**TB - 39**
**Technical Bulletin**

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# Thermal performance of roofing materials

## Background

There is increased interest in understanding product performance and key considerations relating to energy efficiency in residential housing and the thermal comfort of occupants.

This is largely being driven by:

- regulatory changes to energy efficiency requirements in residential housing as an important means to tackling climate change,
- rising energy costs to homeowners, and
- the discomfort to residents and broader communities created by extreme weather conditions (in particular increasing temperatures).

Roofing can be an important consideration in terms of thermal comfort and energy costs due to the large area exposed to the sun.

This Bulletin provides residential home decision makers with an overview of some of the key considerations when choosing roofing materials and how COLORBOND® steel roofing can assist.

**Figure 1. Your roof is the most exposed part of your home to summer sun.**

## Roofing and energy efficient homes

Energy efficiency is an important area of focus in the National Construction Code (NCC).

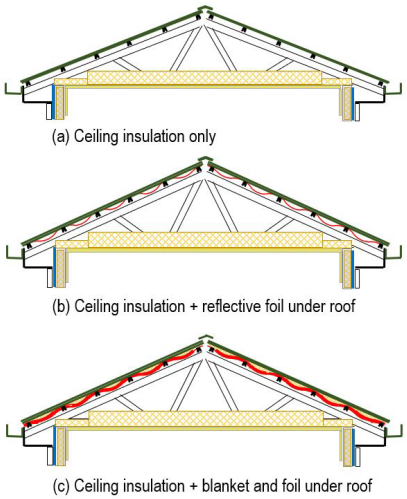
- Energy efficiency stringency has been increasing since its introduction into the NCC in 2003, which targeted a 3.5-star Nationwide House Energy Rating Scheme (NatHERS) rating. A 7-star NatHERS rating is planned for introduction in NCC 2022.
- The solar absorptance (SA) of the roof chosen for your home may influence the amount of roof insulation required and/or it's NatHERS star rating.

In complying with the NCC and similarly for Building Sustainability Index (BASIX) in NSW, the solar absorptance (SA) of the roof chosen for your home has always been a factor that may influence the amount of insulation required under the deemed-to-satisfy elemental requirements. Insulation may be installed upon the ceiling and at the roof.

NatHERS also includes details about the design of your roof and requires the roof SA to be entered directly or as a range representing dark, medium and light colours.

In terms of meeting energy efficiency requirements, it is worth noting that metal roofing has the potential to allow for a higher net insulation value (R-value) than other common roofing products as the system of installation allows the opportunity to install both insulation blanket and foil at the roof in combination with insulation at the ceiling. In addition, the ability to place blanket insulation directly beneath the metal roof reduces attic temperature extremes, helping ducted air conditioner systems to run more efficiently.

**Figure 2. Options for insulation on metal roofing.**
Note: Highest thermal performance may be achieved using blanket and foil under a metal roof in combination with ceiling insulation (Option (c)).



(a) Ceiling insulation only

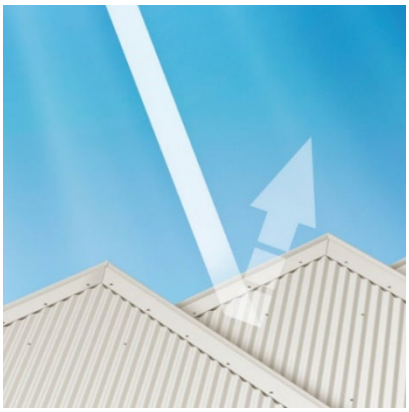
(b) Ceiling insulation + reflective foil under roof

(c) Ceiling insulation + blanket and foil under roof

## Solar Absorptance

Low SA roofs absorb less heat from the sun helping keep your home and the air surrounding your home cooler than a high SA roof. In turn, this can help you save on cooling costs and improve summertime thermal comfort. The benefits of low SA roofs are greatest in warm climates where the cooling load is higher.

**Figure 3. Low SA roofs stay cooler by reflecting away more heat from the sun.**



Australian cooler climate zones also often experience hot summers. In these cooler climates, whilst the importance of SA is typically much less with respect to heating and cooling of the building, low SA roofs are usually still beneficial. This is because solar properties are most relevant in summer to help keep the building cool, when days are long, clear and the sun is high in the sky. In winter, when days are shorter, there is often cloud cover and the sun is lower in the sky, the contribution of a roof to absorb/reflect solar energy to help warm the building is less. Consequently, even in Australia's cooler climate zones the summer benefits of low SA roofs (lighter roof colours) usually outweigh any additional winter heating of the building that may be required.

Most Australian climates have hot summers and using low SA roofs will help with summertime thermal comfort, performance in heatwaves and mitigation of Urban Heat Islands.

SA is expressed as a ratio between 0 and 1. A SA value of 0 indicates that a roof absorbs none and a value of 1 indicates that a roof absorbs 100% of the incoming solar radiation. Solar reflectance (SR) is sometimes communicated and is the inverse of SA for opaque materials. For instance, a material that has a SA of 0.7 will have a SR value of 0.3.

Solar reflectance index (SRI) is another term that is sometimes used for ranking the coolness of a roof under hot sunny conditions. SRI is a relative value between a reference 'hot' black absorbent surface (SRI=0) and a 'cool' white reflective surface (SRI=100). SRI measures are used in Green Star rating tools to help mitigate the heat island effect (Urban Heat Islands are discussed in more detail later in this document).

References to SA values for housing are set out in the NCC, and BASIX in NSW; and are also in some cases being set out in design covenants. Manufacturers of roofing products should be able to provide details to assist Builders/Developers make decisions and comply with any requirements.

BlueScope provides current solar absorptance values for COLORBOND® steel roofing and walling products. These can be found on the back of product colour swatches or at http://steel.com.au/products/coated-steel/colorbond-steel/basix-and-bca-classification.

## The impact of colour on Solar Absorptance

### Light versus dark colours

Light coloured roofs remain cooler than dark-coloured roofs. This is because light-coloured roofs reflect more visible sunlight and therefore have lower SA than darker colours. During hot sunny weather, the surface temperature of a light-coloured roof can be up to 35°C cooler than a dark-coloured roof.[1]

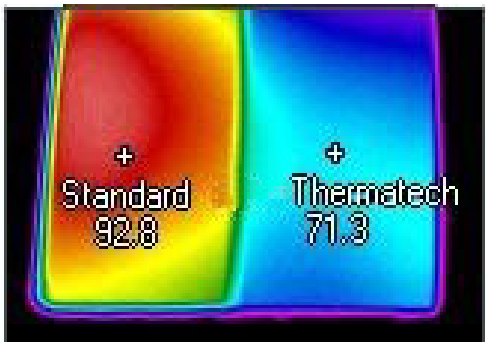
### Identical or similar colours and the impact of Thermatech® solar reflectance technology

It's important to note that identical or similar coloured roofs can also have quite different SA values. Colour is impacted by the way the surface reflects the solar radiation that we can see. However solar radiation also contains a large portion of energy we cannot see in the near infrared. Each roof's surface is unique in the way that it reflects near infrared energy.

Some roofing products have been developed to reflect more energy away in the near infrared spectrum of sunlight, helping the roof stay cooler without influencing its inherent colour. COLORBOND® steel provides an example of this. 21 of the 22 standard colours (excluding Night Sky®) and the 5 Matt colours in the COLORBOND® steel range feature Thermatech® solar reflectance technology which works at enhancing the solar reflectance across the colour range, i.e. the technology results in lower SA values, particularly effective on darker colours.

**Figure 4. COLORBOND® steel Woodland Grey® is cooler in the daytime with Thermatech® solar reflectance technology.**






**Thermal image on mild sunny day**
Left: Without Thermatech® technology
Right: Featuring Thermatech® technology

**Thermal image under heat lamps**
Left: Without Thermatech® technology
Right: Featuring Thermatech® technology

It's more than just colour. The SA of other similar coloured roofing products compared to COLORBOND® steel with Thermatech® technology can be very different. COLORBOND® steel in the colour Woodland Grey® is cooler in the daytime with Thermatech® technology.

Having low SA is therefore more than just colour. Similar dark colours of roofing materials can have a solar absorptance difference of more than 0.20[1]. As it is not possible for the human eye to distinguish between paint technologies which may be used to achieve the same colour, laboratory test results are required to identify the level of SA so check with the roofing product manufacturer.

The SA values of COLORBOND® steel are measured at BlueScope's NATA approved laboratory in accordance with ASTM E903-96, Standard test method for solar absorptance, reflectance and transmittance of materials using integrating spheres. The solar absorptance values are nominal values based on new product.

For further information on Thermatech® technology visit http://www.steel.com.au/products/coated-steel/colorbond-steel/colorbond-thermatech.

## The impact of material on Solar Absorptance and Thermal Performance

Roofing material can impact:

- SA values,
- how SA values change with time, and
- the roof system's thermal mass.

### Solar Absorptance over time

Both coating technology and underlying roofing material can influence its SA value, and there can be significant differences in SA between different products of a similar colour.

Also, while the initial SA of the product is important, it's important how its SA (and its associated SRI) changes with time. Green Star rating tools recognize the importance of materials maintaining their thermal performance over time by taking into account both initial SRI and 3-year SRI values in the Heat Island Effect and Heat Resilience credits.

Initial SRI values based on new product are available for all COLORBOND® steel colours, and a 3-year SRI value is also available for many colours. 3-year SRI values for COLORBOND® steel remain relatively close to the initial SRI value. Please contact Steel Direct for the relevant 3-year SRI value.

Outdoor exposure racks, located at various Australian sites, help BlueScope further understand, monitor, and provide confidence in the durability and ongoing thermal performance (SA, SRI) of COLORBOND® steel.

**Figure 5. Outdoor exposure racks, located at various Australian sites, help BlueScope understand the Thermal Performance of its products over time.**

## Influence of thermal mass

Thermal mass is the ability of a material to store heat. The roofing material can influence the thermal mass of the roofing system and how it performs thermally.

Whilst high thermal mass can be a benefit in some climates, how thermal mass is designed into the building is a key factor on whether it is beneficial or not. According to the Australian government publication 'Your Home: Australia's guide to environmentally sustainable homes'[2]:

> *"Thermal mass, correctly used, moderates internal temperatures by averaging out diurnal (day−night) extremes. This increases comfort and reduces energy costs.*
>
> *Poor use of thermal mass can exacerbate the worst extremes of the climate and can be a huge energy and comfort liability. It can radiate heat to you all night as you attempt to sleep during a summer heatwave or absorb all the heat you produce on a winter night."*

Ideally thermal mass is best located inside your home. It allows you to trap the heat generated by sunlight coming in through your windows and release it slowly at night to naturally warm your home. Floors and internal walls with high thermal mass are ideal for this purpose. In summer, these surfaces can be protected from the high-altitude sun by the eaves on the outside of your home. Because roofs cannot be shielded from the sun, during hot weather roof systems with high thermal mass store heat during the day for release later in the evening and night. This can create an unhelpful thermal lag that can contribute toward uncomfortable sleeping conditions during the night with increased reliance on air-conditioning. With a predicted warming climate, this is of concern for housing, particularly in heatwave conditions. Using lower thermal mass responsive materials, like COLORBOND® steel, can help because it cools down fast once the sun is off the roof.

The benefit of low SA and low thermal mass metal roofing is observed in a full-scale study of seven identical homes built in the same street with different roofing, including both white tile, white metal and dark-coloured shingle roofing[3]. The white metal roof performed best at reducing cooling demands being attributed to its thermal behaviour.

> *"The better performance of white metal is believed to be due to the effect of thermal mass. The metal roof incurred lower nighttime and early morning attic temperatures than did the tile or shingles, leading to lower nighttime cooling demand."*

**Figure 6. Use lightweight, solar reflective roof materials to avoid storing summer heat.**

In summer, a lightweight insulated roof made from COLORBOND® steel will cool down once the sun sets causing less heat to be radiated into your home at night helping your home to cool. The Thermatech® technology (featured in 21 of the 22 standard colours (excluding Night Sky®) and the 5 Matt colours in the COLORBOND® steel range) further helps achieve this by working to minimise heat entering the building during the day.

In winter the same steel roof, properly insulated, helps keep the heat inside helping your home stay warm.

Whilst high thermal mass can help with extremes, it should be protected from summer sun or else it can become a liability in hot weather. A roof cannot be protected from summer sun and as such lightweight options are preferable, such as an insulated COLORBOND® steel roof.

**For further information on thermal mass in buildings:**
2. *Your Home: Australia's guide to environmentally sustainable homes* (2020). © Commonwealth of Australia Department of Industry, Science, Energy and Resources. https://www.yourhome.gov.au/passive-design/thermal-mass

**For further information on full scale study on homes with different roofing:**
3. *Painted metal roofs are energy-efficient durable and sustainable* (2003), William A. Miller, Danny S. Parker, Hashem Akbari, https://www.researchgate.net/publication/237335655_Painted_metal_roofs_are_energy-efficient_durable_and_sustainable

## Light coloured roofs and glare

Glare is sometimes raised as an area of concern with the use of lighter coloured building materials (and may be a subject for building compliance). Some points to be aware of include:

- A darker colour will not necessarily reduce glare issues AND can have adverse impacts on energy efficiency.
- Case by case consideration of reflected light from roofs can help identify where mitigation may be appropriate. There are a number of building design solutions and considerations including orientation, roof pitch, topography, shielding, seasons/weathering, choice of colour and finish.

For further information on reflectivity and building materials visit: BlueScope Technical Bulletin TB 28 Building materials, thermal efficiency and reflectivity.

## Mitigating 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.

Urban development replaces vegetation, that provides shade and cooling, with materials that are often impervious, high thermal mass and non-reflective. This change contributes to the formation of urban heat islands.

UHIs can have a multitude of impacts upon energy, thermal comfort and health. UHIs can:

- result in increases in cooling energy consumption and peak demand;
- impact on thermal comfort within buildings and their surrounds; and
- impact on heat related illness and death as a result of higher daytime temperatures, reduced nighttime cooling, and higher air-pollution levels.

Planning communities and development that includes urban forestry and cool roofs are globally recognised as two of the most effective ways to reduce the intensity of UHIs. Vegetation, selection of cool roofs and materials having high SRI values, are all recognised in Green Star rating tools to help mitigate heat islands.

Overall, choosing a cooler roof with lower SA or of lighter colour, on a building surrounded by trees and vegetation – to provide shade and water movement to the atmosphere – is one of the best design scenarios to mitigate UHIs.

**Figure 7. A cool white metal roof amongst a sea of hot dark roofs.**

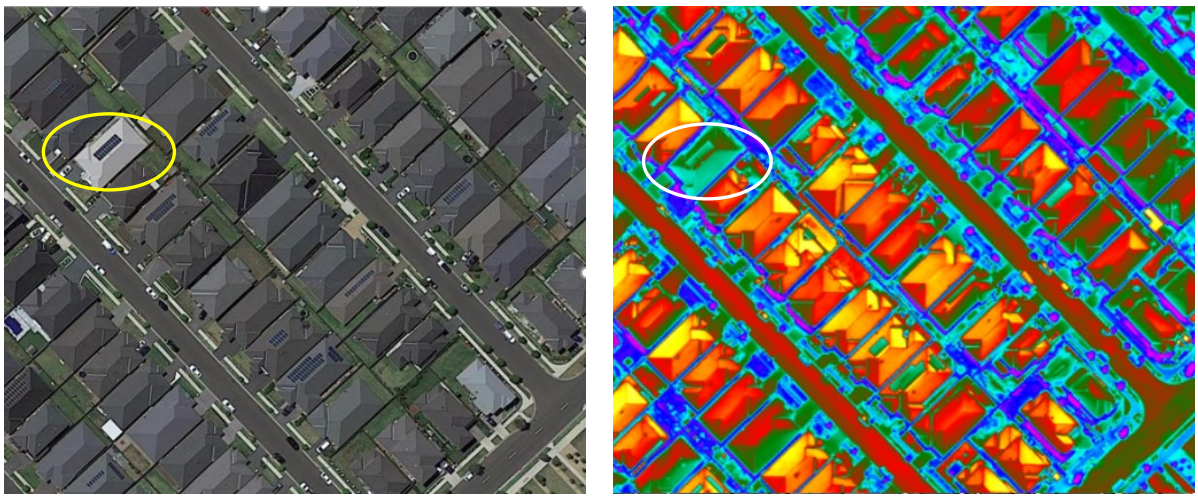


Image credits: Microclimate and Urban Heat Island Mitigation Decision-Support Tool, RP2023, Low Carbon Living CRC, 2018.

COLORBOND® steel offers a range of light colours, and 21 of the 22 standard colours (excluding Night Sky®) feature Thermatech® technology, reflecting more of the sun's heat on hot sunny days, helping mitigate urban heat.

For further information on UHIs and cool roofs visit: BlueScope Sustainability Technical Bulletin STB-2 Urban Heat Islands

## Sustainability considerations

Choosing thermally efficient roofing, such as COLORBOND® steel, can help reduce greenhouse gas emissions associated with the energy required to make your home thermally comfortable. Because it is also lightweight, the roof's supporting structure (battens, frame, lintels, foundations) may be sized smaller thereby requiring less material, which in turn can help avoid upfront carbon emissions associated with their production.

COLORBOND® steel is also durable and resilient to Australia's harsh climate. Its long life helps conserve resources that may otherwise be invested in products with a shorter life span.

## Summary

There are many considerations to achieving good building design. As discussed in this bulletin, roofing is an important choice that can influence energy efficiency, thermal comfort and urban heat islands.

COLORBOND® steel can contribute to a design solution for your home to help achieve high energy efficiency to save on running costs and year-round thermal comfort in all climates, including broader environmental and community comfort/health benefits associated with UHI mitigation.

## Related BlueScope Technical Bulletins

Technical Bulletin TB 28 Building materials, thermal efficiency and reflectivity

Sustainability Technical Bulletin STB-2 Urban Heat Islands

## References


1. *State of the art on the development of cool coatings for buildings and cities,* (2017), A.L. Pisello, Jan 2017, p664.
2. *Your Home: Australia's guide to environmentally sustainable homes*, 2020, ©Commonwealth of Australia Department of Industry, Science, Energy and Resources https://www.yourhome.gov.au/passive-design/thermal-mass.
3. *Painted metal roofs are energy-efficient durable and sustainable,* (2003), William A. Miller, Danny S. Parker, Hashem Akbari, https://www.researchgate.net/publication/237335655_Painted_metal_roofs_are_energy-efficient_durable_and_sustainable.