SOLAR REFLECTIVE (COOL) COATINGS

Minimising heat gains inside buildings

Radiant energy from the sun heats a building's exterior, creating heat gains that can be transferred into the building's interior, thus increasing the internal temperature. In Australia, good building design combines various approaches – such as building orientation, shading and insulation – to mitigate unwanted heat gains. This Building Technology Resource explains whether solar reflective coatings, also known as cool coatings, can be used to reduce indoor temperatures and thus minimise electricity consumption.

The average price of electricity for residential consumers increased by 56% in real terms over the ten-year period from 2007–2008 to 2017–2018, and electricity bills increased by 35% in real terms (Australian Competition and Consumer Commission, 2018). It is therefore not surprising that consumers want to reduce their electricity consumption. One way to do this is to minimise the use of heating, ventilation and air-conditioning (HVAC) systems to regulate indoor temperature.

Solar reflective coatings are marketed as a potential solution for reducing the amount of electricity needed to cool the interior of a building. These coatings are applied to parts of the building that are exposed to the outside environment, such as the roof and external walls. They are promoted as optimising the reflection of solar radiation, which hinders the warming of building materials and thus the transfer of heat into the building.

HOW THE SUN HEATS BUILDINGS

Heat gains from a building's roof and external walls contribute significantly to heating the interior of the building envelope (Figure 1). The rate of heat flow through a building material depends on the material's thermal resistance and the temperature difference between the inside and outside surfaces of the material. Without the inclusion of insulation, materials used for the external walls, roof and windows typically have poor thermal resistance and, consequently, conduct heat to the interior of the building envelope.

Australia's National Construction Code separates the country into eight climate zones, each with different heating and cooling requirements (Figure 2). Climate zones 1–3, which have warm to hot summers and mild to warm winters, benefit from year-round reduction of heat flows to the inside of the building envelope, while climate zones 4–8 benefit from seasonal reduction of heat flows to the building interior.

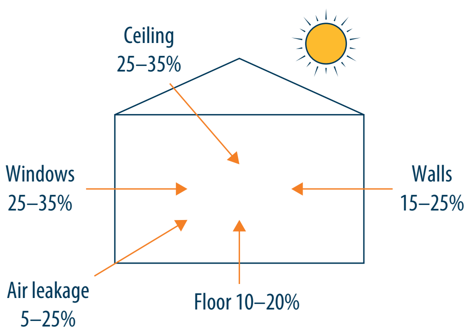

FIGURE 1 Typical summer heat gains in an uninsulated building. (Sustainability Victoria 2018)

The temperature difference across a building material can be reduced by minimising the heat gain on its outside surface. Reflective foils and insulation can be used to reduce heat gains via the roof and walls, while external shading, energy-efficient glazing and frames, window films and window furnishings can be used to reduce heat gains via the windows. For building surfaces that have direct exposure to the sun, the use of a solar reflective coating may assist in minimising heat gains.

WHAT ARE SOLAR REFLECTIVE COATINGS?

Solar reflective coatings are formulated to optimise the reflection of solar radiation and are applied to external elements of the building envelope, such as the roof and outside walls.

Because solar reflective coatings reflect solar radiation, they provide a benefit only where the building element is exposed to direct sunlight. They are not a type of insulating material, as they do not resist heat flow into or out of the building envelope. This is true of all architectural and decorative coatings.

Manufacturers and distributors of solar reflective coatings claim that their products reduce energy consumption and costs, create a healthier and more natural living environment, extend the service life of building materials, and reduce a building's environmental footprint.

MEASURING COATING PERFORMANCE

The following terms are used to describe the solar performance of a coating (regardless of whether or not the coating is marketed as being solar reflective).

SOLAR REFLECTANCE AND ABSORPTANCE

The solar reflectance, or total solar reflectance, of a coating is a measure of the solar radiation that it reflects back to the atmosphere, relative to the solar radiation that it receives. Solar reflectance is expressed as an absolute number between 0 and 1: a value of 0 indicates no reflectance of solar radiation, while a value of 1 indicates full reflectance of solar radiation.

The solar absorptance of a coating is a measure of the solar radiation that it absorbs from the atmosphere, relative to the solar radiation that it receives. Solar absorptance is expressed as an absolute number between 0 and 1: a value of 0 indicates no

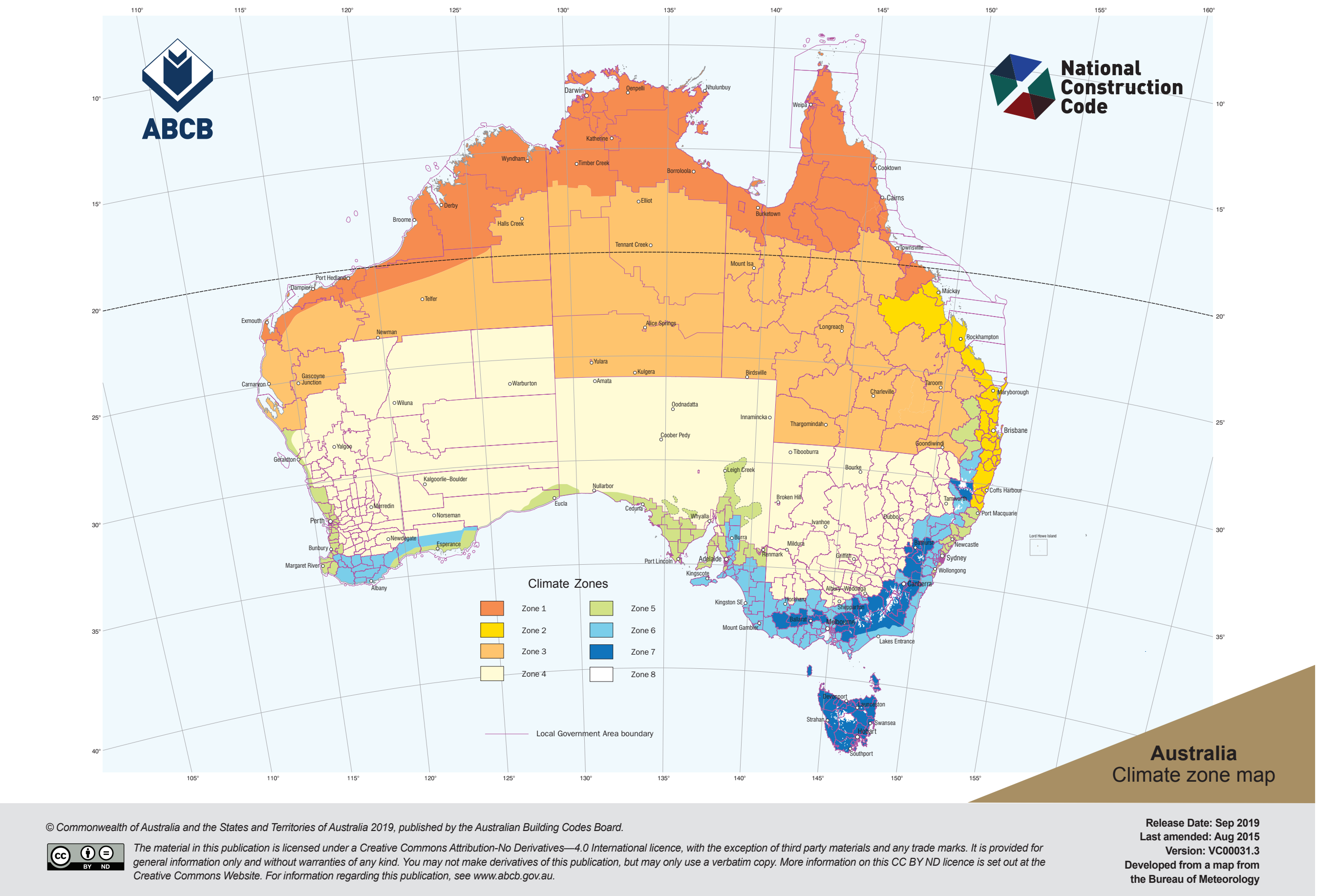

FIGURE 2 Australia's eight climate zones. (©Commonwealth of Australia and the States and Territories of Australia 2019, published by the Australian Building Codes Board)

absorptance of solar radiation, while a value of 1 indicates full absorptance of solar radiation.

Coatings with higher solar reflectance or lower solar absorptance reflect greater amounts of solar radiation back to the atmosphere, minimising heat gain in the coated building material and thus temperature gain inside the building envelope. By contrast, coatings with lower solar reflectance or higher absorptance reflect lower amounts of solar radiation, maximising heat gain in the coated building material and thus temperature gain inside the building.

Solar reflectance is an intrinsic characteristic of white surfaces, including all types of white coatings. Similarly, solar absorptance is an intrinsic characteristic of black surfaces, including all types of black or near-black coatings.

EMITTANCE

The emittance of a coating is a measure of its effectiveness in releasing the heat gained by solar radiation. It is expressed as a ratio of the radiation emitted from the coated surface to that emitted from a standard black surface at the same temperature, either as an absolute number (0.0–1.0) or as a percentage (0–100%). All non-metallic coatings have an emittance of ~90%, regardless of colour.

SOLAR REFLECTANCE INDEX

The solar reflectance index (SRI) is a measure of a material's ability to reflect solar radiation, and thus incorporates both solar reflectance and emittance in a single value. The higher the SRI, the greater the ability of the material to reject solar radiation (Table 1). SRI values are defined such that a standard black surface (solar

TABLE 1. SOLAR PERFORMANCE MEASURES FOR VARIOUS COLOURS. PERFORMANCE MEASURES ARE FOR NEW MATERIALS.
COLORBOND® DATA PROVIDED BY BLUESCOPE STEEL.

Colour		Solar absorptance	Solar reflectance index (SRI)
Standard white		0.20	100
Colorbond® Surfmist® (off-white)		0.32	82
Colorbond® Classic Cream™ (cream)		0.32	82
Colorbond® Dune® (medium grey)		0.47	61
Colorbond® Manor Red® (dark red)		0.69	31
Colorbond® Monument® (dark charcoal)		0.73	26
Colorbond® Cottage Green® (dark green)		0.75	23
Colorbond® Deep Ocean® (dark blue)		0.75	23
Standard black		0.95	0
Colorbond® Night Sky® (black)		0.96	–4

reflectance 0.05, emissivity 0.90) has an SRI of 0 and a standard white surface (solar reflectance 0.80, emittance 0.90) has an SRI of 100. However, SRI values may be less than 0 or more than 100. For example, stainless steel has an SRI of 112, a perfect mirror has an SRI of 122, and black EPDM (a type of synthetic rubber) has an SRI of –1.

OPTIMISING COATING PERFORMANCE

The extent to which any coating reflects solar radiation is primarily a function of its colour.

Optimal solar reflectance is best achieved using a standard white colour. Because solar reflectance is an intrinsic characteristic of white coatings, there is no discernible benefit in choosing a white solar reflective coating over a conventional white architectural and decorative coating.

Solar reflectance decreases with the use of any colour other than white. If standard white cannot be used – for example, because it is not aesthetically pleasing or not allowed due to local regulations – the next best option is to use a colour that is light in tone (that is, a colour with a solar absorptance value of 0.4 or less).

The darker the colour, the greater the heat gain will be in the building material. Whereas a solar reflective coating can be expected to reflect more solar radiation than a conventional architectural and decorative coating in any colour other than white, the solar reflectance of a mid-tone or dark-coloured solar reflective coating will still be less than that of a white or light-coloured conventional architectural and decorative coating.

The ability of a solar reflective coating to maintain its solar reflectance depends on its cleanliness. A coating that enables surface contaminants, such as dirt, to be more readily removed will afford optimal performance. To this end, optimising the cleanliness of the coating is best achieved using a gloss finish. If a gloss finish is not practical – for example, because of excessive glare – the next best option is a semi-gloss or satin finish.

The method used to apply the coating will also affect the coating's ability to shed surface contaminants. A coating of uniform texture is most likely to allow for the removal of surface contaminants. To optimise the formation of a coating of uniform texture, spray application is recommended.

The performance of any coating will diminish over time. As the coating deteriorates, with age and/or increasing surface contamination, its solar reflectance will decrease.

ASSESSING COATING PERFORMANCE

Manufacturers and distributors of solar reflective coatings typically evaluate their products' performance by comparing, for a given colour, two situations in which the only variation is the type of coating used: one that is solar reflective, and one that is not (Figure 3). For reasons of cost, convenience and reproducibility, these comparisons are usually made using simulations in which simplified models represent buildings and infra-red heat lamps substitute for solar radiation.

Assessing the performance of a solar reflective coating applied to the surface of a roof, for example, is done by comparing two model buildings, in otherwise identical circumstances: one whose roof has a solar reflective coating (Building A), and the other whose roof has a coating that is not solar reflective (Building B). Manufacturers and distributors of solar reflective coatings claim that their products are effective in reducing temperature gains inside the building, because such a simulation would likely show that:

- the surface temperature of Building A's roof is discernibly lower than that of Building B's roof
- the temperature inside the roof space of Building A is discernibly lower than that of Building B
- the temperature of the living area inside Building A is discernibly lower than that of Building B.

Of course, the real-world use of solar reflective coatings is unlikely to reduce heat gains to the same extent as in a simulation. A model dwelling is not representative of a typical residential or commercial building; the lack of insulation means that heat flows to the inside of the building will be artificially high. Also, a simulation does not replicate the true characteristics of solar radiation: infra-red heat lamps produce 100% infra-red radiation, whereas solar radiation is in the order of 52% infra-red, 43% visible and 5% ultraviolet radiation; and heat lamps produce constant radiation from a fixed position, whereas solar radiation is variable and reaches the building envelope at different intensities depending on how directly the surfaces face the sun. Simulations disregard significant

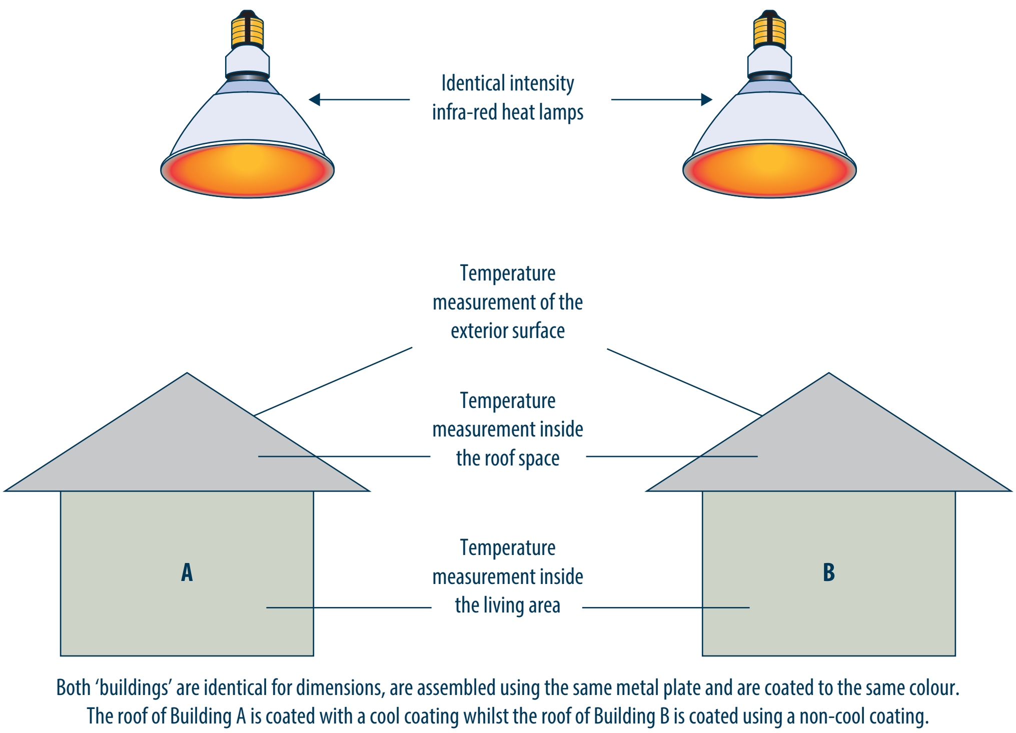

FIGURE 3 Testing a solar reflective coating.

heat gains from other elements of the building envelope, such as windows and external walls, which cannot be ignored when determining the overall heat gain of the building envelope.

In the real world, the extent of temperature gain inside a building depends on a number of parameters – including the building's design, orientation and environmental surrounds; the materials used to construct the exterior envelope; the use of insulation; and the local climate – which a simulation does not take into account.

For an uninsulated building constructed in whole or in part out of metal, the application of a solar reflective coating to exterior metal surfaces may discernibly reduce the temperature inside the building – keeping in mind that the reduction of inside temperature gains will diminish over time as the coating deteriorates with age and accumulates surface contaminants.

For most buildings, the application of a solar reflective coating as a single remedial action is unlikely to substantially reduce the indoor temperature. Where other action has been taken to reduce heat gains via the roof, walls and/or windows, the application of a solar reflective coating is even less likely to substantially reduce the temperature inside the building.

MORE INFORMATION

Additional information can be found in the following resources. Please check your local authorities for specific legislation, codes and guidelines, as they can vary between states and territories.

Australian Building Codes Board (2019) National construction code. Canberra: Australian Building Codes Board

Australian Competition and Consumer Commission (2018) Restoring electricity affordability and Australia's competitive advantage. Retail Electricity Pricing Inquiry – Final Report. Canberra: Australian Competition and Consumer Commission

Sustainability Victoria (2018) Energy Smart Housing Manual. Melbourne: Sustainability Victoria