STB - 2
Sustainability Technical Bulletin

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Urban Heat Islands and their mitigation

Introduction

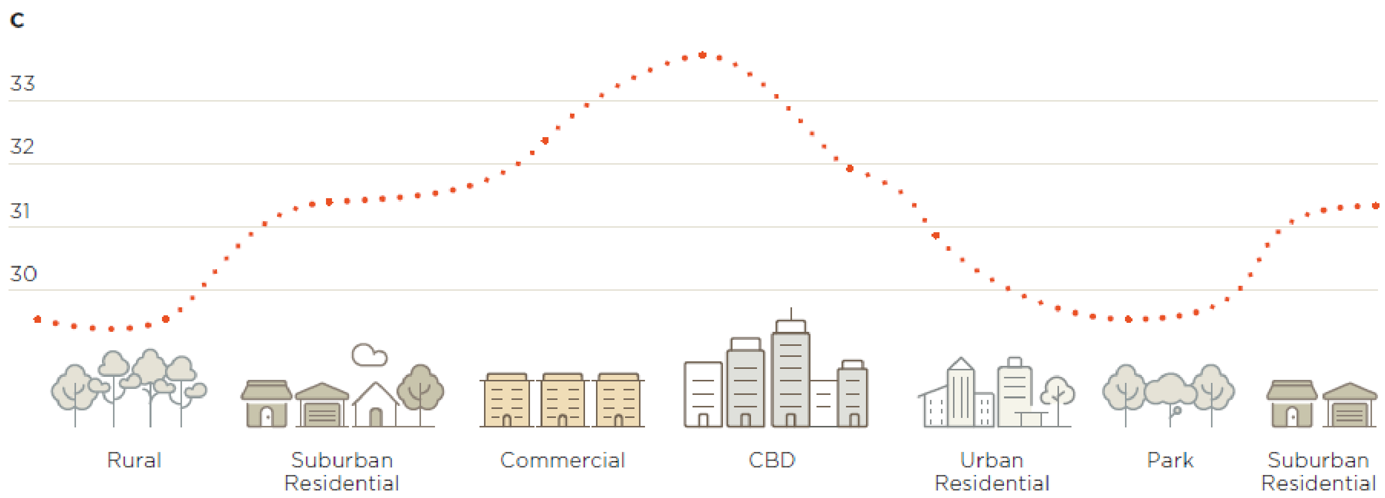
BlueScope has a long-standing commitment to developing innovative, responsible products and services that can help to address environmental issues such as Urban Heat Islands.

The term *Urban Heat Island* (UHI) is used to refer to the fact that cities and urban areas are often significantly warmer than the rural or undeveloped areas that surround them. This technical bulletin details why UHIs form; the consequences of UHI formation; and what can be done to mitigate these. *Urban forestry* and *cool roofs* are two of the most effective ways to reduce the intensity of UHIs: light coloured COLORBOND® steel can be used to create cool roofs because it has high solar reflectance and high thermal emittance.

Formation of Urban Heat Islands

Urban Heat Islands are not a new phenomenon. In 1833 Luke Howard – a chemist and amateur meteorologist – presented evidence that the air and surface temperatures in London were often higher than in the surrounding countryside: this is now considered to be the first documented case of an UHI.[1] Today, many cities and suburbs record air temperatures warmer than the surrounding natural land cover (Figure 1.). Australia has warmed on average by 1.44 °C since national records began in 1910, with most warming occurring since 1950, and is getting increasingly hotter.[2]

Figure 1. Urban Heat Island Profile (adapted from Reference 3).



Urban Heat Islands form when vegetation is replaced with non-reflective, high mass, water resistant, impervious surfaces that absorb a high percentage of incoming solar radiation. There are three main drivers of heat island formation: increased absorption and retention of heat due to decreased *surface reflectance; reduced evapotranspiration* due to decreased vegetation cover; and *heating as a result of human activities*.

- **Surface Reflectance and Increased Absorption of Heat:** All surfaces reflect a proportion of the energy that arrives from the sun (*solar* or *shortwave radiation*). The more reflective a surface is, the less solar energy it absorbs and the cooler it is. Conversely, the less reflective a surface is, the more solar energy it absorbs and the higher its surface temperature will be. Compared to natural land cover, urban environments have lower surface reflectance and absorb more of the available incoming solar radiation, and are consequently warmer, contributing to the formation of UHIs.
- **Reduced Evapotranspiration:** Vegetation helps reduce air temperatures through a process called evapotranspiration, in which plants release water to the surrounding air, dissipating ambient heat. Evapotranspiration is generally decreased when vegetation is replaced with an urbanscape which evaporates less water and has fewer transpiring plants. Decreased evapotranspiration can contribute to elevated surface and air temperatures.
- **Anthropogenic Heating (Heating as a Result of Human Activities):** The third factor that contributes to UHIs is the increase in near-surface temperatures that is a result of human activities, for example, the heat produced from industrial processes, electricity generation, building and traffic heat loss.

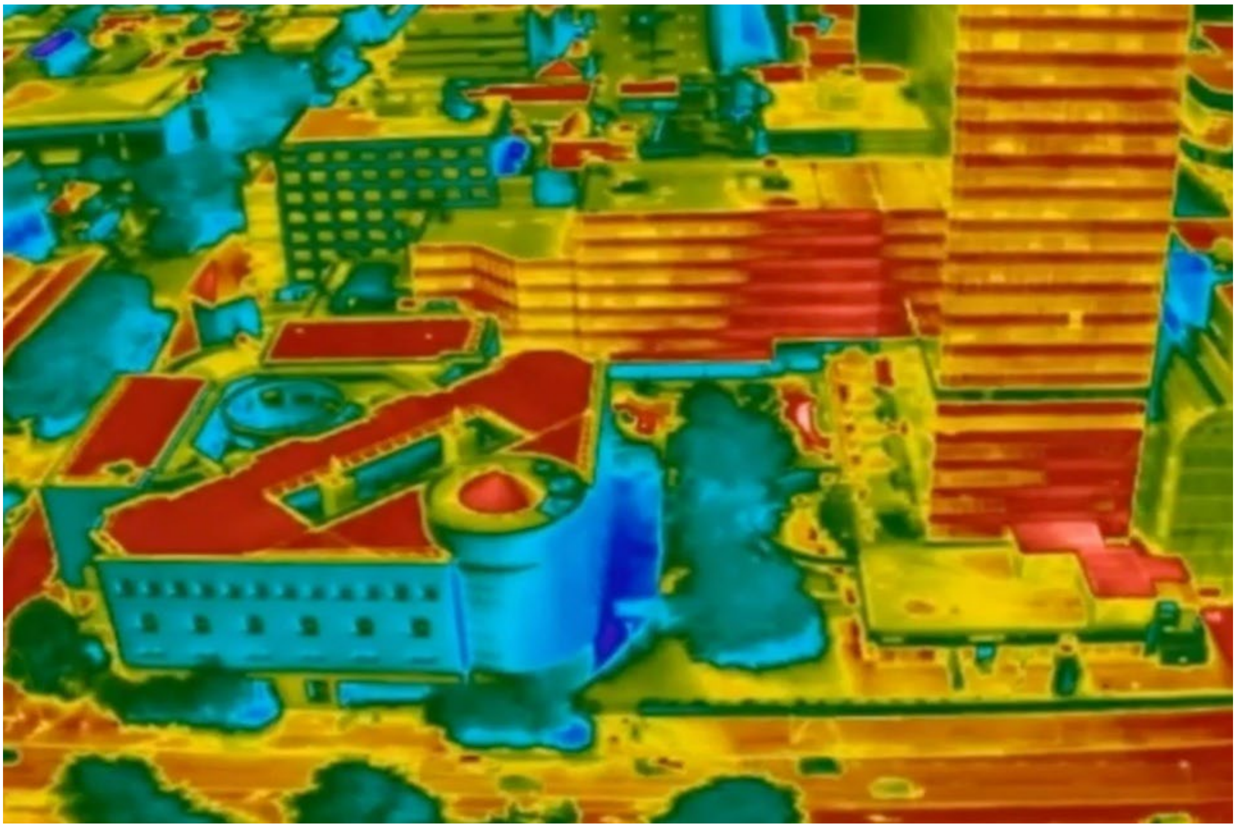
The formation of heat islands is not necessarily uniform across cities, nor over time: heat islands can evolve around a single building, across a small section of the city or over the entire urban region. Some researchers have also reported that local and regional climate, and the topographic features of cities affects the strength and persistence of heat islands.[3]

Consequences of Urban Heat Islands

In Australia's cities, increased local temperatures often lead to increases in energy demand for air-conditioning, particularly in the summer.

This in turn places a strain on power delivery systems and may result in the need for additional power generation sources. If power is generated using fossil fuels, then Greenhouse Gases (GHGs) and particulate emissions are also increased contributing to air pollution. Water temperature can also rise which may affect aquatic ecosystems, especially the metabolism and reproduction of many aquatic species.[4] Higher daytime temperatures, reduced night-time cooling and higher pollution levels may also contribute to heat related health conditions ranging from general discomfort to respiratory difficulties, heat cramps, heat exhaustion, and non-fatal heat stroke.[4]

Figure 2. Heat map of Parramatta CBD supplied by Prof. Mat Santamouris, School of Built Environment, UNSW Sydney.



The brighter colours (red, orange, and yellow) indicate warmer temperatures (more heat and infrared radiation emitted) while the purple, blue and green colours indicate cooler temperatures (less heat and infrared radiation emitted).

Two of the key strategies for reducing the intensity and longevity of UHIs are: increasing surface reflectance to reduce the amount of solar energy absorbed and converted into heat (e.g., via cool roofs); and evapotranspiration to cool the surface through latent heat loss (e.g., through urban forestry).

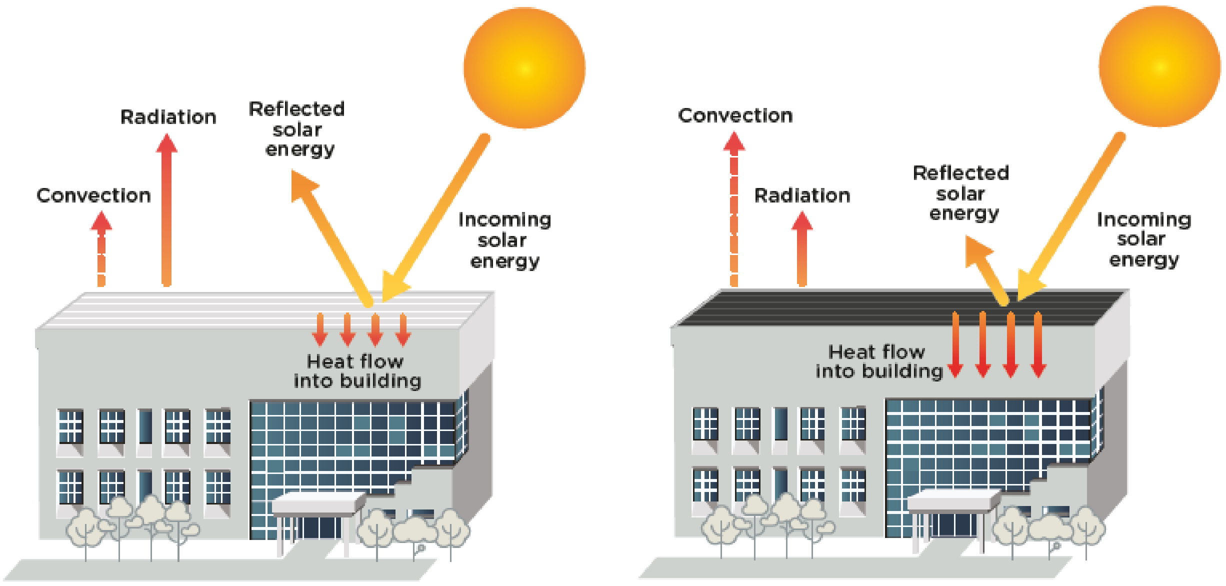
Initiatives identified by Penrith City Council, NSW, to combat UHIs focus on enhanced, more sustainable urban design that ensures increased reflectance, Water Sensitive Urban Design (WSUD), and Green Infrastructure.[5]

Urban forestry has been found to produce the greatest reduction in surface temperature per unit area, because of the increase in evapotranspiration and the additional shading of buildings and pavements.[6]

Cool roofs help reduce the intensity of UHIs, as well as help maintain thermal comfort which can minimise energy demand in buildings. Cool roofs have high solar reflectance and high thermal emittance. High solar reflectance means that less energy is absorbed into the roof initially, thereby reducing the amount of energy that can be converted to heat and re-radiated as longwave radiation (Figure 3). High thermal emittance means that any energy that is absorbed into the roof is re-radiated from the building quickly (again helping to increase thermal comfort and potentially minimising energy demand).

Figure 3. Cool Roofs

Cool roofs combine high solar reflectance and high thermal emittance
to reduce energy absorbed into the roof that converts to heat.



Cool roofs – limit heating due to high reflectance of solar energy and maximise heat loss via radiation due to high thermal emittance.

Hot dark roofs – cause heating due to low reflectance of solar energy and low loss of heat via radiation due to low thermal emittance. Heats the outdoor air due to convection.

Therefore, high thermal emittance helps reduce the heat that can move from the roof to the atmosphere by convection and conduction – the surface temperature of a light-coloured roof can be up to 35°C cooler than a dark coloured roof – and this can limit the amount of longwave radiation that can interact with GHGs and heat the atmosphere.[7]

There are also financial benefits for building owners. Cool roofs can generally help reduce the annual cooling energy costs of a building.[*] Therefore a cool roof, such as one made from light coloured COLORBOND® steel, has the potential to help reduce the up-front capital cost or ongoing operational cost of air-conditioning equipment. Cool roofs may also help reduce stresses on the roof and its materials by limiting the quantity of absorbed solar energy and reducing daily temperature fluctuations, which can cause repeated contraction and expansion.

A light coloured COLORBOND® steel roof not only reduces the amount of solar radiation absorbed but can also be very effective at re-radiating heat.

[*] Compared to conventional roofing materials of lower Solar Reflectance Index (SRI). Any savings and/or the extent to which a building is cooler may vary and depend upon the circumstances of the building, including building location, level of insulation, location of air-conditioning when installed, building shape, building function and environmental factors.

Thermal performance of roofing materials is commonly understood based on two values:

Solar Absorptance (SA), expressed as a value between 0 and 1, indicates the proportion of incoming solar radiation that is absorbed by the roofing material. In this case, a lower SA indicates that the roofing colour choice can help keep the roof space and building cooler on hot days. It is used to classify materials under the National Construction Code (NCC).

Solar Reflectance Index (SRI) provides a metric to compare the roof surfaces. It's calculated using both the solar reflectance and thermal emittance values described above. The higher the SRI, the cooler the surface temperature of the roof will be in the sun.

NCC 2022 Commercial (Volume 1)

The National Construction Code (NCC) uses the SA value to classify roofing materials. Section J In Volume One of the NCC, (which primarily regulates multi-residential, commercial, industrial, and public assembly buildings), requires the SA of the upper roof surfaces to be not more than 0.45 to use the "deemed-to-satisfy" pathway to compliance.[8] BlueScope produces a collection of COLORBOND® steel materials in designated cool roofing colours which meet this specification.

Alternatively, roof surfaces with SA greater 0.45 must use an NCC Performance Solution pathway for compliance.[8]

NCC 2022 Residential (Volume 2)

Volume 2 of the NCC (which regulates smaller scale buildings including residential buildings, sheds, carports etc.) uses roof and wall SA values as energy efficiency design parameters in the "deemed-to-satisfy" elemental and NatHERS compliance pathways. Insulation concessions in warmer climates under the elemental pathway, and improvements to star rating in most climates under the NatHERS pathway, may be achieved by using lower solar absorptance external roof and wall colours .[8]

Table 1. COLORBOND® steel products' Solar Absorptance (SA) and Solar Reflectance Index (SRI) values

Category	Colour	Solar Absorptance (SA)	Solar Reflectance Index (SRI)
COLORBOND® Coolmax® steel	Whitehaven®	0.23	95
COLORBOND® steel in a Classic finish	Dover White™	0.28	88
	Classic Cream™	0.33	81
	Surfmist®	0.33	81
	Southerly®	0.40	71
	Evening Haze®	0.43	67
	Paperbark®	0.43	67
	Shale Grey™	0.44	66
	Dune®	0.48	60
	Bluegum®	0.57	48
	Windspray®	0.60	44
	Pale Eucalypt®	0.60	44
	Gully®	0.64	39
	Wallaby®	0.64	39
	Jasper®	0.67	35
	Basalt®	0.67	35
	Manor Red®	0.70	31
	Woodland Grey®	0.70	31
	Monument®	0.73	27
	Ironstone®	0.73	27
	Cottage Green®	0.70	27
	Deep Ocean®	0.74	25
	Night Sky®	0.95	-1

Category	Colour	Solar Absorptance (SA)	Solar Reflectance Index (SRI)
COLORBOND® steel in a Matt finish	Surfmist®	0.35	78
	Shale Grey™	0.46	63
	Dune®	0.48	60
	Bluegum®	0.59	45
	Basalt®	0.71	29
	Monument®	0.79	19
COLORBOND® steel in a Metallic finish	Galactic®	0.34	80
	Cosmic®	0.39	73
	Rhea®	0.49	59
	Astro®	0.62	41
	Aries®	0.70	31
	Celestian®	0.94	1

Solar Absorptance (SA) is a measure of how much of the sun's heat that a material absorbs. Choosing a colour with a lower SA is a cooler option and may help you meet building regulations such as the NCC. These are nominal values based on new product and measured in accordance with ASTM E 903-96.

Solar Reflectance Index (SRI) provides a guide of a surface's ability to reject solar heat on the basis of the relative temperature of surfaces with respect to a reference black (SRI=0) and white surface (SRI=100). The SRI value of a surface is calculated from its solar reflectance and thermal emittance. These are nominal values based on new product and determined in accordance with ASTM E1980-11.

A light coloured, low Solar Absorptance COLORBOND® steel roof not only reduces the amount of solar radiation absorbed but can also be very effective at re-radiating heat. This means that the building can be cooler overall and may cool down faster when the sun is not shining, which can potentially help reduce energy demand.

A light-coloured painted steel roof, on a building which is surrounded by trees that provide both adequate shade and evapotranspiration conditions to the atmosphere, has the potential be one of the best design scenarios to help reduce the intensity and overall impact of UHIs.

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