spaces where vulnerable people can find relief from heat are included in the project design.	A designated cool refuge has been provided in the project design that offers an accessible space for vulnerable people to seek shelter from extreme heat. The refuge can be any public space and should have adequate cooling systems as well as back-up power supplies in the case of a black out.	There is good evidence and supporting strategies around the development and implementation of cooling centres to prevent heat-related illness. This includes the following building characteristics: • Establish familiar places (i.e., dedicated cooling centres are poorly used. Familiar spaces such as churches, shops, clubs etc are better, supporting the argument **that all new public/publicly used buildings** should be equipped to function as cooling centres if needed) • Reliable air-conditioning (i.e. capacity to function at likely maximum temperatures for a location), and backup power/generator to ensure operation during blackout events • Provision of adequate seating and drinking water • Accessible design e.g., wheelchair access and disabled toilet.	(28)
RES5: Safe transport routes	To support safe travel during extreme heat events.	Provision of targeted measures to improve heat safety along known active transport routes. This includes adequate shading and water provision at bus stops and train stations.	While active transport is not recommended during extreme heat events, many vulnerable groups may rely on such routes and services to access cool spaces away from their residences. Provision of shade and water supports safer travel during these times.	(29) (30)



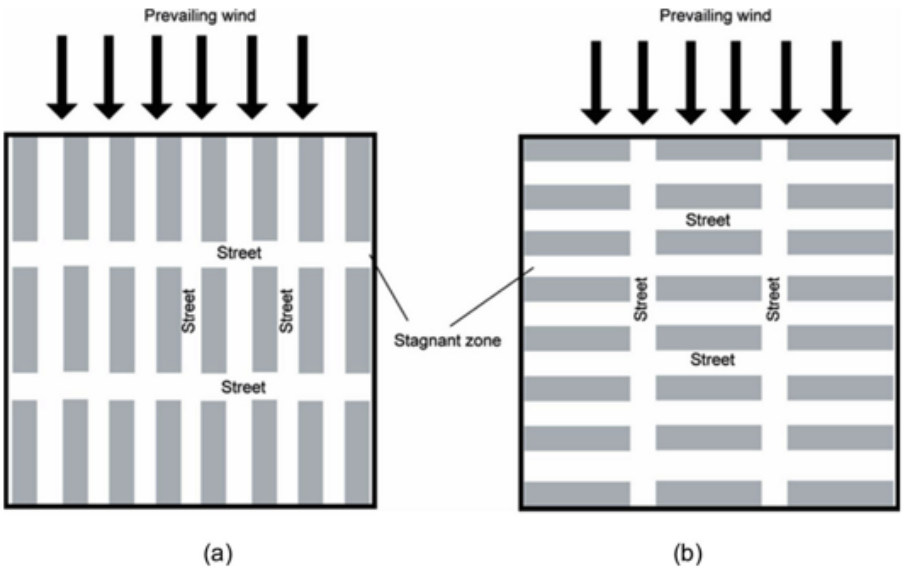
SECTION 4

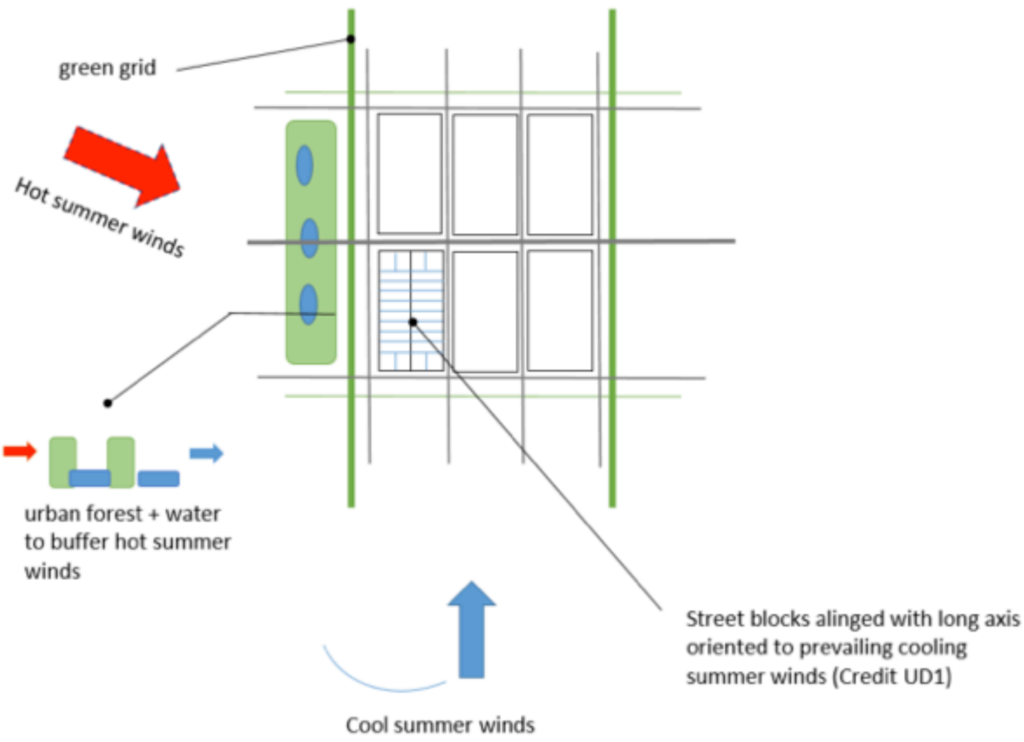
APPENDIX A – SCIENTIFIC BASIS FOR CREDITS

APPENDIX A – SCIENTIFIC BASIS FOR CREDITS

This Appendix provides an overview and science rationale for each Credit in the Cool Suburbs Tool.
A list of cited references is included in the References section of this document.

URBAN DESIGN

CREDIT: UD1: WIND PATHS	
Credit Outcome	Channelling of breezes to lower local air temperature by removing stagnant, heated air and improve outdoor thermal comfort.
Credit Points	3
Credit Criteria	At least 75% of the development's total street length is oriented (+/- 30°) to the dominant prevailing summer breezes. *NB. Hot summer winds can be "cooled" using methods described in Credit UD2 – Wind Buffering / Filtering.*
Guidance	Wind rose (wind speed and direction) data is available from the Bureau of Meteorology.  **Figure UD1-1** The pattern of street canyon for ventilation: (a) Recommended, (b) Not recommended. (Source: Ng, 2009, as cited in He, *et al* 2019)
Science Rationale	Research shows urban ventilation performance primarily corresponds to lower building height, lower compactness, wider streets and orientation (31) (32) (33). Orienting streets (street canyons) to channel the prevailing cooling summer winds displaces pockets of stagnant hot air and improves thermal comfort. The research (34) shows ventilation efficiency lies in adjusting street canyons parallel to prevailing wind, as shown in Fig. UD1-1 (a). In the street pattern in Fig. UD1-1(b), most areas are stagnant zones and wind speeds are consistently very low. Comparatively, the wind speeds in the streets shown in the Fig. UD1-1(a) are higher because of the increase of urban permeability, and reduction in amount of stagnant area. In reality, it is difficult to align all streets to the dominant prevailing summer wind direction, in which case the variation of incidence angle for effective ventilation should be less than 30°.
Related Credits	UD2 – Wind buffering / filtering UD3 – Street canyons UD4 – Green and blue open space All of the Cool Street Credits

CREDIT: UD2: WIND BUFFERING/FILTERING	
Credit Outcome	Cooling of hot prevailing summer winds to reduce local air temperatures and improve outdoor thermal comfort.
Credit Points	2
Credit Criteria	Hot wind buffering is provided to over 75% of the development edge length that is perpendicular (+/- 30°) to the dominant prevailing hot summer winds. *Buffered means the strategic placement of urban forest and/or waterbodies (rivers, lakes, ponds or wetlands) on the upwind boundary of the development and upwind of heat sensitive land uses such as schools, community centres, public transport hubs, hospitals, and child / aged-care facilities.*
Guidance	 **Figure UD2-1** Idealised wind buffering and urban grid configuration for Western Sydney
Science Rationale	For inland areas, effort is required to buffer unfavourable hot summer winds by channelling the airflow through "cooling environments" such as urban forests and/or waterbodies (rivers, lakes, ponds and wetlands) (31). For Western Sydney, hot summer winds typically emanate from inland Australia as hot north-westerlies. Channelling these hot summer winds through "cooling environments" enhances the cooling benefits provided by precinct ventilation measures. This is particularly the case when "cooling environments" are strategically located up-wind of heat sensitive land uses such as schools, community centres, public transport hubs, hospitals, and child / aged-care facilities.
Related Credits	UD1 – Wind paths UD4 – Green and blue open space UD5 – Retention of existing tree canopy UD5 – Water sensitive urban design All of Cool Parks Credits

<table>
<tr><th colspan="2">CREDIT: UD3: STREET CANYONS</th></tr>
<tr><td>Credit Outcome</td><td>Street canyons configured to promote shade and ventilation to reduce local air and surface temperatures and improve outdoor thermal comfort.</td></tr>
<tr><td>Credit Points</td><td>4</td></tr>
<tr><td>Credit Criteria</td><td>At least 75% of the development’s street canyons have an aspect ratio (H:W) between 0.3 and 1.0 with a notional maximum height of 20m (five storeys).</td></tr>
<tr><td>Guidance</td><td>Design of the urban morphology is to prioritise shallow street canyons to allow for solar access to the public realm in winter, space for street tree planting, ventilation and nocturnal cooling.

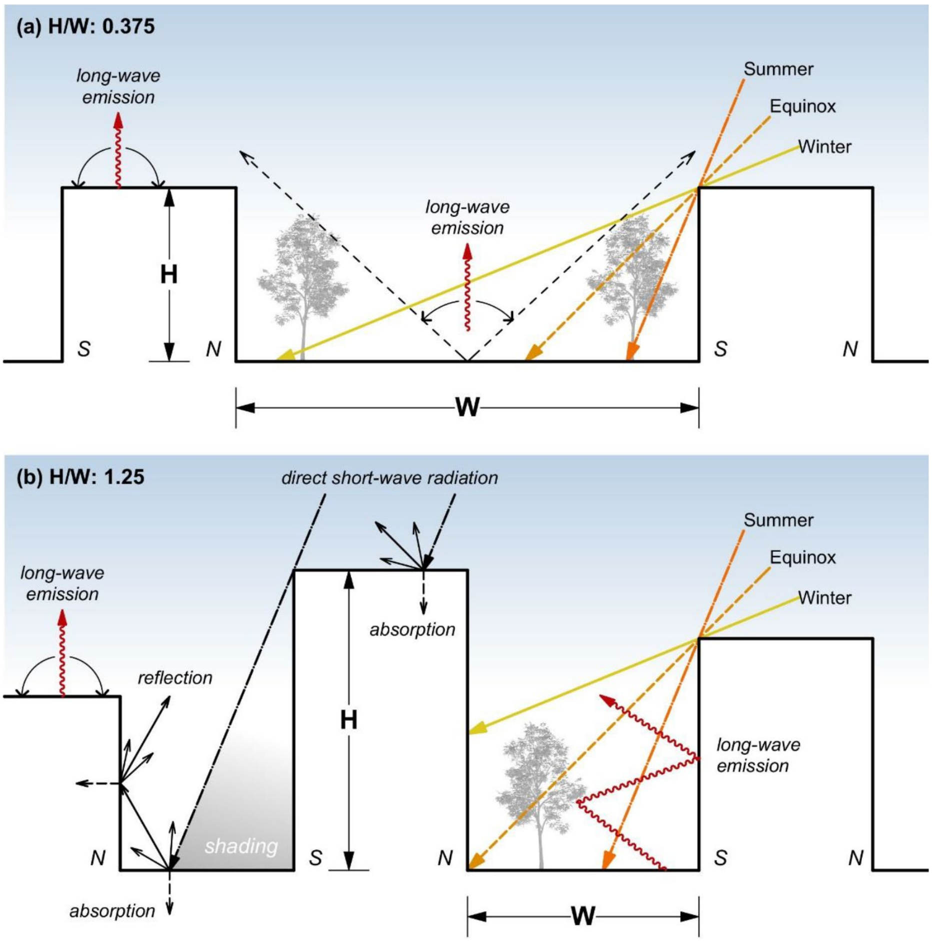


Figure UD3-1 Street canyon solar access and heat fluxes (Images adapted from (35)</td></tr>
<tr><td>Science Rationale</td><td>Research shows better ventilation and nocturnal cooling performance primarily corresponds to lower building height, lower compactness and wider streets (34) (32) (33).

In an analysis of daytime thermal imagery, street trees in Melbourne were found to be particularly effective at reducing surface temperatures in street canyons with an aspect ratio H:W < 0.8, whilst above this H:W the effects of trees on surface temperature were reduced due to over-shadowing by surrounding buildings (36).</td></tr>
<tr><td>Related Credits</td><td>UD1 – Wind paths
All Cool Streets Credits</td></tr>
</table>

CREDIT: UD4: GREEN AND BLUE OPEN SPACE	
Credit Outcome	Green and blue open space designed and positioned to reduce local air and surface temperatures and improve outdoor thermal comfort.
Credit Points	8
Credit Criteria	Perviousness: • The development area comprises at least 60% pervious surfaces and at least 50% of pervious surfaces provided as soft (green) landscaped surfaces. Placement: • Green (and blue) open space is distributed to achieve walkable access and, where practicable, is located upwind of heat sensitive land uses such as schools, community centres, public transport hubs, hospitals, and child / aged-care facilities.
Guidance	• Urban designers should take into account the prevailing summer wind direction when positioning parks and water bodies. • Downwind cooling effect of urban parks extends to about one park width (rule of thumb). • Distributed parks are preferred over a single large park. • Prioritise locations upwind of high heat exposure areas. • Prioritise provision of canopy shade for parks where daytime cooling is the priority (e.g., parks within city centres, commercial areas and low-rise residential developments). • Prioritise more open green areas (shade trees planted to park edges) for parks where night-time cooling is the priority (e.g., parks in higher density residential areas). • A heterogeneous tree canopy planted in groves is preferred to a homogeneous tree canopy planted in continuous rows. • Irrigated green space provides the best cooling benefit. • Distributed smaller water bodies orientated perpendicular to the dominant prevailing summer wind flow will provide cooling to a greater area than a single large linear water body oriented parallel to the wind flow. • Downwind cooling benefits of water bodies will be greatest if located upwind of street canyons designed for efficient ventilation.
Science Rationale	Research on the influence of different surface types and their relative cover on air temperatures in Western Sydney shows, amongst other findings (37) (15): • Increasing the area of green open spaces and tree canopy leads to cooling. • When provided in equal proportions, warming from hard surfaces exceeds cooling from open space. • The largest cooling benefits are generated by open space as opposed to hard surfaces and buildings. • Open space and tree canopy cover can markedly reduce summer night-time air temperatures. With reference to Figure UD4-1, effective cooling at sites that contain both surface types can only be achieved once the ratio of open space to hard surfaces is 2:1 or greater.

CREDIT: UD4: GREEN AND BLUE OPEN SPACE

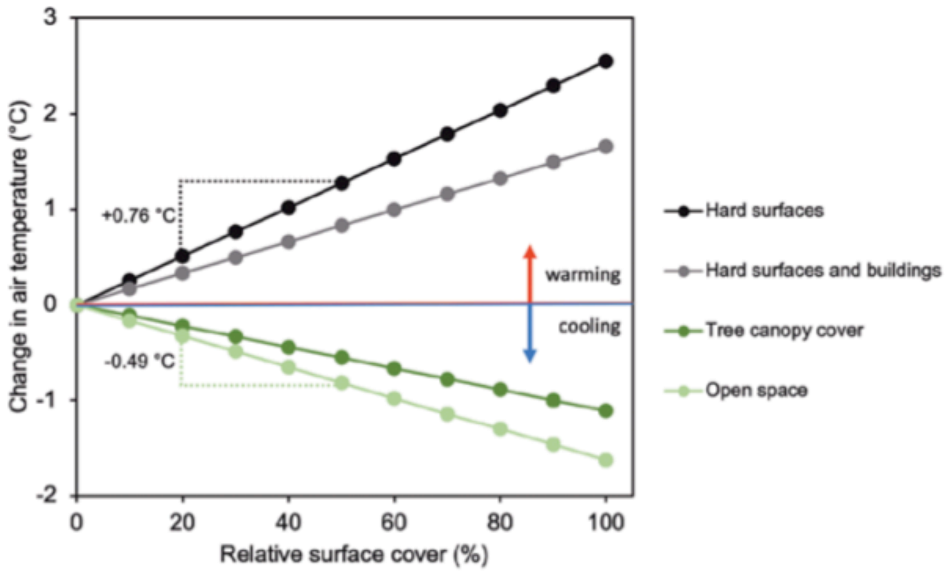


Figure UD4-1 Predicted changes in mean summer air temperature along a gradient of different surface cover types and tree canopy. Source: Pfautsch, S., Tjoelker, A R. (2020)

Research on the downwind cooling effect of urban parks suggests that downwind cooling extends to about one park width (38)

Research of microscale cooling effects of water sensitive urban design and irrigation at Mawson Lakes in South Australia shows urban water bodies, such as lakes and wetlands have incidental microclimate cooling benefit. The research states that with additional planning and consideration, water bodies can provide even greater cooling benefits. For example, smaller and well-distributed water bodies placed perpendicular to prevailing winds will create the most efficient urban canopy layer cooling per m^2 of lake surface (39)

Given the potential cooling benefits, practitioners should take into account the wind regime when designing and incorporating blue and green open space into the urban environment.

Related Credits	UD1 – Wind paths UD2 – Wind buffering / filtering UD4 – Retention of existing tree canopy UD5 – Water sensitive urban design All Cool Park Credits

CREDIT: UD5: RETENTION OF EXISTING TREE CANOPY	
Credit Outcome	The development retains existing tree canopy cover to provide shade, lower surface radiative temperatures, promote ventilation and improve Human Thermal Comfort.
Credit Points	7
Credit Criteria	Retention of at least *80% of the existing tree canopy cover within the development boundary. **Where a qualified arborist identifies existing trees to be in poor health and/or not a suitable species for the local area then the development shall prepare and implement a staged tree replacement plan so the overall canopy cover within the development boundary does not diminish due to development.*
Guidance	• Consider the species, health, location and future resilience of existing trees within the development boundary and avoid the unnecessary removal of any trees in good health and of a suitable species for the local area. • Where practicable, transplant (on-site) viable trees that cannot be retained in their existing positions. • Provide active management of younger trees to support crown development.
Science Rationale	Trees are an effective urban heat mitigation solution for several reasons. A vast range of tree species enables the selection of trees that best fit with the climate and environment of the location (e.g., soil type, water availability, light availability, etc.). Tree roots can access deep-water sources, compared to shallow rooting grasses and shrubs. Trees provide multiple benefits in addition to urban cooling, including reduced stormwater runoff volumes, air quality benefits (depending on tree species selection), carbon uptake and storage, habitat, and building and neighbourhood energy savings (40). Trees provide cooling through both transpiration and shade. Shade in particular is critical for improved Human Thermal Comfort during warm sunny conditions (40). A comparison of Human Thermal Comfort levels outside and below tree canopies in the CBD of Melbourne during a heatwave found that shading dramatically reduced the mean radiant temperature, reducing the Universal Thermal Climate Index (UTCI) from a level of 'very strong' heat stress to 'strong' heat stress (41). Tree canopy shade reduces the amount of heat absorbed by surfaces during the day, which in turn results in cooler air temperatures at the beginning of the night and less emission of heat during the night (37). In Western Sydney, this effect is relatively large, and it is at night when the cooling benefits of canopy shade on ambient air temperature become apparent. Conversely, during daytime the air temperatures under tree canopy in Western Sydney is similar to the surrounding ambient air temperature due to air mixing (17). Advice regarding the best species to plant in a given geography based on various planting factors including future climate is available on the https://www.whichplantwhere.com.au website.
Related Credits	UD1 – Wind paths UD2 – Wind buffering / filtering UD4 – Green and blue open space UD6 – Water sensitive urban design CS1 – Shade CP1 – Shade CH2 – Site shade CB2 – Site shade

CREDIT: UD6: WATER SENSITIVE URBAN DESIGN	
Credit Outcome	The development's water sensitive urban design elements provide evapotranspiration and shade, reduced surface radiative temperatures, promote ventilation and improve Human Thermal Comfort.
Credit Points	6
Credit Criteria	The development adopts and implements a distributed "at-source" WSUD strategy; And At least 50% of the development's aggregate WSUD treatment area (excluding constructed wetlands) incorporate shade trees.
Guidance	• Aim to maximize the cooling potential of existing green infrastructure first. WSUD and stormwater harvesting can support fit-for-purpose water for widespread landscape irrigation to maintain healthy vegetation and accentuate urban cooling and Human Thermal Comfort (HTC) benefits. Irrigation is also likely to be particularly effective due to the ability to apply water across a large proportion of the landscape, as well as controlling the times of irrigation. • Target dense urban environments with little or no vegetation. WSUD is most effective under warm and dry conditions where the access to additional passive watering and irrigation can provide the greatest benefit. This is convenient because these are commonly areas of highest heat exposure that can place vulnerable populations at risk. • Areas of poor energy efficiency should also be targeted to improve indoor HTC and minimize energy consumption. • Harness the cooling and HTC benefits of trees. WSUD should be combined with increased tree cover to maximize cooling via both evapotranspiration and shading. Trees are also an efficient means of water use to provide cooling and HTC benefits. Increased tree cover should also target areas of high solar exposure. • Aim for many, smaller, distributed WSUD technologies and features at regular intervals throughout the urban environment to retain stormwater in the urban landscape and promote widespread infiltration into soils. Atmospheric cooling and HTC effects of WSUD are likely to be highly localized, so while a treatment wetland can meet stormwater quality objectives for a residential subdivision, it may only provide a HTC benefit for those residents in the immediate vicinity. Distributing WSUD throughout the landscape should provide a larger areal extent of cooling than large concentrated green areas. • Work with the built environment to accentuate cooling influences. WSUD should be strategically designed into the urban landscape, with features implemented upwind of target areas and where urban canopy layer cooling is maximized (within urban canyons where people reside). Urban spaces should be sensitive to local and regional climatic influences (such as sea breezes) and maintain natural cooling mechanisms such as ventilation and trees.
Science Rationale	Examples of WSUD solutions for commercial, industrial and housing developments that can address these criteria are described in Sydney Water's Urban Typologies and Stormwater Management Solutions (42). Implementation of WSUD and greening generally occurs at the household and street scale (the micro-scale) through planting of street trees, construction of WSUD elements like biofiltration systems, and creation of open space (41). These micro-scale implementations will influence the micro-climate. When WSUD features and urban greening is widespread across the neighbourhood, it will have an influence on the local climate. This is presented conceptually in Figure UD6-1, which shows the widespread implementation of WSUD and urban greening at the micro-scale, and the anticipated benefits at the local-scale. When several neighbourhoods begin to support cooling through these and other mitigation approaches, this is when the city-scale urban heat island will be reduced.

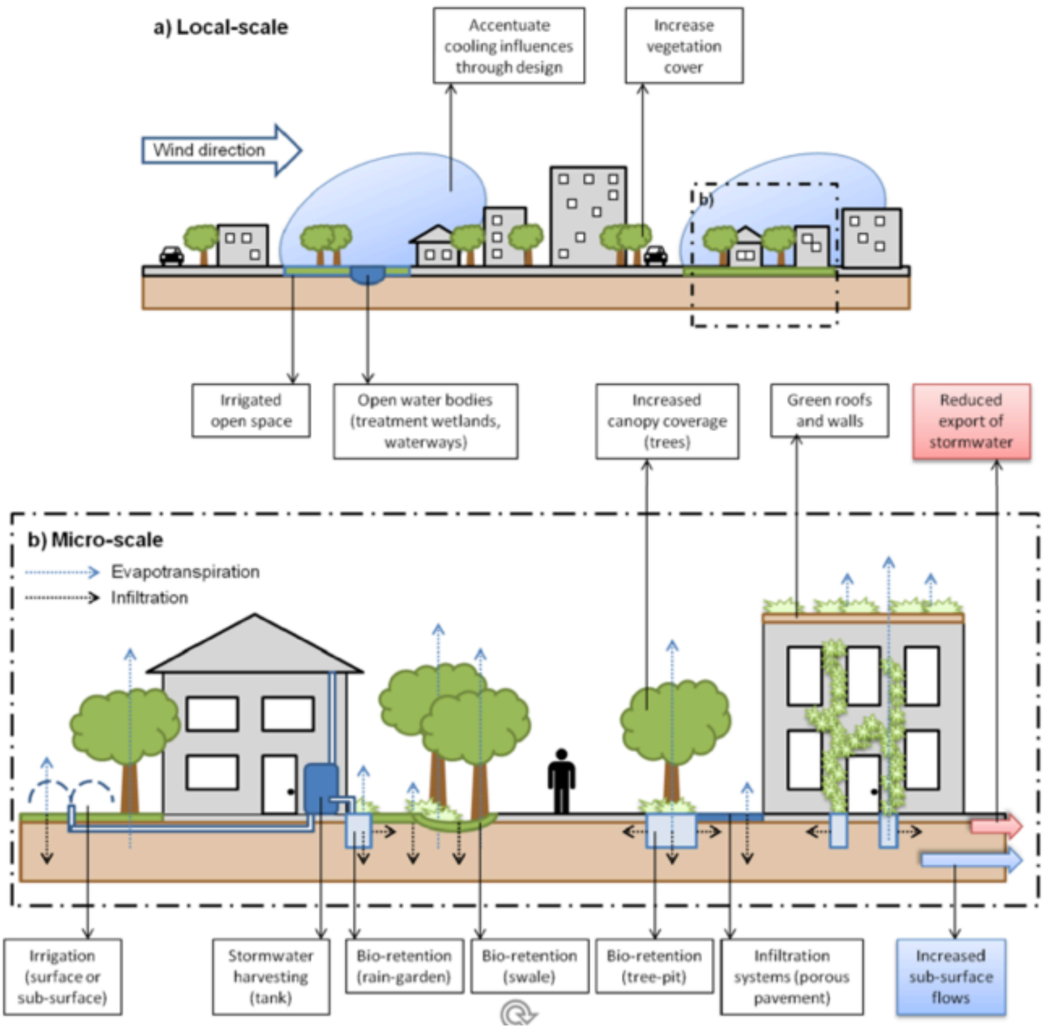


Figure UD6-1 Schematic representation of widespread WSUD elements at the micro-scale in the restoration of a more natural water balance, along with increased vegetation cover. This enhances urban evapotranspiration and shading resulting in local-scale cooling effects that can improve Human Thermal Comfort

WSUD aims to reintegrate stormwater back into the urban landscape to help restore the water balance and influence the urban climate by modifying the urban radiation budget and surface energy balance (43). This in turn drives the environmental parameters that influence Human Thermal Comfort. Figure UD6-2 theorizes the key processes involved in developing urban micro-climates during warm summertime conditions between a conventional (water limited) urban landscape (Figure UD6-2, a and c) and a water sensitive urban landscape (Figure UD6-2, b and d), which each exert environmental influences on Human thermal Comfort (HTC).

CREDIT: UD6: WATER SENSITIVE URBAN DESIGN

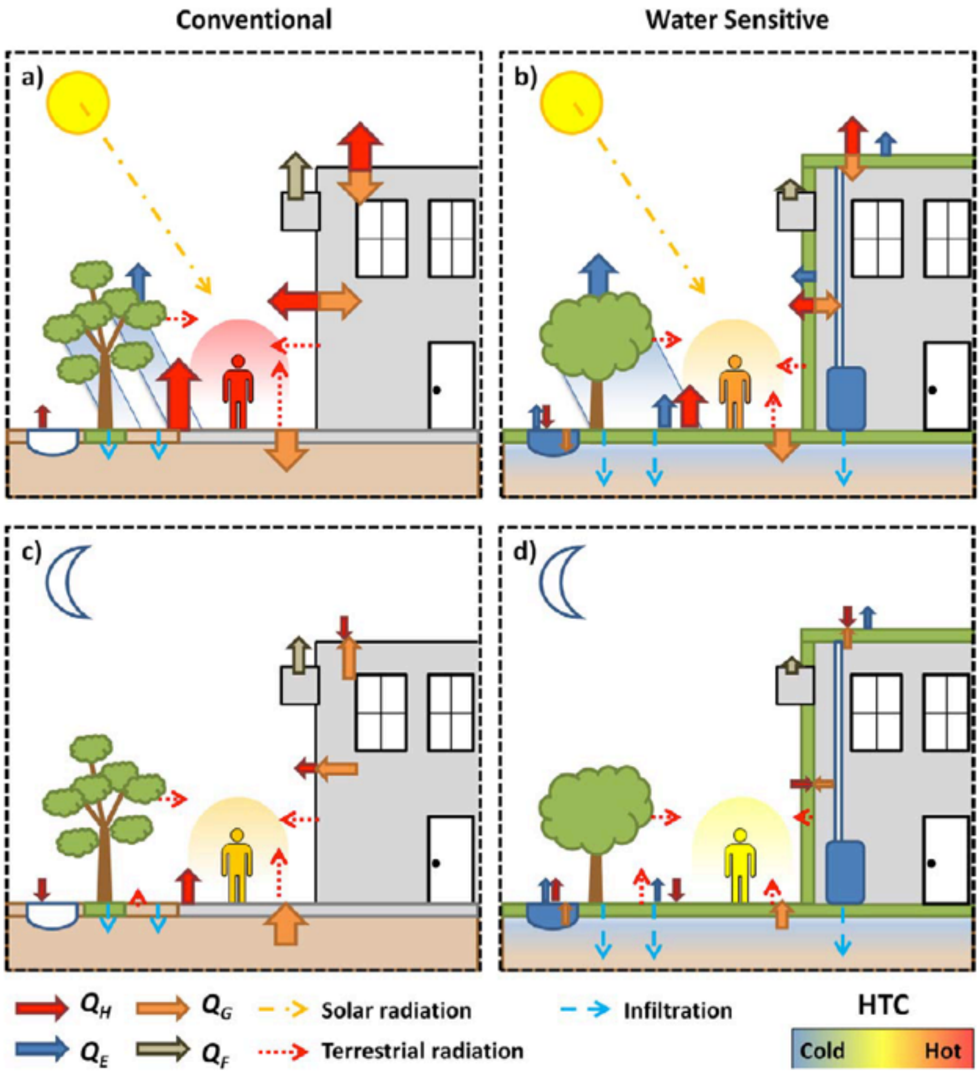


Figure UD6-2 Generalisation of key processes in the formation of urban micro-climates during summer for conventional (water limited) urban landscapes (a and c) and water sensitive urban landscapes (b and d). Source: Modified after Oke (2009).

With respect to Figure UD6-2, during the day when aiming to limit heat stress, promoting shading and limiting atmospheric heating is important for creating a more comfortable thermal environment. The water sensitive scenario (along with healthy vegetation) serves to increase shading, evapotranspiration and reduce surface temperatures, thereby reducing Q^H (sensible heat flux or the loss of energy by the surface by heat transfer to the atmosphere) and radiative loadings on pedestrians, as well as supporting an overall reduction in Q^G (ground heat flux) (Figure UD6-2 b). This is in contrast to a more conventional urban landscape (Figure UD6-2a) where water is limited, and vegetation health is compromised. Under this arrangement, Q^H dominates, and intense surface heating and reduced shading supports higher radiative loading on the human body. This also increases energy demand for cooling, increasing Q^F (anthropogenic heat flux). At night, promoting long-wave cooling and ventilation can create more comfortable thermal environments. Furthermore, the water sensitive scenario (having generally stored less heat during the day) is less conducive to supporting urban canopy layer warming (Figure UD6-2d) than the conventional urban layout (Figure UD6-2c).

Related Credits	All Credits

CREDIT: CS1: SHADE

Credit Outcome	Shade and evapotranspiration provided by street trees reduces local surface temperatures and improves local Human Thermal Comfort.
Credit Points	6
Credit Criteria	At least 75% of the development's streets must have greater than 30% tree canopy cover at maturity. *This credit is only available if Credit CS2 is also satisfied*
Guidance	• Trees have the greatest cooling effect when they are positioned to shade hard surfaces during the hottest times of the day. • Street tree planting recommendations: > E-W streets: both sides of street with priority to southern side > N-S streets: prioritise eastern side of street > Non-cardinal (i.e. do not follow North-South-East-West orientation) streets: prioritise predominant sunny side of street • Tree species selection to suit in-situ soil conditions and resilience to high heat stress. • Use deciduous trees for areas near indoor spaces that require light and solar access in winter. • Use evergreen trees for areas that will benefit from year-round shade. • A heterogeneous canopy (variety of suitable tree species) is preferred to increase the urban canopy roughness through different tree heights and foliage types. • It is important that a complete canopy cover is not present, as regular breaks in the canopy are required to support nocturnal cooling. • Selection and placement of street trees for shading of pedestrians should consider peak-use times (e.g., after school finishes) to ensure shade provided minimises pedestrian's solar exposure during summer months.

Design response matrix

Green = Suitable Yellow = May be suitable [–] = Unlikely to be suitable

Increasing space for green infrastructure →

Generally increasing movement significance ↕ Generally increasing place significance ↑

	A. Grated tree pits	B. Trees with permeable paving	C. Open tree pits	D. Infiltration trenches and wells	E. Trees in raingardens	F. Trees in grass verges	G. Sheet flow* to grass and trees
1. Pedestrian zone	Green	Green	–	–	Yellow	–	–
2. Neighbour-hood zone	Yellow	Green	Green	–	Green	–	–
3. Urban street	Green	Yellow	Yellow	–	–	–	–
4. Suburban street	–	–	Yellow	Green	Yellow	Green	–
5. Activity street	Yellow	Yellow	–	–	Green	Yellow	–
6. Boulevard	–	–	–	Green	Yellow	Green	–
7. Major thoroughfare	–	–	–	Green	–	Green	Yellow
8. Freeway	–	–	–	–	–	Yellow	Green

* Sheet flow refers to wide shallow movement of water across a surface, as distinct from concentrated overland flow in channels or narrow flow paths. In this context, sheet flow refers to water that spreads across the length of the roadway into the adjacent verge, rather than flowing through dedicated channels, inlets and entry points.

Figure CS1-1 Likely suitability of street tree design responses for common streetscapes (source: Victoria Government Department of Environment, Land, Water and Planning)

CREDIT: CS1: SHADE	
Science Rationale	Trees are an effective urban heat mitigation solution for several reasons. A vast range of tree species enables the project team to select trees that best fit with the climate and environment of the location (e.g., soil type, water availability, light availability, etc.) (43). Tree roots can access deep-water sources, compared to shallow rooting grasses and shrubs. Trees provide multiple benefits in addition to urban cooling, including reduced stormwater runoff volumes, air quality benefits (depending on tree species selection), carbon uptake and storage, habitat, and building and neighbourhood energy savings. Trees provide cooling through both transpiration and shade. Shade in particular is critical for improved Human Thermal Comfort during warm sunny conditions (40). Tree canopy shade reduces the amount of heat absorbed by surfaces during the day, which in turn results in cooler air temperatures at the beginning of the night and less emission of heat during the night (37). In Western Sydney, this effect is relatively large, and it is at night when the cooling benefits of tree canopy shade on ambient air temperature become apparent. Conversely, during daytime the air temperatures under tree canopy in Western Sydney is similar to the surrounding ambient air temperature due to air mixing. A study of microclimatic variation across the City of Parramatta during the summer of 2018/19 showed a street with 30% tree canopy cover experienced only 5 days of air temperatures greater than 40°C whereas a nearby street where canopy cover was just over 10% the air temperatures soared above 40°C on 13 days (44). A comparison of Human Thermal Comfort levels outside and below tree canopies in the CBD of Melbourne during a heatwave found that shading dramatically reduced the mean radiant temperature, reducing the Universal Thermal Climate Index (UTCI) from a level of 'very strong' heat stress to 'strong' heat stress (43). Research comparing the micro-climate of two residential streets with similar aspect ratio (H:W) in East Melbourne, where one street had very little tree canopy cover (12%) and the other had a good tree canopy cover (45%), showed during hot conditions air temperature in the street with more trees was 0.2-0.6°C cooler than the street without many trees (43). The street with more trees was also up to 0.9°C cooler during the morning as the trees delayed surface heating. Moreover, heat stress was lower in the street with trees.
Related Credits	UD5 – Retention of existing tree canopy UD6 – Water sensitive urban design CS2 – Irrigation INV2 – Data collection and analysis

CREDIT: CS2: IRRIGATION	
Credit Outcome	Suitable irrigation is provided to enable street reserve landscapes to thrive in average summer conditions and to survive in extreme heat conditions. Irrigated street reserve landscapes reduce local surface temperatures, cool local air temperatures and improve local thermal comfort.
Credit Points	3
Credit Criteria	The developer must provide a detailed water management plan which achieves water efficiencies and supports the continued achievement of objectives outlined in CS1. *This credit is only available if the criteria for CS1 is also satisfied*
Guidance	The water management plan should address the following aspects: • An alternative water supply such as stormwater runoff and/or reticulated recycled water to be used for the primary irrigation water source with potable (town) water as a backup. • A smart irrigation system is adopted which relies on rain and/or soil moisture sensors and night scheduling. In extreme heat situations, the irrigation system should be capable of prioritising trees that can provide shade. • Irrigation rates guided by local best practice for species and soil profile. • Drip irrigation lines (above or sub-surface) are used. Water management plan must complement the design and objectives of CS1.
Science Rationale	As our cities increasingly experience hot weather events, it is important to ensure green spaces and tree canopies are receiving sufficient water to continue to thrive (45). This must be done in a water efficient way. Vegetation that is water stressed has higher surface temperatures than irrigated vegetation; inadequate irrigation will lead to reduced plant transpiration (and subsequent cooling) when it is most required (32). An investigation of the impact of irrigation on urban cooling for the suburb of Mawson Lakes in Adelaide showed during a heatwave event a 10% increase in irrigated pervious cover led to a 0.25°C reduction in daily average temperature (39). The amount of cooling tapers off at high irrigated pervious covers and/or high levels of irrigation as the maximum amount of cooling is reached. An investigation of the cooling effects of nocturnal irrigation at two Melbourne botanic gardens showed the cooling effects from nocturnal irrigation of garden and lawn areas intensify during heatwaves compared with the non-heatwave periods (46). At some garden sites, nocturnal irrigation was associated with 0.5 °C – 1 °C of cooling during non-heatwave conditions. However, the cooling associated with nocturnal irrigation was greater (2°C – 4°C) during heatwave conditions.
Related Credits	UD6 – Water sensitive urban design CS1 – Shade INV1 - New technologies

CREDIT: CS3: COOL AND/OR POROUS PAVEMENTS	
Credit Outcome	Cool, porous and/or permeable pavements reduce local surface temperatures and local air temperatures and enhance Human Thermal Comfort.
Credit Points	5
Credit Criteria	The development incorporates cool pavement solutions (three-year Solar Reflectance Index (SRI) >50) across at least 75% of street carriageways and footpaths. or; The development incorporates porous pavement solutions across at least 75% of street carriageways and footpaths. And: There must also be a demonstrated commitment to maintaining the asset (including scheduled replacement or renewal as necessary) due to the diminishing performance (e.g., reduced permeability) of such materials over time owing to local operating and environmental factors.
Guidance	There are a range of strategies for designing pavements that reduce urban heat impacts, including: • Increase use of ‘cool materials’ – those that are more reflective, store less heat and may have greater moisture capacity/ permeability. • Use lighter pigments in mixing asphalts, concretes and pavers to increase reflectance by 30%. • Incorporate a thin coating of a reflective layer to assist in the reflectance of the material. This must be considerate of driver safety and pedestrian comfort - its use can lead to glare and discomfort for drivers and some thermal discomfort for pedestrians at times of peak daytime sunlight. Designing-in reflective surfaces must be demonstrated to be considerate of driver safety and pedestrian comfort. • Choose materials with a low emissivity rating, meaning they will be less prone to embodying heat. • Designing using materials which a) reflect the solar radiation and/or b) have lower emissivity will result in an overall cooler local environment. • Use of materials and coatings must be appropriate for particular setting, accounting for traffic vs pedestrian use, longevity in local environment and surrounding materials. Permeable pavements should consider the following in their design: • Permeable paving allows for the drainage, infiltration and evaporation of water more effectively through urban surfaces. • Permeable paving can be achieved through the use of non-traditional pavements (made from plastic, metal or concrete) filled or interspersed with permeable materials (vegetation, gravel) laid over a permeable base. • Maximum impact occurs when designed in conjunction with the principles of CS3, namely highly reflective materials and materials less prone to storing heat. • Foam based concrete is more permeable than traditional concrete and can be used in low-traffic areas and pathways (and additionally, playgrounds). • Permeable natural resins used in place of traditional masonry binders can be adopted for walking and biking paths.
Science Rationale	Standard and common materials used in roads and pavements absorb heat, retain heat and radiate heat, instead of reflecting the heat and energy (47). The standard solar reflectance of concrete and other common paving materials is 25-40%. When these low solar reflectance materials are used, the surface temperatures can reach 65°C in summer impacting the immediate ambient air temperatures significantly. Because these materials store heat, the effect of this absorption can remain long after peak direct sunlight. More reflective materials reflect the solar radiation rather than absorbing it. High emissivity materials heat up more readily in response to external temperature changes and as such contribute more readily to the ambient air temperature than low emissivity materials. Emissivity is less easily modified as most common building materials have a high emissivity.

CREDIT: CS3: COOL AND/OR POROUS PAVEMENTS

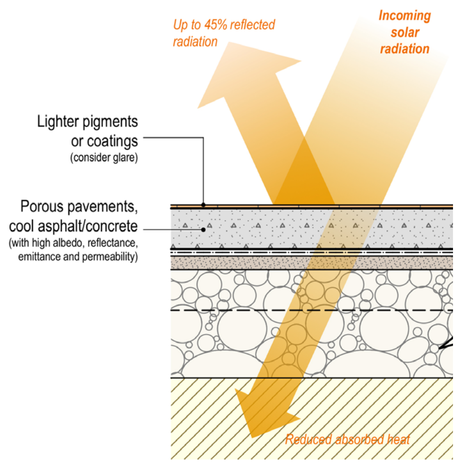


Figure CS3-1 Typical section through a cool pavement. source: (47)

Evaporative cooling from porous and permeable surfaces may decrease surface temperature by up to 20°C (47).

Incorporating porous and/or permeable surfaces in conjunction with highly reflective materials with low emissivity will reduce local temperatures, increase cooling effect in summer and reduce surface run-off. It has the additional benefit of increased soil moisture benefitting verge plantings.

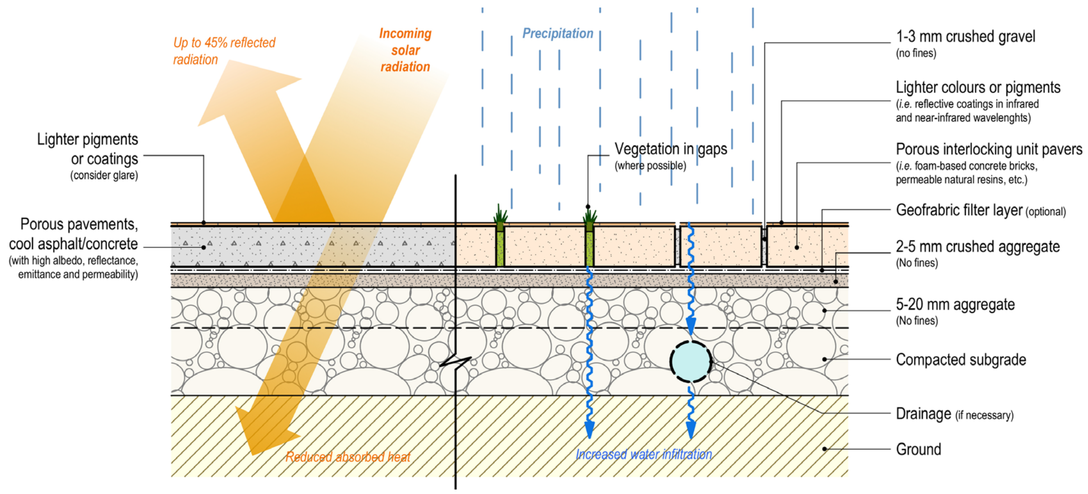


Figure CS3-2 Typical section through a porous pavement. source: Osmond P and Sharifi E (2017)

Related Credits	UD6 – Water sensitive urban design CS2 – Irrigation CS3 – Cool and/or porous pavements INV1 – New technologies

COOL PARKS

CREDIT: CP1: SHADE	
Credit Outcome	Shade provided by trees reduces mean radiant temperatures and improves human comfort and enjoyment of community spaces.
Credit Points	6
Credit Criteria	The development's communal open space must have have at least 40% tree canopy cover, And: Park masterplan protects at least 80% of the existing tree canopy (where relevant). *This credit is only available if the criteria for Credit CP2 is also satisfied.*
Guidance	• Existing mature trees that cannot be retained in position should be transplanted where practicable. • The introduction of tree species should consider the suitability of the species, including existing soil conditions, heat tolerance and water requirements. The placement of new trees should also consider their ability to channel breezes if applicable. • Deciduous trees should be used where sunlight is desirable in winter; evergreen trees should be used where year-round shade is preferable. • Consideration of safety is paramount with species selected to minimise risk to public safety. • A variety of suitable tree species is preferred to increase the urban canopy roughness through different tree heights and foliage types . • A continuous (i.e., 100%) canopy is not desirable as it hinders the ability of the space to self-regulate temperature at nighttime and cool down. • Trees should be clustered with occasional breaks in canopy rather than evenly spaced. • Trees should be positioned to provide shade to hard surfaces during the hottest times of the day, particularly pedestrian pathways. • Where site constraints do not allow for the planting of trees, other shade solutions such as vegetation covered pergolas and light-coloured artificial shade structures should be considered. • A detailed irrigation plan which prioritises maintenance of canopy and year-round heat mitigation benefits of shade and canopy will support the viability and success of any shade and canopy project. • Park design can address down-wind cooling effects of shade and canopy beyond the park boundaries.
Science Rationale	An overall lack of vegetation is a key defining feature of developed urban areas and a major contributor to the UHI effect through decreased evapotranspiration (47). Increasing urban vegetation is a simple and effective way to reduce the UHI. Radiant temperatures in parks that have well-irrigated trees can be 2-4°C cooler than adjacent un-vegetated or build up areas; the extent and proportion of tree plantings can have a 1-2°C impact on the actual temperature. Trees provide cooling through both transpiration and shade. Shade in particular is critical for improved Human Thermal Comfort during warm sunny conditions (40). Trees deliver greater cooling effect and enhance human comfort more than other urban green approaches (shrubs, grass) (40). Existing established trees provide the greatest benefit for heat minimisation and should be prioritised in planning. Tree canopy shade reduces the amount of heat absorbed by surfaces during the day, which in turn results in cooler air temperatures at the beginning of the night and less emission of heat during the night. In Western Sydney, this effect is relatively large, and it is at night when the cooling benefits of tree canopy shade on ambient air temperature become apparent (37). Conversely, during daytime the air temperatures under tree canopy in Western Sydney is similar to the surrounding ambient air temperature due to air mixing. Vegetation that is water stressed has higher surface temperatures than irrigated vegetation; inadequate irrigation will lead to reduced plant transpiration (and subsequent cooling) when it is most required (32). In the right positioning and with correct irrigation, parks can provide down-wind cooling effects beyond the park boundaries. Urban green spaces cool more effectively if they contain scattered trees and receive irrigation.
Related Credits	UD2 – Wind buffering / filtering UD4 – Green and blue open space UD5 – Retention of existing tree canopy UD6 – Water Sensitive urban design CS2 – Irrigation INV2 – Data collection and analysis

CREDIT: CP2: IRRIGATION	
Credit Outcome	Suitable irrigation is provided to communal park spaces to enable park landscapes to thrive in average summer conditions and to survive in extreme heat conditions. Irrigated park landscapes reduce local surface temperatures, cool local air temperatures and improve local thermal comfort.
Credit Points	6
Credit Criteria	The developer must provide a detailed water management plan which achieves water efficiencies and supports the continuous objectives of CP1. In lieu of a detailed water management plan the developer (or government authority) should at least be able to demonstrate how it intends to provide a secure irrigated water supply that prioritises use of alternative water sources over potable (town) water supplies. *This credit is only available if the criteria for CP1 is also satisfied*
Guidance	The water management plan should address the following aspects: • An alternative water supply such as stormwater runoff and/or reticulated recycled water to be used for the primary irrigation water source with potable (town) water as a backup. • A smart irrigation system is adopted which relies on rain and/or soil moisture sensors and night scheduling. In extreme heat situations, the irrigation system should be capable of prioritising trees capable of providing shade. • Irrigation rates guided by local best practice for species and soil profile. • Drip irrigation lines (above or sub-surface) are used. Water management plan must complement the design and objectives of CP1 – increasing shade and usability of public spaces owing to maximum cooling effect.
Science Rationale	As our cities increasingly experience hot weather events, it is important to ensure green spaces and tree canopies are receiving sufficient water to continue to thrive (45). This must be done in a water efficient way. Vegetation that is water stressed has higher surface temperatures than irrigated vegetation; inadequate irrigation will lead to reduced plant transpiration (and subsequent cooling) when it is most required (32). An investigation of the impact of irrigation on urban cooling for the suburb of Mawson Lakes in Adelaide showed during a heatwave event a 10% increase in irrigated pervious cover led to a 0.25°C reduction in daily average temperature (39). The amount of cooling tapers off at high irrigated pervious covers and/or high levels of irrigation as the maximum amount of cooling is reached. An investigation of the cooling effects of nocturnal irrigation at two Melbourne botanic gardens showed the cooling effects from nocturnal irrigation of garden and lawn areas intensify during heatwaves compared with the non-heatwave periods (45). At some garden sites, nocturnal irrigation was associated with 0.5°C to 1°C of cooling during non-heatwave conditions. However, the cooling associated with nocturnal irrigation was greater (2°C – 4°C) during heatwave conditions. Examples of WSUD solutions for commercial, industrial and housing developments that provide a secure irrigation water supply that prioritises use of alternative water sources over potable (town) water supplies are described in Sydney Water's Urban Typologies and Stormwater Management Solutions (42).
Related Credits	UD6 – Water Sensitive urban design CP1 – Shade INV1 – New technologies

CREDIT: CP3: COOL AND/OR POROUS PAVEMENTS	
Credit Outcome	Cool, porous and/or permeable pavements reduce local surface temperatures and local air temperatures and enhance Human Thermal Comfort.
Credit Points	3
Credit Criteria	At least 75% of the park's hardstand areas and paths use cool pavement materials (three-year SRI >50). or; The development incorporates porous pavements to at least 75% of park hardstand and paved areas. And: There must also be a demonstrated commitment to maintain the asset (including scheduled replacement or renewal as necessary) due to the diminishing performance (e.g., pavement permeability) of such materials over time owing to local operating and environmental factors.
Guidance	There are a range of strategies for designing pavements that reduce urban heat impacts, including: • Increases use of 'cool materials' – those that are more reflective, store less heat and may have greater moisture capacity/ permeability, where using lighter pigments in mixing asphalts, concretes and pavers can increase reflectance by 30%. • Incorporating a thin coating of a reflective layer can assist in the reflectance of the surface but must be considerate of pedestrian comfort at times of peak solar radiation. • Choose materials with a high emissivity rating, meaning they will be less prone to embodying heat. • Designing using materials which a) reflect the solar radiation and/or b) have higher emissivity will result in an overall cooler local environment. Permeable pavements should consider the following in their design: • Permeable paving allows for the drainage, infiltration and evaporation of water more effectively through urban surfaces, which can be achieved via the use of non-traditional pavements (made from plastic, metal or concrete) filled or interspersed with permeable materials (vegetation, gravel) laid over a permeable base. • Maximum impact occurs when permeable pavements are designed in conjunction with the principles of cool pavements described above, namely highly reflective materials and materials less prone to storing heat. • Foam based concrete is more permeable than traditional concrete; permeable natural resins used in place of traditional masonry binders can be adopted for low impact areas. • Porous pavements and surface coverings adjacent to garden beds and tree plantings will enhance surface water absorption and therefore water access for these plants.
Science Rationale	Standard and common materials used in roads and pavements absorb heat, retain heat and radiate heat, instead of reflecting the heat and energy (47). The standard solar reflectance of concrete and other common paving materials is 25-40%. When these low solar reflectance materials are used, the surface temperatures can reach 65°C in summer impacting the immediate ambient air temperatures significantly. Because these materials store heat, the effect of this absorption can remain long after peak direct sunlight. More reflective materials (SR> 50%) reflect the solar radiation rather than absorbing it. High emissivity materials heat up more readily in response to external temperature changes and as such contribute more readily to the ambient air temperature than low emissivity materials (48). Emissivity is less easily modified as most common building materials have a high emissivity.

CREDIT: CP3: COOL AND/OR POROUS PAVEMENTS

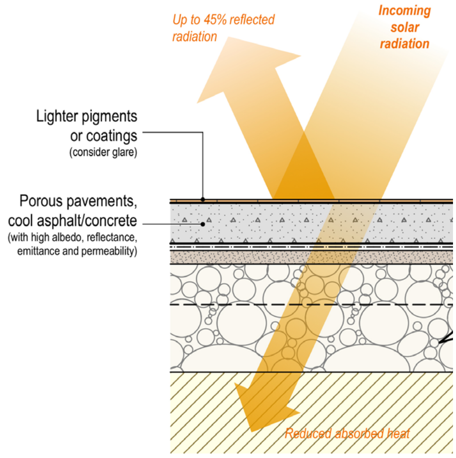


Figure CP3-1 Typical section through a cool pavement. source: Osmond P and Sharifi E (2017)

Evaporative cooling from porous and permeable surfaces may decrease surface temperature by up to 20°C. Incorporating porous surfaces in conjunction with highly reflective materials with low emissivity will reduce local temperatures, increase cooling effect in summer and reduce surface run-off. It has the additional benefit of increased soil moisture benefitting verge plantings (47).

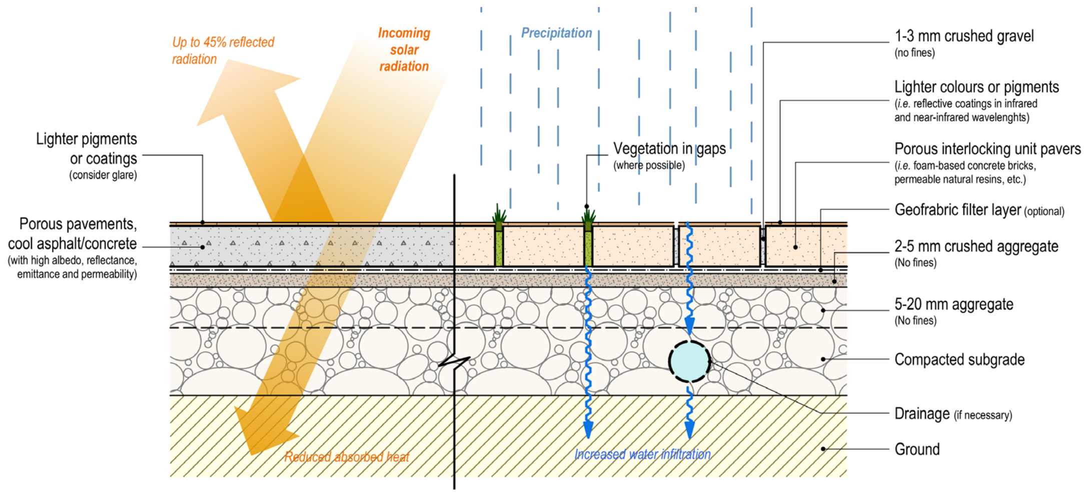
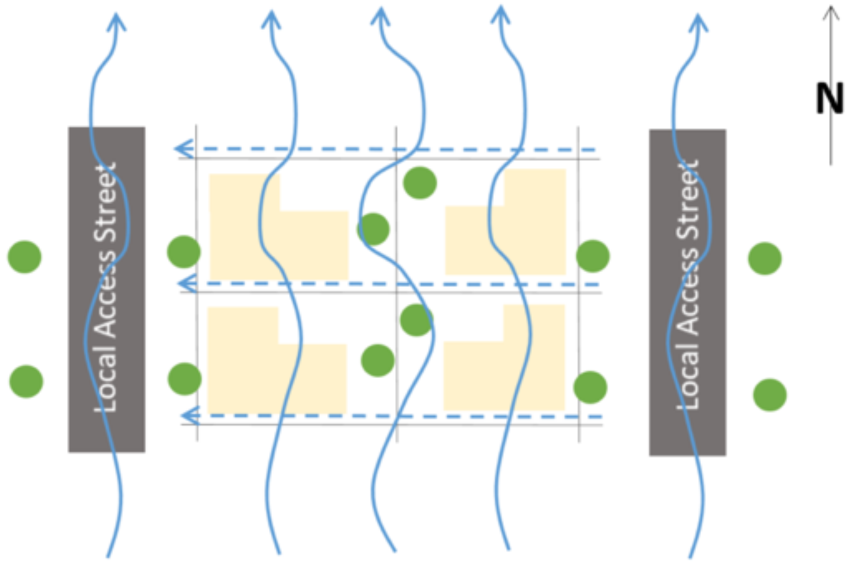
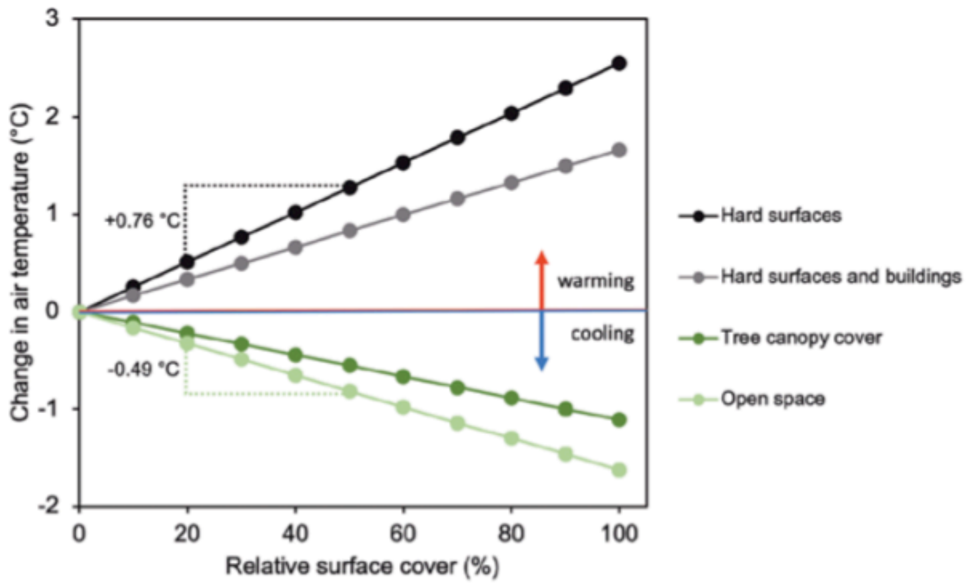


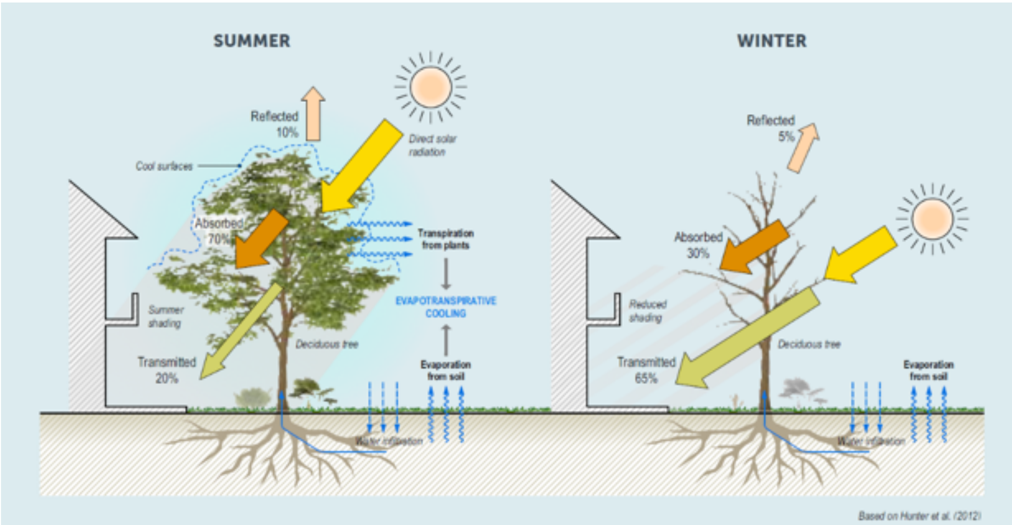
Figure CP3-2 Typical section through a porous pavement. source: Osmond P and Sharifi E (2017)

Related Credits	CP3 – Cool and/or porous pavements INV1 – New technologies

COOL HOMES

CREDIT: CH1 - SITE COVERAGE	
Credit Outcome	Site layout provides sufficient pervious area for shade and evapotranspiration from site landscapes to reduce mean radiant temperatures and air temperatures and improve thermal comfort.
Credit Points	2
Credit Criteria	Minimum planting area of 15 m² for a deep-rooted shade tree (preferably located in the N-W corner of the site); and Minimum 50% site perviousness (can include green roofs and porous pavements). *Note: This Credit is only available if the criteria for CH2 and CH3 are also satisfied.*
Guidance	• Site layout should follow passive design principles. • Site layout should be configured to achieve larger contiguous private open space areas oriented to channel cooling summer winds. • Site layout should make provision for trees to provide shade to exposed hard surfaces during the hottest times of the day.  **Figure CH1-1** Idealised site layout arrangement and tree placements for cooling (solid blue arrows are primary wind paths and dashed lines secondary wind paths).
Science Rationale	Research on the influence of different surface types and their relative cover on air temperatures in Western Sydney shows, amongst other findings (37) (44): • Increasing the area of pervious open spaces (public and private) and tree canopy leads to cooling. • When provided in equal proportions, warming from hard surfaces exceeds cooling from open space (public and private). • The largest cooling benefits are generated by open space. • Open space and tree canopy cover can markedly reduce summer night-time air temperatures. • With reference to Figure CH1-2, effective cooling at sites that contain both surface types can only be achieved once the ratio of open space to hard surfaces is 2:1 or greater.

CREDIT: CH1 - SITE COVERAGE	
	 **Figure CH1-2** Predicted changes in mean summer air temperature along a gradient of different surface cover types and tree canopy. Source: Pfautsch, S., Tjoelker, A R. (2020) Given the potential cooling benefits, practitioners should take into account the wind regime when designing and incorporating open space (public and private) into the urban environment.
Related Credits	UD1 – Wind paths UD5 – Water sensitive urban design CH2 – Site shade CH3 – Site irrigation CH4 – Passive cooling CH7 – Porous pavements

CREDIT: CH2 - SITE SHADE	
Credit Outcome	Site shade solutions provide shade to north and west external walls and to site hard and paved surfaces.
Credit Points	3
Credit Criteria	At least 50% of the development's residential lots have a medium to large deep rooted shade tree of at least 8m height and 8m canopy spread (at maturity) planted to the N-W corner of the site; and All other residential dwelling lots are provided with building integrated shading devices to shade north and west facing walls. *Note: This Credit is only available if the criteria for CH1 and CH3 are also satisfied.*
Guidance	• The introduction of tree species should consider the suitability of the species, including existing soil conditions, heat tolerance and water requirements*. The placement of new trees should also consider their ability to channel breezes if applicable. • Deciduous trees should be used where sunlight is desirable in winter; evergreen trees should be used where year-round shade is preferable.  **Figure CH2-1** Cooling effect of a tree in a sunny day in summer and winter. Source: Osmond P and Sharifi E (2017)
Science Rationale	An overall lack of vegetation is a key defining feature of developed urban areas and a major contributor to the UHI effect through decreased evapotranspiration (47). Increasing urban vegetation is a simple and effective way to reduce the UHI. Radiant temperatures in parks that have well-irrigated trees can be 2-4°C cooler than adjacent un-vegetated or build up areas; the extent and proportion of tree plantings can have a 1-2°C impact on the actual temperature. Trees provide cooling through both transpiration and shade (40). Shade in particular is critical for improved Human Thermal Comfort during warm sunny conditions. Trees deliver greater cooling effect and enhance human comfort more than other urban green approaches (shrubs, grass) (40). Existing established trees provide the greatest benefit for heat minimisation and should be prioritised in planning. Tree canopy shade reduces the amount of heat absorbed by surfaces during the day, which in turn results in cooler air temperatures at the beginning of the night and less emission of heat during the night (37). In Western Sydney, this effect is relatively large, and it is at night when the cooling benefits of tree canopy shade on ambient air temperature become apparent. Conversely, during daytime the air temperatures under tree canopy in Western Sydney is similar to the surrounding ambient air temperature due to air mixing. Vegetation that is water stressed has higher surface temperatures than irrigated vegetation; inadequate irrigation will lead to reduced plant transpiration (and subsequent cooling) when it is most required (32). In the right positioning and with correct irrigation, parks can provide down-wind cooling effects beyond the park boundaries. Urban green spaces cool more effectively if they contain scattered trees and receive irrigation.
Related Credits	CH3 – Site irrigation CH4 – Passive cooling

*Guidance on species selection is provided on the Which Plant Where website http://www.whichplantwhere.com.au/

CREDIT: CH3: SITE IRRIGATION	
Credit Outcome	Suitable irrigation is provided to enable site landscapes to thrive in average summer conditions and to survive in extreme heat conditions. Irrigated site landscapes reduce local surface temperatures, cool local air temperatures and improve local thermal comfort.
Credit Points	1
Credit Criteria	The developer must provide a detailed water management plan which achieves water efficiencies and supports the continuous objectives of CH2. *This credit is only available if the criteria for CH2 is also satisfied*
Guidance	The water management plan should address the following aspects: • An alternative water supply such as roof runoff, stormwater runoff and/or reticulated recycled water as the primary irrigation water source(s) with potable (town) water as a backup. • A smart irrigation system is adopted which relies on rain and/or soil moisture sensors and night scheduling. In extreme heat situations, the irrigation system should be capable of prioritising trees capable of providing shade. • Irrigation rates guided by local best practice for species and soil profile. • Drip irrigation lines (above or sub-surface) are used. Water management plan must complement the design and objectives of CH2.
Science Rationale	As our cities increasingly experience hot weather events, it is important to ensure green spaces and tree canopies are receiving sufficient water to continue to thrive. This must be done in a water efficient way (45). Vegetation that is water stressed has higher surface temperatures than irrigated vegetation; inadequate irrigation will lead to reduced plant transpiration (and subsequent cooling) when it is most required (32). An investigation of the impact of irrigation on urban cooling for the suburb of Mawson Lakes in Adelaide showed during a heatwave event a 10% increase in irrigated pervious cover led to a 0.25°C reduction in daily average temperature (39). The amount of cooling tapers off at high irrigated pervious covers and/or high levels of irrigation as the maximum amount of cooling is reached. An investigation of the cooling effects of nocturnal irrigation at two Melbourne botanic gardens showed the cooling effects from nocturnal irrigation of garden and lawn areas intensify during heatwaves compared with the non-heatwave periods (46). At some garden sites, nocturnal irrigation was associated with 0.5°C to 1°C of cooling during non-heatwave conditions. However, the cooling associated with nocturnal irrigation was greater (2°C – 4°C) during heatwave conditions.
Related Credits	UD6 – Water sensitive urban design CH1 – Site cover CH2 – Site shade CH4 – Passive cooling INV1 – New technologies

CREDIT: CH4: PASSIVE COOLING	
Credit Outcome	Residential buildings use passive design to maintain a comfortable internal temperature thereby minimising impact on the external environment.
Credit Points	2
Credit Criteria	In addition to meeting relevant minimum legislated building requirements, the individual home design incorporates at least two of the following passive cooling approaches: • Envelope design (including thermal zoning) • Natural cooling sources • Hybrid cooling systems For multi-house developments, this credit is only achievable if at least 75% of all homes within the development achieve the above criteria.
Guidance	• Homes that adopt passive design minimise their impact on their surrounding environment by reducing energy requirements in heating and cooling and by minimising their contribution to the external environment through excess heat loss/ heat production generated by mechanical cooling systems (the exhaust from an air-conditioner unit). • Passive cooling principles require consideration of the floor plan and building form, local climate, house positioning, thermal mass considerations, appropriate materials and positioning for windows, shading, insulation and buffer zones. • It is important to design homes for the local environment, i.e., prevailing winds/ breezes, tree type and positioning, proximity to other dwellings and climate. • To demonstrate compliance with these criteria, developers must illustrate compliance with housing design guidelines issued to home builders. Envelope Design: • Envelope design is the integrated design of building form and materials in totality to maximise comfort and energy savings. All aspects of the build design need to consider the climate response and site conditions, which can then result in optimal thermal performance. Natural Cooling Sources: • To maximise heat loss during hot seasons, passive design considers air movement, breezes, evaporation, earth coupling and reflection of radiation. Solution should be considerate of local climatic conditions. • Solutions may include breeze capture, access to cool night air, convective air movement, solar chimneys, evaporative cooling (i.e., from a water source), earth coupling.

<table>
<tr><th colspan="2">CREDIT: CH4: PASSIVE COOLING</th></tr>
<tr><td></td><td>

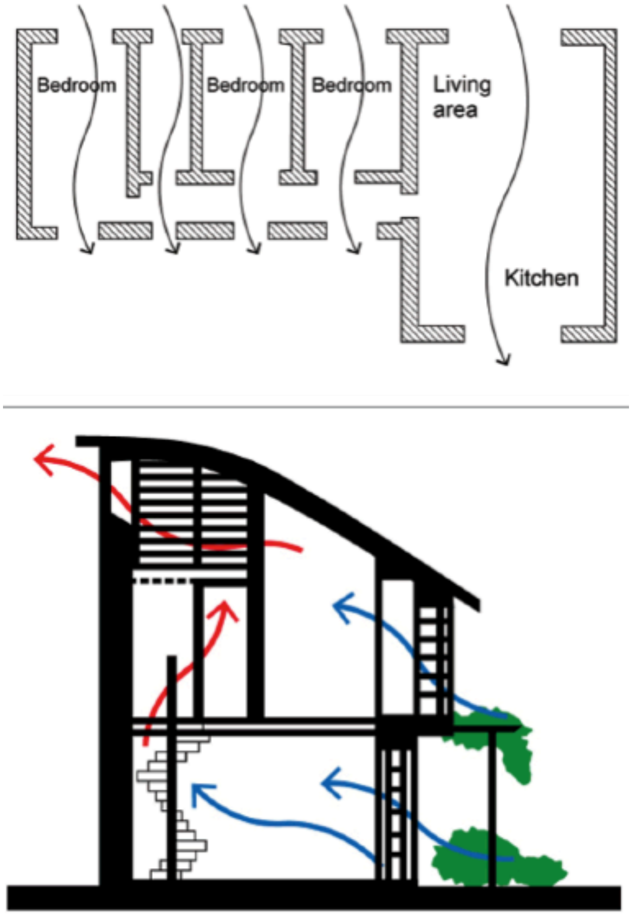


Figure CH4-1 Capturing breezes, using convection properties and solar chimneys are all effective natural cooling systems in the right climate.

Hybrid Cooling Systems:

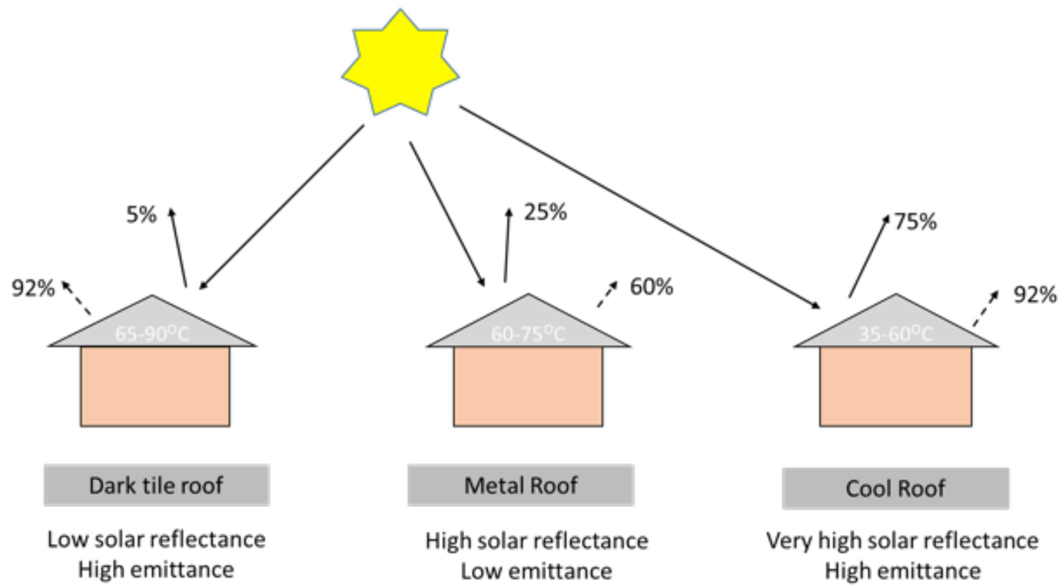
- Employ a variety of cooling options for a holistic, efficient and effective cooling solution. They maximise passive cooling opportunities when possible but are efficient in their adoption of mechanical cooling when required.
- Fans should be positioned strategically to circulate cooler air and expel heated air. Air conditioning can be included in building design to complement natural and fan cooling.

</td></tr>
<tr><td>Science Rationale</td><td>

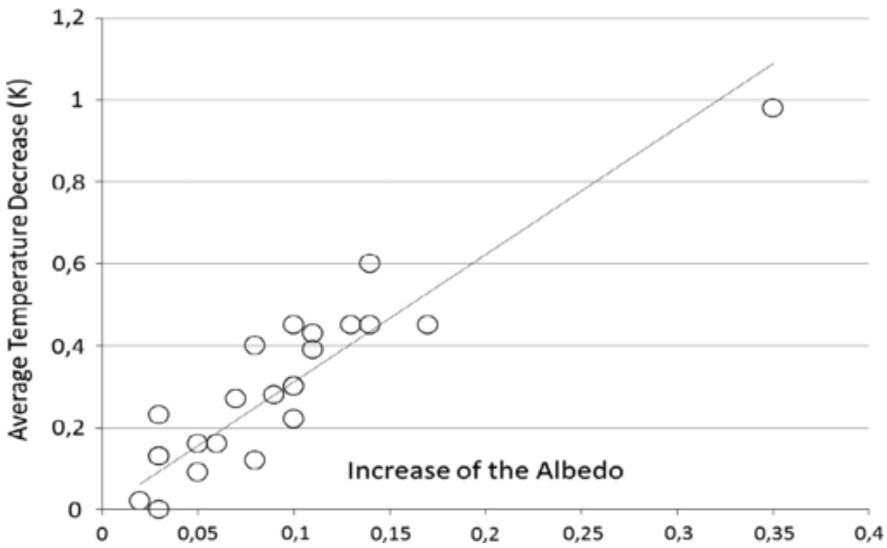
All buildings in Australia require some cooling in warmer months (49). The type of passive cooling options available depend predominately on climate. Consideration of passive cooling and heating opportunities should occur at the preliminary design stage as it can determine orientation, materials used, height, levels and other significant design components.

Heating and cooling accounts for 40% of a typical home's energy use. This is a costly impact for the occupants and the environment (50).

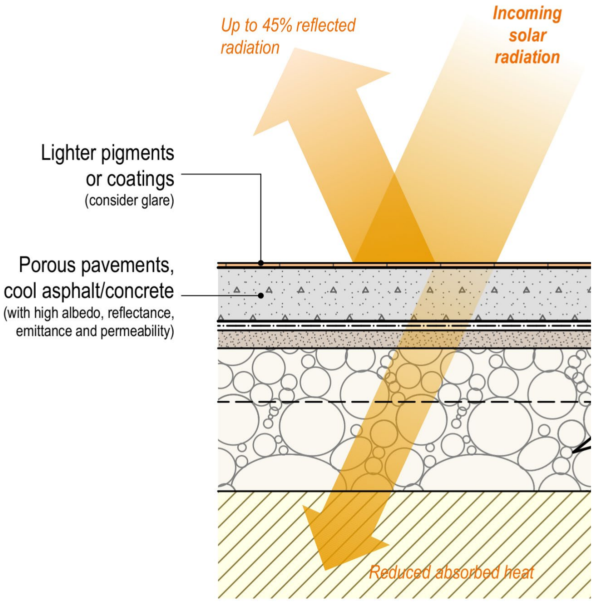
</td></tr>
<tr><td>Related Credits</td><td>All other Cool Homes Credits</td></tr>
</table>

CREDIT: CH5: COOL ROOF MATERIALS	
Credit Outcome	Cool roof materials reflect more solar radiation and emit more heat to improve indoor thermal comfort and reduce air temperatures (night-time).
Credit Points	3
Credit Criteria	All residential buildings have roofing materials installed with compliant three-year solar reflectance index (SRI): • Roofs pitched <15°: three-year SRI > 64 • Roofs pitched >15°: three-year SRI > 34 There must also be a demonstrated commitment to maintain the asset (including scheduled replacement or renewal as necessary) due to the diminishing performance of cool materials and green roofs over time owing to local operating and environmental factors. Incorporating solar PV panels into the design is an acceptable deviation from the specifications.
Guidance	• Incorporating high reflectance and high emittance materials in the roofing design generates lower temperatures compared to dark roofing material. • When combined with strategically designed irrigated vegetation and shade the effect is particularly impactful (CH2 & CH3).  **Figure CH5-1** Reflectance and emittance of different roof materials. Source: Osmond P and Sharifi E (2017)
Science Rationale	Building rooftops cover almost 20% of the urban surfaces in Australian cities. Rooftops are generally more exposed to direct sunlight compared with other urban surfaces. Thus, during a typical sunny day, rooftops retain more heat load than other urban elements. Most rooftop materials are heavy and dark and therefore store significant heat. Conventional roof surfaces (with a solar reflectance of 5% to 25%) can reach a surface temperature of 50- 90°C on a typical hot summer day and cause significant stress to building occupants, cooling systems, energy infrastructure, roofing materials and urban microclimates. Cool roofs adopt high reflectance (>65%) and high emissivity (>85%) surfaces to deflect up to 75% of solar radiation energy. The impact of this can be 33°C cooler surface temperatures and decreased indoor temperatures (47). This can save 18-34% energy on air-conditioning – but can require increased heating in winter months. On a city-scale, maximum near-surface temperature decrease of 0.50°C occurred when albedo was increased from 0.50 to 0.70, or 0.25°C per 0.1 albedo increase (48).

CREDIT: CH5: COOL ROOF MATERIALS

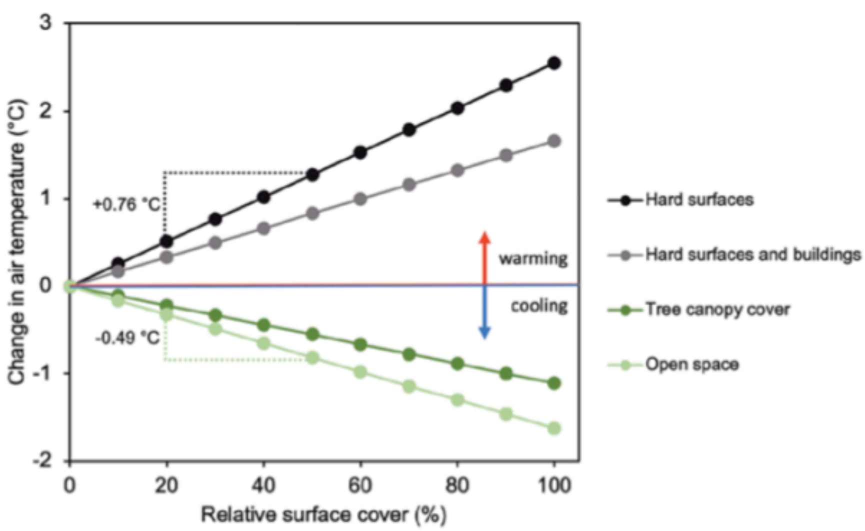
	 **Figure CH5-2** Correlation between the possible albedo change in roof materials and the corresponding decrease of the average ambient temperature in urban areas. Source: Santamouris M ((51)).
Related Credits	CH4 – Passive cooling INV1 – New technologies

CREDIT: CH6: COOL AND/OR POROUS PAVEMENTS	
Credit Outcome	Cool, porous and/or permeable pavements reduce local surface temperatures and local air temperatures and enhance Human Thermal Comfort.
Credit Points	1
Credit Criteria	At least 50% of the site's hardstand areas and paths with high reflective finishes and/or materials (three-year SRI >50). Or; At least 50% of the site's hardstand areas and paths with porous pavement and other permeable surface covering solutions. There must also be a demonstrated commitment to maintain the asset (including scheduled replacement or renewal as necessary) due to the diminishing performance of such materials over time.
Guidance	There are a range of strategies for designing pavements that reduce urban heat impacts, including: • Increased use of 'cool materials' – those that are more reflective, store less heat and may have greater moisture capacity/ permeability, where using lighter pigments in mixing asphalts, concretes and pavers can increase reflectance by 30%. • Incorporating a thin coating of a reflective layer can assist in the reflectance of the surface but must be considerate of home occupants and pedestrian comfort at times of peak solar radiation. • Choose materials with a high emissivity rating, meaning they will be less prone to embodying heat. • Designing using materials which a) reflect the solar radiation and/or b) have higher emissivity will result in an overall cooler local environment. Permeable pavements should consider the following in their design: • Permeable paving allows for the drainage, infiltration and evaporation of water more effectively through urban surfaces, which can be achieved via the use of non-traditional pavements (made from plastic, metal or concrete) filled or interspersed with permeable materials (vegetation, gravel) laid over a permeable base. • Maximum impact occurs when permeable pavements are designed in conjunction with the principles of cool pavements described above, namely highly reflective materials and materials less prone to storing heat. • Foam based concrete is more permeable than traditional concrete; permeable natural resins used in place of traditional masonry binders can be adopted for low impact areas. • Porous pavements and surface coverings adjacent to garden beds and tree plantings will enhance surface water absorption and therefore water access for these plants.
Science Rationale	Standard and common materials used in pavements absorb heat, retain heat and radiate heat, instead of reflecting the heat and energy (48) (47). The standard solar reflectance of concrete and other common paving materials is 25-40%. When these low solar reflectance materials are used, the surface temperatures can reach 65°C in summer impacting the immediate ambient air temperatures significantly. Because these materials store heat, the effect of this absorption can remain long after peak direct sunlight. More reflective materials reflect the solar radiation rather than absorbing it. High emissivity materials reflect heat more readily in response to external temperature changes and as such result in a lower ambient air temperature than low emissivity materials. Emissivity is less easily modified as most common building materials are inherently high emissivity.

CREDIT: CH6: COOL AND/OR POROUS PAVEMENTS	
	 **Figure CP6-1** Typical section through a cool pavement. source: Osmond P and Sharifi E (2017) Evaporative cooling from porous and permeable surfaces may decrease surface temperature by up to 20°C (47). Incorporating porous and/or permeable surfaces in conjunction with highly reflective materials with high emissivity will reduce local temperatures, increase cooling effect in summer and reduce surface run-off. It has the additional benefit of increased soil moisture benefitting adjacent garden beds.
Related Credits	UD5 – Water sensitive urban design CH4 – Passive cooling CH6 – Cool and/or porous pavements INV1 – New technologies

CREDIT: CH7: ALTERNATIVE ENERGY SUPPLY	
Credit Outcome	The home generates and stores sufficient renewable energy onsite to balance its predicted energy use over a year.
Credit Points	3
Credit Criteria	The home has installed (or designed for install) a solar PV array, inverter and battery system with the following minimum capacity: • Homes up to 150m^2: 5kW PV system • Homes between 150m^2 - 250m^2: 7.5kW PV system • Homes between 250m^2 - 350m^2: 10kW PV system *NB this credit is only available if the criteria for CH4 and CH5 are also satisfied.*
Guidance	• The solar PV system shall be designed by a Clean Energy Council accredited designer and installed by an accredited installer. • Solar panels to be installed to face between East, through North to West orientations. • PV array panels to be installed at roof pitch or at latitude tilt angle (or on trackers as desired). • Design documentation to be submitted that proves the PV system is not shaded by neighbouring buildings or trees across the year.
Science Rationale	Australia has the most solar coverage of any continent on earth – making solar the most plausible renewable energy source to use on a home (52). With solar panel efficiency increasing and prices decreasing dramatically, installing solar is accessible and can have a considerable impact on energy purchasing costs. Electricity accounts for about 53% of the energy used in Australian households but contributes 87% of total household related GHG emissions (49). An increased reliance on air conditioning in recent years has caused a rise in peak demand (which refers to the maximum amount of electricity demanded by a location) (50). During a heatwave, the grid is under the greatest pressure due to widespread use of air conditioning systems. The increased uptake of household and business solar PV is having a positive reduction effect on the instances of blackouts during heatwaves, however batteries are required to maintain the load post peak solar radiation. Without renewable storage options, the peak demand is simply delayed until later in the day when solar radiation is reduced but cooling is still required.
Related Credits	CH4 – Passive cooling CH5 – Cool roofs materials INV1 – New technologies

COOL BUILDINGS

CREDIT: CB1: SITE COVERAGE	
Credit Outcome	Site layout provides sufficient pervious area for shade and evapotranspiration from site landscapes to reduce mean radiant temperatures and air temperatures and improve thermal comfort.
Credit Points	3
Credit Criteria	Minimum 10m building setback from North and West facing boundaries to allow for the planting deep rooted shade trees; and Minimum 50% site perviousness (can include green roofs and porous pavements) *Note: This Credit is only available if the criteria for CB2 and CB3 are also satisfied.*
Guidance	• Site layout should follow passive design principles to maximise thermal comfort and efficiency. • Where practicable, loading dock areas and other external working areas should be located on the southern side of the building to reduce heat exposure. • Site layout should be configured to achieve larger contiguous private open space areas oriented to channel cooling summer winds to reduce the need for active cooling systems. • Site layout should make provision for trees to provide shade to exposed hard surfaces (building walls and ground surfaces) during the hottest times of the day.
Science Rationale	Research (15) (38) on the influence of different surface types and their relative cover on air temperatures in Western Sydney shows, amongst other findings: • Increasing the area of pervious open spaces (public and private) and tree canopy leads to cooling. • When provided in equal proportions warming from hard surfaces exceeds cooling from open space (public and private). • The largest cooling benefits are generated by open space. • Open space and tree canopy cover can markedly reduce summer night-time air temperatures. • With reference to Figure CB1-1, effective cooling at sites that contain both surface types can only be achieved once the ratio of open space to hard surfaces is 2:1 or greater.  **Figure CB1-1** Predicted changes in mean summer air temperature along a gradient of different surface cover types and tree canopy. Source: Pfautsch, S., Tjoelker, A R. (2020) Given the potential cooling benefits, practitioners should take into account the wind regime when designing and incorporating open space (public and private) into the urban environment.
Related Credits	UD1 – Wind paths UD5 – Water sensitive urban design CB2 – Site shade CB3 – Site irrigation CB4 – Passive design CB7 – Porous pavements

<table>
<tr><th colspan="2">CREDIT: CB2: SITE SHADE</th></tr>
<tr><td>Credit Outcome</td><td>Site shade solutions through increased tree canopy provide shade to north and west facing external walls and to site hardstand and paved surfaces.</td></tr>
<tr><td>Credit Points</td><td>3</td></tr>
<tr><td>Credit Criteria</td><td>Deep rooted shade trees of at least 8m height and 8m canopy spread (at maturity) planted to form a near continuous canopy cover to shade the exposed north and western facades of the building.

Note: This Credit is only available if the criteria for CB1 and CB3 are also satisfied.</td></tr>
<tr><td>Guidance</td><td>

- The introduction of tree species should consider the suitability of the species, including existing soil conditions, heat tolerance and water requirements. The placement of new trees should also consider their ability to channel breezes if applicable.
- Deciduous trees should be used where sunlight is desirable in winter; evergreen trees should be used where year-round shade is preferable.

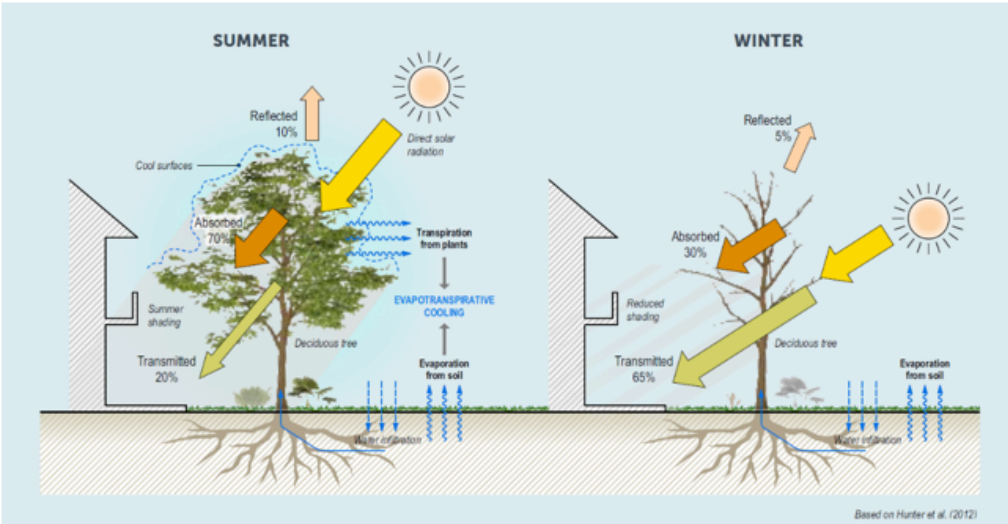


Figure CB2-1 Cooling effect of a tree in a sunny day in summer and winter.
Source: Osmond P and Sharifi E (2017)</td></tr>
<tr><td>Science Rationale</td><td>An overall lack of vegetation is a key defining feature of developed urban areas and a major contributor to the UHI effect through decreased evapotranspiration (47). Increasing urban vegetation is a simple and effective way to reduce the UHI. Radiant temperatures in parks that have well-irrigated trees can be 2-4°C cooler than adjacent un-vegetated or build up areas; the extent and proportion of tree plantings can have a 1-2°C impact on the actual temperature.

Trees provide cooling through both transpiration and shade. Shade in particular is critical for improved Human Thermal Comfort during warm sunny conditions (40).

Trees deliver greater cooling effect and enhance human comfort more than other urban green approaches (shrubs, grass (40)). Existing established trees provide the greatest benefit for heat minimisation and should be prioritised in planning.

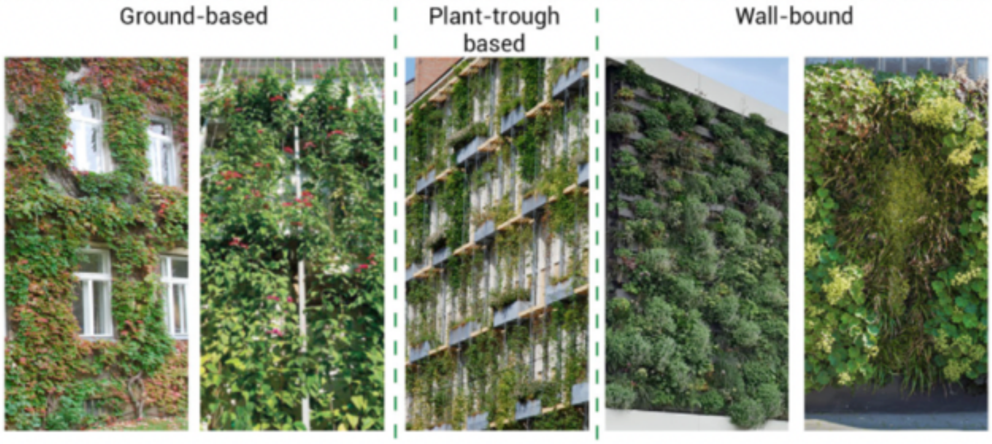
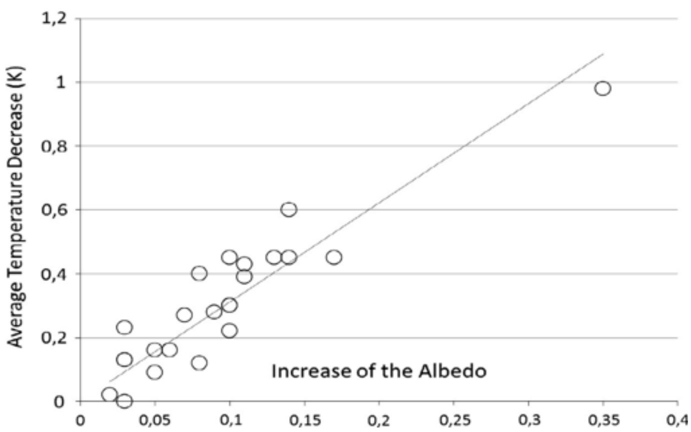
Tree canopy shade reduces the amount of heat absorbed by surfaces during the day, which in turn results in cooler air temperatures at the beginning of the night and less emission of heat during the night (37). In Western Sydney, this effect is relatively large, and it is at night when the cooling benefits of tree canopy shade on ambient air temperature become apparent. Conversely, during daytime the air temperatures under tree canopy in Western Sydney is similar to the surrounding ambient air temperature due to air mixing.

Vegetation that is water stressed has higher surface temperatures than irrigated vegetation; inadequate irrigation will lead to reduced plant transpiration (and subsequent cooling) when it is most required (32). In the right positioning and with correct irrigation, parks can provide down-wind cooling effects beyond the park boundaries. Urban green spaces cool more effectively if they contain scattered trees and receive irrigation.</td></tr>
<tr><td>Related Credits</td><td>CB3 – Site irrigation
CB4 – Passive design
CB5 – Cool roofs, green roofs and green walls</td></tr>
</table>

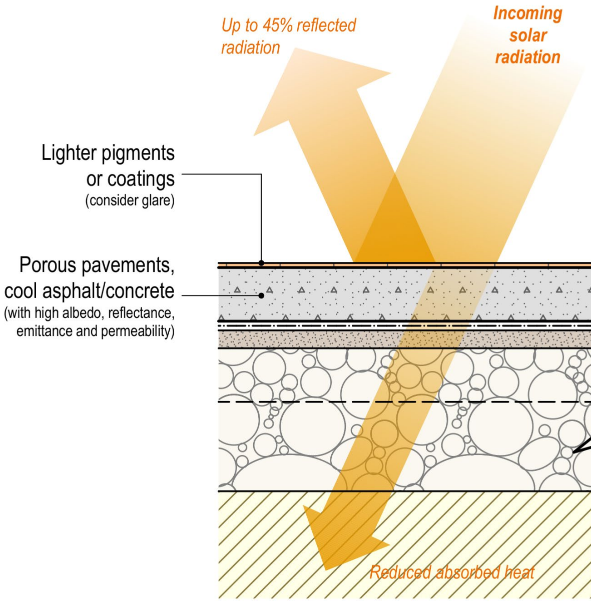
CREDIT: CB3: SITE IRRIGATION	
Credit Outcome	Suitable irrigation is provided to enable site landscapes to thrive in average summer conditions and to survive in extreme heat conditions. Irrigated site landscapes reduce local surface temperatures, cool local air temperatures and improve local thermal comfort.
Credit Points	1
Credit Criteria	The developer must provide a detailed water management plan which achieves water efficiencies and supports the continuous objectives of CH2. *This credit is only available if the criteria for CB2 is also satisfied*
Guidance	The water management plan should address the following aspects: • An alternative water supply such as roof runoff, stormwater runoff and/or reticulated recycled water as the primary irrigation water source(s) with potable (town) water as a backup. • A smart irrigation system is adopted which relies on rain and/or soil moisture sensors and night scheduling. In extreme heat situations, the irrigation system should be capable of prioritising trees capable of providing shade. • Irrigation rates guided by local best practice for species and soil profile. • Drip irrigation lines (above or sub-surface) are used. Water management plan must complement the design and objectives of CB2 – increasing shade to maximise cooling effect.
Science Rationale	As our cities increasingly experience hot weather events, it is important to ensure green spaces and tree canopies are receiving sufficient water to continue to thrive (45). This must be done in a water efficient way. Vegetation that is water stressed has higher surface temperatures than irrigated vegetation; inadequate irrigation will lead to reduced plant transpiration (and subsequent cooling) when it is most required (32). An investigation of the impact of irrigation on urban cooling for the suburb of Mawson Lakes in Adelaide showed during a heatwave event a 10% increase in irrigated pervious cover led to a 0.25°C reduction in daily average temperature (39). The amount of cooling tapers off at high irrigated pervious covers and/or high levels of irrigation as the maximum amount of cooling is reached. An investigation of the cooling effects of nocturnal irrigation at two Melbourne botanic gardens showed the cooling effects from nocturnal irrigation of garden and lawn areas intensify during heatwaves compared with the non-heatwave periods (46). At some garden sites, nocturnal irrigation was associated with 0.5°C to 1°C of cooling during non-heatwave conditions. However, the cooling associated with nocturnal irrigation was greater (2°C – 4°C) during heatwave conditions.
Related Credits	UD6 – Water sensitive urban design CB2 – Site shade CB3 – Passive cooling INV1 – New technologies

CREDIT: CB4: PASSIVE DESIGN	
Credit Outcome	Passive cooling maximises the efficiency of the building envelope by minimising heat gain from the external environment and facilitating heat loss. Passive cooling also maximises the ability of the occupants to lose heat to natural sources of cooling.
Credit Points	2
Credit Criteria	In addition to meeting relevant minimum legislated building requirements, the design incorporates at least two of the following passive cooling approaches: • Envelope Design (including thermal zoning) • Natural Cooling Sources • Hybrid Cooling Systems
Guidance	• Buildings that adopt passive design minimise their impact on their surrounding environment by reducing energy requirements in heating and cooling and by minimising their contribution to the external environment through excess heat loss and heat production generated by mechanical cooling systems (the exhaust from air-conditioner units). • Passive cooling principles require consideration of the floor plan and building form, local climate, building positioning, thermal mass considerations, appropriate materials and positioning for windows, shading, insulation and buffer zones. It is also relevant to consider the use of the building in designing for passive cooling – i.e., daytime use vs night-time use, number of users and alternative uses. • It is important to design buildings for the local environment, i.e., prevailing winds/ breezes, tree types and positioning, proximity to other dwellings and climate. • To demonstrate compliance with these criteria, developers must illustrate compliance with building design guidelines issued to builders. • Thought should also be given to occupant useability – effectiveness of this criteria is dependent on proper adoption by the occupant. • When considering ventilation of buildings on busy roads, the internal air quality is an important factor. Envelope Design: • Envelope design is the integrated design of building form and materials in totality to maximise comfort and energy savings. All aspects of the build design need to consider the climate response and site conditions, which can then result in optimal thermal performance. • Cross-building ventilation, shade and awnings are important considerations, as are the elements of CB5. Natural Cooling Sources: • To maximise heat loss during hot seasons, passive cooling design incorporates consideration of air movement, breezes, evaporation, earth coupling and reflection of radiation. Solution should be considerate of local climatic conditions. • Solutions may include breeze capture, convective air movement, solar chimneys, evaporative cooling (i.e., from a water source), earth coupling. Hybrid Cooling Systems: • Employ a variety of cooling options for a wholistic, efficient and effective cooling solution. • Maximise passive cooling opportunities when possible and demonstrate that mechanical cooling is a secondary option. • Fans should be positioned strategically to circulate cooler air and expel heated air, particularly in foyers/lobbies. Air conditioning can be included in building design to complement natural and fan cooling. Air conditioning can be limited to few rooms with maximum whole of level/floor impact. • Air conditioning systems must be of a standard to withstand extreme temperatures.
Science Rationale	All buildings in Australia require some cooling in warmer months (49). The type of passive cooling options available depend predominately on climate and building type. Consideration of passive cooling and heating opportunities should occur at the preliminary design stage as it can determine orientation, materials used, height, levels and other significant design components.
Related Credits	CB1 – Site coverage CB2 – Site shade CB5 – Cool roofs, green roofs and green walls

CREDIT: CB5: COOL ROOFS, GREEN ROOFS AND GREEN WALLS	
Credit Outcome	Building roof and wall(s) reflect solar radiation, reduce surface temperatures and/or enhance evapotranspiration.
Credit Points	2
Credit Criteria	Either one of the following: 100% of roofing materials with compliant three-year solar reflectance index (SRI): • Roof pitch <15°– three-year SRI of minimum 64; or • Roof pitch >15°– three-year SRI of minimum 34. Or: An irrigated green roof, with minimum 80% foliage cover of freely transpiring plants. And (in addition to one of the above) A vertical garden/ green wall with potted foliage covering at least 60% of all West facing exterior wall surfaces. There must also be a demonstrated commitment to maintain the asset (including scheduled replacement or renewal as necessary) due to the diminishing performance of cool materials and green roofs/walls over time.
Guidance	Cool Roofs: • Solar glare causing discomfort is not as critical an issue for rooftops compared to high reflectance materials at ground surface which can impact people using a given area. • Incorporating high emittance materials in the roofing design can further dispel heat as these store less heat, but design must consider the interaction with SRI. • In collaboration with strategically designed irrigated vegetation and shade, the effect is particularly impactful. • Incorporating solar PV panels into the design is an acceptable deviation from the specifications. Green Roofs: • The green roof must have a drought resilient irrigation supply (rainwater, recycled water). • The minimum 80% foliage cover should be made up of freely transpiring plants, which does not include succulents. • Green roofs must be properly designed to ensure building integrity is not compromised by the additional weight. • Incorporating solar PV panels into the design is an acceptable deviation from the specifications. Green Walls: • Green walls lower the ambient air temperature by a) enabling evapotranspiration and b) cooling the air that passes between the support system and the building wall. • Green walls or vertical gardens are distinct from a green façade as they feature multiple plantings across a wall, whereas a green façade will generally feature a small number of vines/ creeper root systems spreading a thin covering over a wall. Green facades are not eligible for this credit. • Green walls must be carefully designed in consideration of sunlight, (drought resilient) irrigation, plant type(s) and fertilisation. • Green walls can provide a visually pleasing aspect to a building and improve the human experience in an urban setting.

CREDIT: CB5: COOL ROOFS, GREEN ROOFS AND GREEN WALLS	
	 This credit only applies to green walls (plant-trough based or wall bound), not ground based (façade). Source: https://efb-greenroof.eu/green-wall-basics/
Science Rationale	Green roofs and walls reduce a building's heating and cooling requirements (53). Green walls directly shade the building surface from direct light, thereby reducing heat gain, while green roofs and cool roofs reduce heat transfer through the roof and reduce ambient temperatures on the roof surface. Green roofs and walls facilitate evapotranspiration, providing a cooling effect. Green walls planted on a support system which is separated from the main wall will provide passive cooling; as the hot air moves up (by convection) between the building surface and the vegetation, it is cooled. Green roofs and green walls can reduce stormwater run-off and improve water quality. Conventional roof surfaces (with a solar reflectance of 5% to 25%) can reach a surface temperature of 50- 90°C on a typical hot summer day and cause significant stress to building occupants, cooling systems, energy infrastructures, roofing materials and urban microclimates (47). Cool roofs adopt high reflectance (>0.65) and high emissivity (>85%) surfaces to deflect up to 75% of solar radiation energy. The impact of this can be surface temperatures 33°C cooler and decreased indoor temperatures. This can save 18-34% energy on air-conditioning – but can require increased heating in winter months. On a city-scale, maximum near-surface temperature decrease of 0.50°C occurred when albedo was increased from 0.50 to 0.70, or 0.25°C per 0.1 albedo increase (48). Green roofs present a relatively high heat island mitigation potential, particularly when applied at a city-wide scale; the difference between green roofs and reflective roofs is dependent on many factors, but both have a significant impact (51). A green roof and a green wall can lead to energy savings for the building of a significant magnitude.  **Figure CB5-1** Correlation between the possible albedo change in roof materials and the corresponding decrease of the average ambient temperature in urban areas. Source: Santamouris M (2012).
Related Credits	CB4 – Passive design CB8 – Alternative energy supply INV1 – New technologies

CREDIT: CB6: COOL AND/OR POROUS PAVEMENTS	
Credit Outcome	Cool, porous and or permeable pavements reduce local surface temperatures and local air temperatures and enhances Human Thermal Comfort.
Credit Points	1
Credit Criteria	At least 50% of the site's hardstand areas and paths with high reflective finishes and/or materials (three-year SRI>50). Or; At least 50% of the site's hardstand areas and paths with porous pavement and other permeable surface covering solutions. There must also be a demonstrated commitment to maintain the asset (including scheduled replacement or renewal as necessary) due to the diminishing performance of such materials over time.
Guidance	There are a range of strategies for designing pavements that reduce urban heat impacts, including: • Increased use of 'cool materials' – those that are more reflective, store less heat and may have greater moisture capacity/ permeability, where using lighter pigments in mixing asphalts, concretes and pavers can increase reflectance by 30%. • Incorporating a thin coating of a reflective layer can assist in the reflectance of the surface but must be considerate of building occupants and pedestrian comfort at times of peak solar radiation. • Choose materials with a high emissivity rating, meaning they will be less prone to embodying heat. • Designing using materials which a) reflect the solar radiation and/or b) have higher emissivity will result in an overall cooler local environment. Permeable pavements should consider the following in their design: • Permeable paving allows for the drainage, infiltration and evaporation of water more effectively through urban surfaces, which can be achieved via the use of non-traditional pavements (made from plastic, metal or concrete) filled or interspersed with permeable materials (vegetation, gravel) laid over a permeable base. • Maximum impact occurs when permeable pavements are designed in conjunction with the principles of cool pavements described above, namely highly reflective materials and materials less prone to storing heat. • Foam based concrete is more permeable than traditional concrete; permeable natural resins used in place of traditional masonry binders can be adopted for low impact areas. • Porous pavements and surface coverings adjacent to garden beds and tree plantings will enhance surface water absorption and therefore water access for these plants.
Science Rationale	Standard and common materials used in pavements absorb heat, retain heat and radiate heat, instead of reflecting the heat and energy (47). The standard solar reflectance of concrete and other common paving materials is 25-40%. When these low solar reflectance materials are used, the surface temperatures can reach 65°C in summer impacting the immediate ambient air temperatures significantly. Because these materials store heat, the effect of this absorption can remain long after peak direct sunlight. More reflective materials reflect the solar radiation rather than absorbing it. High emissivity materials reflect heat more readily in response to external temperature changes and as such result in a lower ambient air temperature than low emissivity materials (48). Emissivity is less easily modified as most common building materials are inherently high emissivity.

CREDIT: CB6: COOL AND/OR POROUS PAVEMENTS	
	 **Figure CB6-1** Typical section through a cool pavement. source: (48) Evaporative cooling from porous and permeable surfaces may decrease surface temperature by up to 20°C (48). Incorporating porous and/or permeable surfaces in conjunction with highly reflective materials with high emissivity will reduce local temperatures, increase cooling effect in summer and reduce surface run-off. It has the additional benefit of increased soil moisture benefitting verge plantings or garden beds.
Related Credits	CB1 – Site coverage CB3 – Site irrigation CB5 – Cool roofs and green roofs and green walls CB6 – Cool and/or porous pavements INV1 – New technologies

CREDIT: CB7: ALTERNATIVE ENERGY SUPPLY	
Credit Outcome	The building uses or generates enough renewable energy onsite to balance its predicted energy use over a year.
Credit Points	3
Credit Criteria	The building has installed (or designed for install) a solar PV array, inverter and battery system sufficiently large to provide enough renewable energy to balance its predicted energy use over a year. If the building cannot support a sufficiently large system, a supply contract is in place to facilitate the purchase of off-site renewables-sourced electricity, in addition to an onsite backup solution. *NB this credit is only available if the criteria for CB4 and CB5 are also satisfied.*
Guidance	This credit is designed to reduce GHG emissions in cities and to establish buildings which are energy-secure during power outages. Obtaining this credit relies on satisfactory compliance with CB4 and CB5; buildings should be designed to have a reduced energy requirement, which is in turn supplied with renewable energy. Key requirements for the alternative energy supply include: • The system shall be designed by a Clean Energy Council accredited designer and installed by an accredited installer. • Solar panels to be installed to face between East, through North to West orientations. • PV array panels to be installed at roof pitch or at latitude tilt angle (or on trackers as desired). • Design documentation to be submitted that proves the PV system is not shaded by neighbouring buildings or trees across the year. • If a supply contract is relied upon for additional renewables support, developer should demonstrate a minimum three-year commitment; this credit cannot be obtained if 100% of electricity is being supplied from an external source – there must be demonstrated capacity to store electricity onsite with an appropriately sized battery system or a back-up generator system, to avoid loss of power (and capacity to cool the building) during an outage or grid failure.
Science Rationale	Australia has the most solar coverage of any continent on earth – making solar the most plausible renewable energy source to use on a home (52). With solar panel efficiency increasing and prices decreasing dramatically, installing solar is accessible and can have a considerable impact on energy purchasing costs. Electricity accounts for about 53% of the energy used in Australian households but contributes 87% of total household GHG emissions (49). An increased reliance on air conditioning in recent years has caused a rise in peak demand – the maximum amount of electricity demanded by a location (state/ region/ neighbourhood) (50). During a heatwave (three or more consecutive days of unusually high temperatures) the grid is under the greatest pressure. Increasing uptake of household and business solar PV is having a positive reduction effect on the instances of blackouts during heatwaves, however batteries are required to maintain the load post peak solar radiation – without renewable storage options, the peak demand is simply delayed until later in the day.
Related Credits	GB4 – Passive cooling GB5 – Cool roofs, green roofs & green walls

INNOVATIVE NEW TECHNOLOGIES

CREDIT: INV1 - NEW TECHNOLOGIES	
Credit Outcome	Provide demonstration of innovative new technologies as "proof of concept".
Credit Points	5
Credit Criteria	Development demonstrates use of innovative new technologies at "proof of concept" stage to mitigate urban heat impacts and/or supply secure alternative energy supplies during extreme heat conditions.
Guidance	The objective of this credit is to continue to enhance awareness, preparedness and capacity to adapt to a warming climate. Obtaining this credit requires the developer to demonstrate that a novel approach has been demonstrated in the pursuit of the Cool Suburbs Tool credits. The following requirements must be met to achieve this credit: • The developer must illustrate the innovative nature of the technology. • The developer must establish a partnership with a university or research institution to demonstrate the innovation value in reducing urban heat impacts.
Science Rationale	This Credit rewards development that commits to advancing development of new technologies for urban cooling. Managing heat impacts is a relatively new area of expertise. Development and testing of new technologies and providing real world applications as demonstrations to facilitate evidence gathering for proof of concept and industry knowledge exchange is important.

CREDIT: INV2 - DATA COLLECTION AND ANALYTICS	
Credit Outcome	A network of temperature sensors and data loggers providing continuous near surface (2m) air temperature data which is analysed and provided in near real time to citizens to inform individual and community decisions and behaviours that enhance resilience to urban heat.
Credit Points	5
Credit Criteria	The development has installed a network of temperature sensors and data loggers providing continuous near surface (i.e., 2m) air temperature data. And; The data collected is made available to community members and other key stakeholders.
Guidance	A qualifying example of a sensor network would consist of continuous air temperature sensors/ loggers deployed and maintained: • Along all streets at a minimum of 1/100m of street verge length (evenly spaced) and on both sides of the street • Within allotment rear yards at min 1/100m of street block long axis (evenly spaced) • Within open space (parks) at minimum 5/ha and positioned to cover the range of use areas • Within carparks at minimum 2/ha and positioned to cover shaded and unshaded areas
Science Rationale	This Credit rewards development that commits to precinct scale data collection and analysis to build the evidence base for urban cooling outcomes realised from portfolios of urban cooling interventions employed at different scales within the development.

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WSROC

The Western Sydney Regional Organisation of Councils' (WSROC) mission is to build collaboration between local governments across Greater Western Sydney, promoting Western Sydney, its people and places, through advocacy, business improvement, strategic leadership, research and partnerships.

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