Case Study
Cool roof energy savings

BLUESCOPE

Study predicts cool roof energy savings underestimated

Colorbond® Coolmax®

COLORBOND® Coolmax® steel

Cool roof energy savings

"In hot weather the air layer above roofs is subject to greater convective warming, creating a micro-climate."

BlueScope and Stockland initiated a study on the effectiveness of cool roofing to reduce the cooling load of larger buildings[^]. The results of the study carried out by Graham Carter of Lend Lease and University of Wollongong predicted that these savings could be greater than estimated using current energy modelling methods, which typically do not account for micro-climate heating effects above larger roof areas.

While actual energy savings will ultimately depend on factors[†] such as building type, roof size, building location, the study found that "a savings multiplier of two to four is likely for any cool roof application over an air conditioned environment with roof top equipment."[1]

BlueScope building science innovation specialist, Mr Jamie Adams, associated the micro-climate above a roof to the phenomenon of urban heat islands, where dark and dense building materials absorb more heat than lighter-coloured natural surfaces, such as fields and forests.

"In hot weather the air layer above roofs is subject to greater convective warming, creating a micro-climate," said Mr Adams."It's much like the tarmac of a dark, hot road, where a blanket of heated air shimmers above the surface."

"A cool roof effectively reduces the amount of hot air above it on a hot sunny day. Cool roofs have high solar reflectance that minimises heat absorption by the surface. Cool roofs also have high thermal emittance to maximise the roof's ability to shed away the heat that it does absorb."

"It's much like the tarmac of a dark, hot road, where a blanket of heated air shimmers above the surface."

^The Harvey Bay shopping centre with a 15,000sqm roof was considered in this study.
† Other factors include climate, insulation levels, cooling plant capital cost and electricity pricing.

"Coolmax® is a super solar-reflective, high thermal-emittance, pre-painted steel, it has the highest solar reflective performance in our COLORBOND® steel range."

Mr Adams said that although cool roofs reduce the micro-climate heating effect, this is not typically recognised by conventional energy modelling. "The problem at present is that energy savings provided by a cool roof aren't accurately estimated on larger roofs where the roof micro-climate is more significant. This is due to energy simulation software packages commonly used by Ecologically Sustainable Development (ESD) professionals not factoring in the heating effects of the air in the micro-climate above roofs^^."

"Current energy modelling tools tend to only assess simple first-order effects, which assume the roof and any plant equipment is immersed in ambient air that is unbiased by any localised heating effects. However, we know there can also be second-order compounding effects such as the convective warming of the ambient air in the micro-climate above the roof which, for larger roofs, impact on air-conditioning loads."

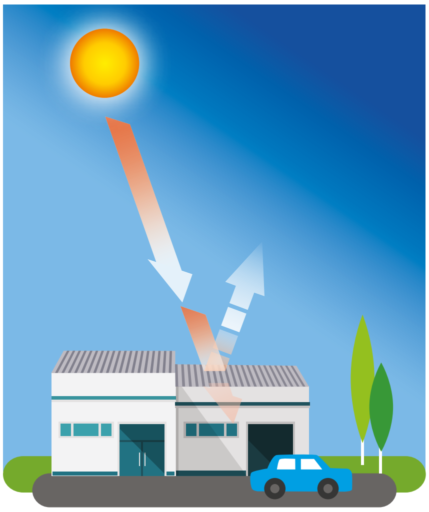
Mr Adams said the degree of unaccounted savings a cool roof might provide varies depending on a range of factors, particularly roof size.

"For a small roof, the likelihood of the roof surface significantly heating the air above is small, and the normal first order assumptions are generally reasonably valid. However, the study results have found that on larger scale roofing, like those common for industrial facilities, shopping centres and airports, the local air temperatures above the roof can increase and become like a heat "bubble", creating the roof's own micro-climate which compounds heating effects and can increase building cooling loads.

It is here that we have an opportunity to save both capital and operational costs through more energy-efficient designs using cool roofing."

Due to a focus on energy savings and environment, BlueScope is aware of the potential for highly solar-reflective cool roofing material to reduce building energy consumption, and the urban heat island effect by minimising heat absorption. Therefore, BlueScope developed COLORBOND® Coolmax® steel in the colour Whitehaven®. "Coolmax® is a super solar-reflective, high thermal-emittance, pre-painted steel," explained Mr Adams. "It has the highest solar reflective performance in our COLORBOND® steel range."

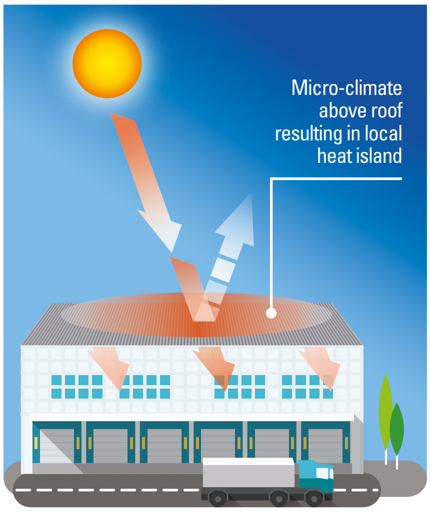
1ST ORDER EFFECTS



On small roofs with no mechanical equipment it is reasonable to account for only 1st Order Effects that assume:

- Unbiased ambient air
- No micro-climate above the roof

2ND ORDER EFFECTS



Above large roofs a micro-climate can form causing local warming of ambient air resulting in additional second order cooling loads due to:

- Warmer ventilation air
- Additional roof loads
- Higher condensing temperatures
- Lower cooling efficiency

^^Which are not cool roofs.


"COLORBOND® Coolmax® steel can also contribute
to Green Star projects due to its contribution to
Urban Heat Island Effect management."

COLORBOND® Coolmax® steel
Green Star

COLORBOND Coolmax® steel and Green Star

The solar reflectance and thermal emittance of a material can be used to calculate a Solar Reflectance Index (SRI), a common measure of cool roofing. An SRI of 100 represents a reflective white roof and at the other end of the spectrum is an absorbing black roof with an SRI of zero.

In addition to the effects predicted by the study, BlueScope sustainability manager, Mr Ross Davies, pointed out that COLORBOND® Coolmax® steel can also contribute to Green Star projects due to its contribution to Urban Heat Island Effect management.

"The Green Star Heat Island Effect credit requirements for roofing materials specify a minimum initial (new) SRI of 82; COLORBOND® Coolmax® steel has an initial SRI of 95. This is not only indicative of its high solar reflective performance but also can provide an effective and easy way to qualify for a Green Star point."

Solar Reflective Index	
100	Ultra White
90-70	White
60-40	Medium
30-10	Dark
0	Jet Black

COLORBOND® steel SRI

SRI-95 **SRI-82** **SRI-82**

The COLORBOND® steel colours shown all meet the GreenStar® tool UHI credit requirements for roofing material with a minimum Solar Reflectance Index of 82.

"The Green Star Heat Island Effect credit requirements for roofing materials specify a minimum initial (new) SRI of 82; COLORBOND® Coolmax® steel has an initial SRI of 95."

Case Study
Stockland Hervey Bay shopping centre extension

To explore just how much the inclusion of micro-climate effects in energy modelling can impact predicted cool roof energy savings, BlueScope and Stockland initiated a modelling study to account for above roof micro heating using a Stockland shopping centre's 15,000 square-metre roof as a reference case.

The focus of the study compared the thermal performance of roofing made from conventional ZINCALUME® steel with COLORBOND® Coolmax® steel in the colour Whitehaven®.

COLORBOND® steel in the colour Surfmist® was also compared, finding improved performance over conventional ZINCALUME® steel roofing, albeit less than for COLORBOND® Coolmax® steel roofing broadly in line with their thermal surface properties.

Stockland National Sustainability Manager, Commercial Property, Greg Johnson, said the company is actively seeking ways to make its assets such as shopping centres more climate resilient. "We have undertaken climate resilience assessments across our portfolio of retail assets, particularly in regions where future climate change scenarios indicate we will experience an increase in extreme heat days," Mr Johnson said. "We seek ways to make our assets more resilient by minimising heat gain through the building envelope, to maintain indoor comfort and reduce energy demand."

"We saw the adoption of cool roof technology as a key way of doing this. In line with our ongoing commitment to sustainable design we decided to explore the practical benefits of BlueScope's COLORBOND® Coolmax® steel as part of our Hervey Bay shopping centre redevelopment. We wanted to understand the role that cool roofs might play in improving indoor comfort, reducing up-front capital costs associated with air-conditioning equipment and reducing energy consumption over the building's life cycle.

From the study, we aimed to gain a quantitative understanding of the energy savings and other benefits we could expect when considering the second-order effects of hot air movement over a building."

Stocklands and BlueScope engaged consultants and academics to investigate both the micro-climate above roofs and the second order impacts on building cooling loads. These included Lend Lease Sustainable Design Manager and member of The Australian Institute of Refrigeration Air Conditioning and Heating (AIRAH), Mr Graham Carter, and University of Wollongong Associate Professor, Dr Buyung Kosasih.

"We seek ways to make our assets more resilient by minimising heat gain through the building envelope, to maintain indoor comfort and reduce energy demand."

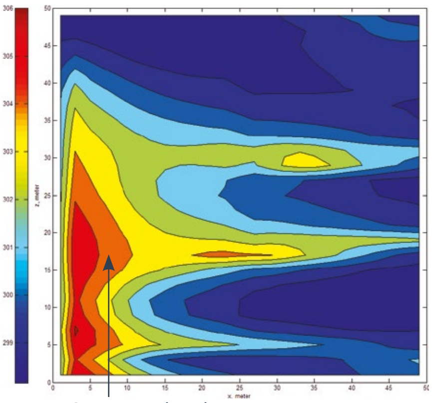
“The outcome of this research revealed that industry simulation tools only account for 25 to 50 per cent of the full energy benefit of cool roofs for larger roofs.”[1]

Mr Carter and Associate Professor Kosasih identify major shortfalls in current thermal energy assessment methods in their publication “Not So Cool Roofs”,[1] which outlines the study and its key findings. In summary, they contend that the effect of micro-climate created by a heat-absorbing roof is ignored by the vast majority of cooling load calculation and energy simulation tools, and that this omission is a key factor in underestimating cool roof energy savings.

They observe that cool roof energy savings for larger roofs, like those common for industrial facilities, shopping centres and airports, are likely to have been greater than forecast using common energy simulation tools.

“The outcome of this research revealed that industry simulation tools only account for 25 to 50 per cent of the full energy benefit of cool roofs for larger roofs.”[1]

“For a conventional ZINCALUME® steel roof, peak ventilation and electrical loads are significantly impacted.”



A 4 to 7°C warming (bias) of air temperatures above the roof for a low wind high heat load condition

“The implications of not accounting for the roof micro-climate above larger roofs are significant and should be addressed within our industry.”

The University of Wollongong (UOW) conducted parametric 3D Computational Fluid Dynamics (CFD) analysis to characterise the roof micro-climate as a function of the convected heat from each roof surface.

Mr Carter’s experience was then called on to estimate the second-order effects of the micro-climate above the Stockland Hervey Bay shopping centre with various hypothetical changes to roof material, wind condition and rooftop plant location.

This was done along with EMF Griffiths simulating first-order effects using current energy simulation tools for each roof type that did not bias local above-roof air temperatures.

BlueScope’s Jamie Adams said the study results found that the second-order effects were significant compared to the first-order effects alone. “The energy savings of specifying COLORBOND® Coolmax® steel over ZINCALUME® steel predicted from current energy simulation using only first-order effects were less than 5 per cent. However, with the second-order effects added to the modelling, the savings were predicted to be closer to 10 per cent.”

“The amount of potential unaccounted savings varies depending on factors such as roof size, climate, insulation level and roof-top plant location but the upshot is that for large roofs, like those common for industrial facilities, shopping centres and airports, our study found that current energy modelling is likely to under-predict the cooling energy savings derived from cool roofing.”

The study team also conducted specific energy modelling scenarios to understand the predicted range of second-order impacts and savings. This included hypothetical modelling of the 15,000 square-metre-roofed Stockland Hervey Bay building in Sydney with the rooftop plant centrally located (having higher heat impact than when located on roof perimeter) and different wind exposure (country and urban). The predicted energy savings multiplier to account for second-order effects ranged from a minimum of two and varied up to four.

For the modelling scenarios considered and the case study roof, the modelling predicted that combined first and second-order annual thermal savings by choosing COLORBOND® Coolmax® steel over conventional ZINCALUME® steel ranged from 27 to 44 kilowatt hours per square metre (kWh_r/m^2) of roofing.

The corresponding electrical savings ranged from 4 to 7 kilowatts of energy per square metre (kWh_e/m^2) on the basis of the Hervey Bay Building’s high-efficiency water-cooled condenser conditioner. Electrical savings would be expected to be greater for a less-efficient cooling plant.

The study also predicted similar magnitude second-order effects on peak cooling loads, not currently considered when sizing air conditioning systems, highlighting the potential for undersized systems to be installed.

With the second-order effects added to the modelling, the peak cooling load was predicted to lower by 169 kW_r (11 W_r/m^2) over ZINCALUME® steel roofing. The predicted reduction was 323 kW_r (21 W_r/m^2) when the building was hypothetically modelled with a centrally located plant in a shielded city environment.

The potential economic value of using COLORBOND® Coolmax® steel over ZINCALUME® steel was assessed assuming an electrical consumption charge of 25 cents per kilowatt hour and an implied value in reducing peak load for the cooling plant of $930 per kilowatt[2]. The range of predicted savings for the Hervey Bay building from actual plant location in an open country environment through to central plant location in a shielded city environment was determined. The range of predicted savings was also determined for minimum code compliant water and air cooled systems to provide a guide to maximum possible savings with different equipment.

Mr Adams encourages ESD consultants and the industry professionals who engage them to investigate second-order effects when predicting cool roof energy savings. Mr Adams also acknowledges that this can be challenging when current tools need to be updated – in the meantime consideration should be given to adjusting first order savings by a conservative multiplier for cool roof energy savings as appropriate to account for their second-order benefits. “Doing so will help ensure that the ability of cool roofs is not undervalued, and more energy-efficient outcomes can be achieved.”

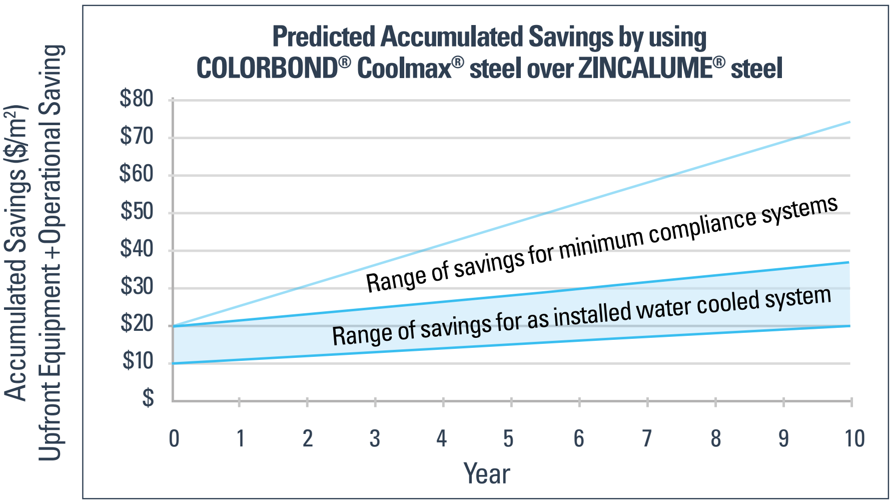
Project: Stockland Hervey Bay
Location: Hervey Bay, QLD
Client: Stockland Development
Principal steel components: COLORBOND® Coolmax® steel in the colour Whitehaven®, COLORBOND® steel in the colour Surfmist®, ZINCALUME® steel
Architect: PDT Architects
Builder: Lend Lease
Structural & civil engineer: Bornhorst + Ward
Photographer: John Wilson

Chiller Type	Performance	Predicted Savings‡		
		Upfront Equipment Saving‡‡	Annual Operational Saving	Accumulated 5 Year Saving‡‡‡
Water cooled (as installed)	IPLV 10.3	\$10.28 - \$19.53 /m^2	\$0.99 - \$1.77 /m^2.pa	\$15.22 - \$28.36 /m^2
Minimum for compliance				
AS4776.2 (>1500kW$_r$)				
Water cooled	IPLV 6.5	\$10.28 - \$19.53 /m^2	\$1.57 - \$2.80 /m^2.pa	\$18.11 - \$33.52 /m^2
Air cooled	IPLV 4.1	\$10.28 - \$19.53 /m^2	\$2.49 - \$4.44 /m^2.pa	\$22.70 - \$41.71 /m^2
BCA Section J (<350kW$_r$)				
Water cooled	IPLV 5.2	\$10.28 - \$19.53 /m^2	\$1.96 - \$3.50 /m^2.pa	\$20.07 - \$37.02 /m^2
Air cooled	IPLV 3.4	\$10.28 - \$19.53 /m^2	\$3.00 - \$5.35 /m^2.pa	\$25.26 - \$46.28 /m^2

‡ Data contained in this table and document has either been taken direct from the publication “Not so cool roofs”, interpreted from data contained in that report or data by the project team. Predicted savings are calculated on the basis of assumed average lifetime roof thermal surface properties.

‡‡ Alternatively, factors such as improved performance in heatwave, less equipment strain and the system operating for less hours might lead to savings.

‡‡‡ Accumulated 5 Year Saving = Upfront Equipment Saving + 5 x Annual Operational Saving.



For more detailed findings from the Stockland Hervey Bay shopping centre study or to further discuss the impact of second-order effects on energy modelling, please contact BlueScope Steel Direct and ask to speak to a Specification Account Manager.

1. For further details refer to Carter G and Kosasih B. (2015) Not So Cool Roofs, AIRAH’s Future of HVAC 2015 Conference, Melbourne, August 18-19, 2015.
2. Kohlenbach P and Dennis M, Solar cooling in Australia: The future of air conditioning?, AIRAH Ecolibrium December 2010.

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