Benefit of Solar Reflective Paint for Buildings in a Hot and Sunny Climate

Prepared for:

Coolshield International Pty Ltd

by

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15 March 2019

Report No 2019-1

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1. Introduction

Sunspin Pty Ltd was approached by Coolshield International Pty Ltd to evaluate the reduction in heat gain from building surfaces painted with SOLACOAT "Cream" paint compared to surfaces painted with an "average" colour paint. For this evaluation a measurement of the solar reflectance for the SOLACOAT "Cream" paint carried out by R&D Services in 2013 following the ASTM C 1549-09 standard [1] was supplied. Background for the evaluation is a report by Selby [2] on the variation of the heat gain through the roof of a building due to changes in the solar reflectance (which in turn is based on a research paper by Suehrcke *et al*. [3]). The need for this evaluation has arisen, as the SOLACOAT "Cream" paint is not covered by Selby report, yet it appears to be the most solar reflective of the Coolshield paint products range.

The reduction in the heat gain from building surfaces (roof and walls) through application of a solar reflective paint can be expressed by comparing the heat gain from a surface coated with the reflective paint to the heat gain from a surface coated with an "average" paint. Alternatively, the difference between a roof or wall coated with a reflective and an average paint can be expressed in terms of the difference in R-value (insulation) required to achieve the same heat flow .

2. Selby report

The Selby report is very useful, however, the R-values used in the report, which are based on the Building Code of Australia (BCA) from 2005, are outdated. Moreover, the section entitled: "Effective R-Factor" calculation appears to contain an error and the conclusion from this section no longer applies under the latest Australian National Construction Codes (NCC 2016 [4] and NCC2019 [5]) requirements.

Using the equation from Suehrcke *et al*. [3], the Selby report correctly expresses that the steady state[1] heat flow per square meter, q, from a roof coated with a paint of solar absorptance, α, and a roof coated with a reference (or average) paint α_{ref} is equal when:

$$q = U\left(\Delta T + \frac{\alpha\, G}{h_o}\right) = U_{ref}\left(\Delta T + \frac{\alpha_{ref}\, G}{h_o}\right) \qquad (1)$$

where U = Overall heat transfer coefficient between the ambient (outside) and building inside, which can also be expressed as in terms of the overall thermal resistance R = $\frac{1}{U} = \frac{1}{h_o} + \frac{1}{h_i}$, where h_o and h_i are the heat transfer coefficients from the roof surface to outside and from roof surface to inside, respectively [W/m^2.K] – see ref [3] for a more detail.

[1] It is noted that the flow of heat through a roof (or wall) usually is not at steady state, as the driving variables, such as solar radiation, keep changing and the roof/wall thermal mass delays the flow of heat to the inside of the building. This causes the instantaneous heat flow into the building to differ from that of Eq. (1). However, as shown in Ref. [3] (see Section 7 and Fig. A.2) the thermal mass does not significantly affect the integrated daily heat gain from a roof or wall into a building and Eq. (1) can be used to reasonably calculate the average daily heat gain when average values of daily solar radiation $\bar{G}$ and other environmental variables are used.

U_{ref} = Same as U, but the numerical value for $R_{ref} = \frac{1}{U_{ref}}$ is set by the BCA or NCC for a roof with average solar absorptance [W/m^2.K].

ΔT = Temperature difference between the ambient (outside) and the building inside ($\Delta T = T_o - T_i$) [K].

α, α_{ref} = Solar absorptance of the paint of interest and solar absorptance of the reference surface (e.g. paint with average solar absorptance).

G = Solar radiation [W/m^2]

h_o = Heat transfer coefficient from the roof surface to the outside environment [W/m^2.K].

h_i = Heat transfer coefficient from the roof surface to the building inside [W/m^2.K].

Given $R_{ref} = \frac{1}{U_{ref}} = 2.2$ m^2.K/W was required by the BCA in 2005 and values:

$\overline{\Delta T}$ = 6.5 K for the (average) daytime[2] temperature difference,
α = 0.23 for the solar absorptance of Solacoat "white",
α_{ref} = 0.65 for the approximate solar absorptance of an average roof,
$\bar{G}$ = 500 W/m^2 for the (average) daytime solar radiation in northern Australia and
h_o = 25 W/m^2.K for the outside heat transfer coefficient,

were assumed, Selby calculates from Eq. (1) that an R-value of only 1.19 m^2.K/W is required for the solar reflective roof compared to the reference roof requiring 2.2 m^2.K/W for equal heat transfer. Unfortunately, this latter value of 1.19 m^2.K/W appears to have been subsequently interpreted as the effective resistance that is provided by the reflective Solacoat paint, when the effective resistance provided by the reflective paint should have been the difference 2.2 – 1.19 = 1.01 m^2.K/W.

3. A better way of defining an effective R-value for solar reflective paint

The problem with the above calculation for the effective R value is is that it is tied to the specific R-value that is required at the time by the NCC (at the time of the Selby report it was the BCA requiring a minimum overall R-value of 2.2 m^2.K/W). A better way expressing the benefit provided by a solar reflective paint may be to define the reduced requirement

[2] It is noted that the Selby report [2] uses daytime average values (≈ 12 h averages) instead of average daily values (24 h averages) used by Suehrcke *et al*. [3]. This increases both the average outside to inside average temperature difference, $\overline{\Delta T}$, and the average solar radiation, $\bar{G}$. However, the results should approximately be the same (see Section 9) and the Selby values will be used also for the subsequent calculations.

for roof insulation, ($R_{ref} - R$), relative to the insulation required for an average roof (R_{ref}) as:

$$\frac{R_{ref} - R}{R_{ref}} = 1 - \frac{R}{R_{ref}} = 1 - \frac{\left(\overline{\Delta T} + \frac{\alpha\,\bar{G}}{h_o}\right)}{\left(\overline{\Delta T} + \frac{\alpha_{ref}\,\bar{G}}{h_o}\right)} \quad (2)$$

which is obtained by forming the ratio of U_{ref}/U from Eq. (1) and then considering that $U_{ref}/U = R/R_{ref}$, i.e. that the thermal resistance is the inverse of the overall heat transfer coefficient. The advantage of Eq. (2) (see also reference [3]) is that it provides the thermal resistance provided by the reflective coating relative to the resistance provided by an average coating. This may be illustrated with the above example for the Solacoat "white" paint.

Assuming the numbers from section 2 are correct (see also Section 9) and applying them for the Solacoat "white" paint, using Eq. (2) gives:

$$\frac{R_{ref} - R}{R_{ref}} = 1 - \frac{\left(6.5 + \frac{0.23 \times 500}{25}\right)}{\left(6.5 + \frac{0.65 \times 500}{25}\right)} = 0.43 \quad (3)$$

The above number suggests that the application of Solacoat "white" paint reduces the insulation requirements for the total roof R-value by 43%! Having obtained the relative reduction in the roof insulation requirement, the effective R-value provided by the reflective Solacoat "white" paint can be calculated using the 4.1 m^2.K/W reference R-value currently necessary in zone 1 of Australia for a roof with average solar absorptance as an example:

$$R_{ref} - R = 0.43 \times R_{ref} = 0.43 \times 4.1 = 1.77 \text{ m}^2\text{.K/W} \quad (4)$$

The values calculated in Eqs. (3) and (4) are likely to be too optimistic, as the white roof (solar absorptance of 0.23) will be affected by the build-up of dust (solar absorptance of approximately 0.8) more than a roof surface covered with average paint (solar absorptance of 0.65). Moreover, it may be questioned if the 0.65 average absorptance assumed for average paint is perhaps too high.

4. Average roof solar absorptance and dust

As already pointed out above, the assumed solar absorptance for the average roof surface is crucial for the benefit assessment of solar reflective paint[3]. Considering the availability of roof coatings that have a lower solar absorptance for the invisible solar radiation spectrum than for the visible one (e.g. BlueScope Thermatech® [6]), the solar absorptance of 0.65 assumed above may be too high. In this context it is noted that Bluescope [6] suggests the introduction of the Thermatech® technology has caused an average reduction of solar absorptance across all colours by 5%.

[3] Other important variables, such as the assumed average solar radiation or the average outside to inside temperature difference, $\overline{\Delta T}$, will be discussed in Section 9.

Using a table from the most recent 2019 NCC preview, an average solar absorptance value of 0.56 is suggested from the listed colours (see Table 1). The listed solar absorptance values are understood to be for new material. However, dust and dirt will settle on the roof surface once it is installed and with rain occasionally rain washing off some dust and dirt the surface will settle into a new "equilibrium" state. Suehrcke *et al*. [3] suggest the change in solar absorptance dust and dirt can be estimated with the below equation:

$$\alpha_{weathered} = \alpha_{new} + 0.15\,\frac{\alpha_{dust} - \alpha_{new}}{\alpha_{dust} - 0.20} \qquad (5)$$

where $\alpha_{dust} \approx 0.8$. Equation (5) considers that dust and dirt affect light coloured surface more than darker coloured surfaces.

Table 1: Typical solar absorptance values based on the NCC 2019 [5] and the NCC solar absorptance values including the approximate effects dust [3] (see Eq. (5)).

Colour	**Value [5]**	**Value [5] incl. dust & dirt**
Slate (dark grey)	0.90	0.87
Red, green	0.75	0.76
Yellow, buff	0.60	0.65
Zinc aluminium — dull	0.55	0.62
Galvanised steel — dull	0.55	0.62
Light grey	0.45	0.54
Off white	0.35	0.47
Light cream	0.30	0.43
Average	**0.56**	**0.62**

In relation to Table 1 the following points are noted:

- For the use of the solar absorptance values for zinc aluminium and galvanised steel in Table 1, it should be considered that these bare metal surfaces have a much lower thermal emittance than painted surfaces (say 0.2 instead of 0.9) and therefore the ability of these bare metal surfaces to lose heat (thermal radiation) to the sky is very much restricted (measurements suggest zinc aluminium and galvanised steel surfaces get as hot a black surface when exposed to sunlight! [3]). In order to compare bare metal zinc aluminium and galvanised steel surfaces with painted surfaces with respect to temperature reached the "effective" solar absorptance of dull bare metal surfaces may be closer to 0.8 or 0.9.

- In real operation all surfaces over time get dusty and dirty. Rain will from time to time wash away some of the dust, but with dust having a solar absorptance of approximately 0.8 [3] this will increase the solar absorptance of most surfaces (the ones with solar absorptance less than 0.8 in the new state, in particularly the light coloured ones).

- The roof colours listed in Table 1 are unlikely to be used in Australia in equal proportions, e.g. a cream colour may get used less often than a dark grey one.

Considering that red clay tiles and zinc aluminium roofs are common, the average effective solar absorptance values are likely to be higher than the averages shown in Table 1.

In view of the above points the average solar absorptance for an average roof surface is (conservatively) assumed as **0.60** for new surfaces and assumed as **0.65** for weathered surfaces in all subsequent calculations. It is noted that the Australian National Construction code (NCC 2019 [5]) assumes a solar absorptance of 0.6 for the reference building.

5. Effective R-value for Solacoat "white" and "cream" roof surfaces

Using the above results, one can now calculate the effective R-value for the Solacoat "white" and "cream" paint for downward heat flow including both new and dusty surface conditions:

(a) Solacoat "white"

For <u>new</u> surface conditions Solacoat "white" should provide about:

$$\frac{R_{ref} - R}{R_{ref}} = 1 - \frac{\left(6.5 + \frac{0.23 \times 500}{25}\right)}{\left(6.5 + \frac{0.60 \times 500}{25}\right)} = 0.40 \qquad (6)$$

of the required R-value for downward heat transfer, i.e. provide for about 40% of the required R-value when it is in new condition. Using a 4.1 m^2.K/W reference R-value for a roof coated with an average paint (see NCC 2019 preview for zone 1), this translates into and effective R-value provided by a <u>new</u> solar reflective Solacoat "white" paint for a roof of:

$$R_{ref} - R = 0.40 \times R_{ref} = 0.40 \times 4.1 = 1.64 \text{ m}^2\text{.K/W} \qquad (7)$$

Now using Eq. (5), $\alpha_{dust} = 0.8$ and α_{new} = 0.23 the <u>weathered</u> solar absorptance for the Solacoat "white" becomes $\alpha_{weathered}$ = 0.373. Therefore, a weathered Solacoat "white" surface should provide about:

$$\frac{R_{ref} - R}{R_{ref}} = 1 - \frac{\left(6.5 + \frac{0.373 \times 500}{25}\right)}{\left(6.5 + \frac{0.65 \times 500}{25}\right)} = 0.285 \qquad (8)$$

of the R-value for downward roof heat flow that would be required for a roof with average absorptance. Again, using a 4.1 m^2.K/W reference R-value for a roof coated with an average paint (see NCC 2019 preview), this translates into and effective R-value provided by <u>weathered</u> solar reflective Solacoat "white" paint for a roof of approximately:

$$R_{ref} - R = 0.285 \times R_{ref} = 0.285 \times 4.1 = 1.17 \text{ m}^2\text{.K/W} \qquad (9)$$

(b) Solacoat "cream"

The measurement by R&D Services suggest the solar absorptance for Solacoat "cream" is 0.151. Therefore, for new surface conditions Solacoat "cream" should provide about:

$$\frac{R_{ref}-R}{R_{ref}} = 1 - \frac{\left(6.5 + \frac{0.151 \times 500}{25}\right)}{\left(6.5 + \frac{0.60 \times 500}{25}\right)} = 0.485 \approx 0.49 \quad (10)$$

of the required R-value for downward heat transfer, i.e. the Solacoat cream surface in new conditions may substitute for about 48% of the required R-value when there is downward heat flow. Using a 4.1 m^2.K/W reference R-value for a roof coated with an average paint (see NCC 2019 preview for zone 1), this translates into and effective R-value provided by a new solar reflective Solacoat "cream" paint for a roof of:

$$R_{ref} - R = 0.49 \times R_{ref} = 0.49 \times 4.1 = 1.99 \text{ m}^2\text{.K/W} \quad (11)$$

Again using Eq. (5) and $\alpha_{dust} = 0.8$ and α_{new} = 0.151, the weathered solar absorptance for the Solacoat "cream" becomes $\alpha_{weathered}$ = 0.313. Therefore, a weathered Solacoat "cream" coating should provide a fraction of the required R-value to resist downward heat flow for a roof of about:

$$\frac{R_{ref}-R}{R_{ref}} = 1 - \frac{\left(6.5 + \frac{0.313 \times 500}{25}\right)}{\left(6.5 + \frac{0.65 \times 500}{25}\right)} = 0.345 \approx 0.35 \quad (12)$$

i.e. provide about 35% of the required R-value to resist downward roof heat flow under northern Australian solar radiation exposure. Again using R_{ref} = 4.1 m^2.K/W for the insulation required for an average roof, the effective R-value provided by the solar reflective Solacoat "cream" paint can be calculated from Eq. (12) as:

$$R_{ref} - R = 0.346 \times R_{ref} = 0.346 \times 4.1 = 1.42 \text{ m}^2\text{.K/W} \quad (13)$$

The results of this section are summarised in the below Table 2.

Table 2: R-value fractions and R-values for Rref = 4.1 m^2.K/W provided by Solacoat "white" and "cream". Note 'alpha' denotes the solar absorptance of the paint.

Surface	alpha	alpha_ref	R-value fraction provided by paint	R-value provided by paint for R_ref = 4.1 m^2.K/W
Solacoat "white" new	0.230	0.60	0.400	1.64
Solacoat "white" weathered	0.373	0.65	0.285	1.17
Solacoat "cream" new	0.151	0.60	0.485	1.99
Solacoat "cream" weathered	0.313	0.65	0.345	1.42

6. Australian National Construction Code (NCC)

The figures in Table 2 are only estimates for high solar radiation and temperature conditions experienced in northern Australia. In Australia the above calculated values cannot substitute for the roof R-value requirements set by the Australian National Construction Code (NCC). The NCC 2019 preview has only three roof solar absorptance ranges (≤ 0.4, 0.4 < solar absorptance ≤ 0.6, > 0.6), where the solar absorptance values for the assessment are understood to relate to new surfaces.

Therefore, the NCC 2019 cannot give full credit for a highly reflecting solar paint, but nevertheless provides about 24% R-value credit (or 1 m^2.K/W) in zone 1 for a roof having a solar absorptance ≤ 0.4 relative to one with 0.4 < solar absorptance ≤ 0.6.

The R-value credit of a solar reflective roof paint is <u>not</u> sufficient to substitute for insulation in Australia even for zone 1. However, one particular low cost case that may be of interest is the use of solar reflective roof paint in combination with thermally reflective insulation (e.g. aluminium coated sarking or thermally reflective insulation sandwiching a thin air space insulation layer – see also Fig. 1 in Section 7).

It is noted that the current NCC does not give an R-value credit for solar reflective wall paint and such credit appears limited to roofs only (see also calculations in Section 8 and discussion in Section 9). However, the NCC 2019 code allows the minimum wall R-value for the zones 1 to 5 to be reduced from 2.8 to 2.4 m^2.K/W when wall is shaded for sun incidence angles of at least 15^o from the vertical (see Fig. 3.12.1.2 in NCC 2019).

7. Reflective insulation in combination with solar reflective roof paint

Combining solar reflective roof paint with reflective insulation (sarking with low thermal emissivity aluminium surfaces just below the roof) is of interest. An example, for the reflective insulation is Kingspan AIR-CELL insulation [7] (see Fig. 1 below).

Residential Metal Roof

Typical Design Details

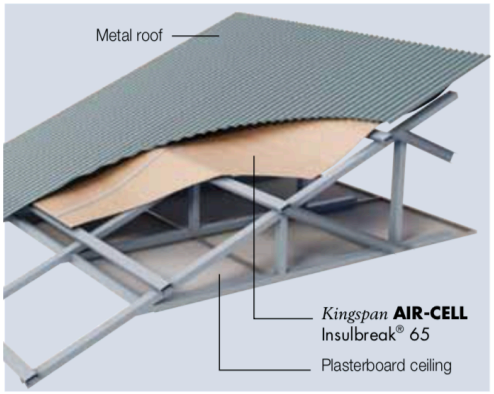

Figure 1 *Kingspan* **AIR-CELL** Insulbreak® 65 in a metal roof with a flat ceiling

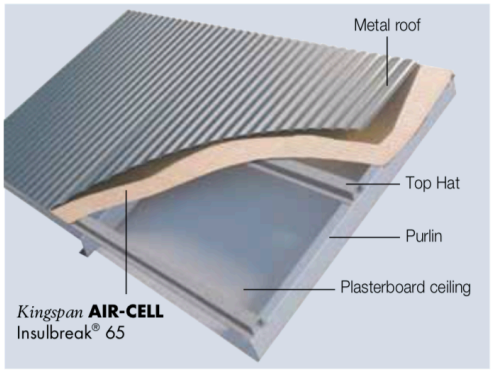

Figure 2 *Kingspan* **AIR-CELL** Insulbreak® 65 in a metal roof with a raked ceiling

Thermal Performance

Residential Metal Roof	Heat flow in	Heat flow out
Flat ceiling, ventilated	R_T 2.7	R_T1.3
Flat ceiling, non-ventilated	R_T 2.4	R_T1.5
Raked ceiling	R_T 2.7	R_T1.5

The R-values shown are Total R-values for the building element as required by the Energy Provisions of the Building Code of Australia. Kingspan **AIR-CELL®** *products are manufactured, tested and packaged in conformance with AS/NZS 4859.1. The contribution of the product Total R-values depends on installation and environmental conditions. The R-value will be reduced in the event of the accumulation of dust on the upward facing surfaces and in those cavities that are ventilated.*

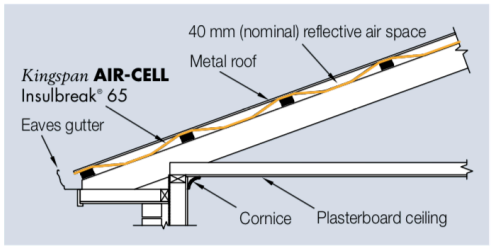

Figure 3 Side elevation of *Kingspan* **AIR-CELL** Insulbreak® 65 in a metal roof with a flat ceiling

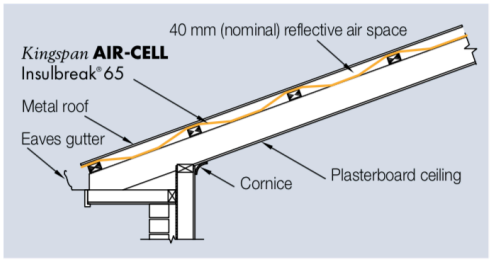

Figure 4 Side elevation of *Kingspan* **AIR-CELL** Insulbreak® 65 in a metal roof with a raked ceiling

Installation Instructions

1. Lay *Kingspan* **AIR-CELL** Insulbreak® 65 from the ridge to gutter, over and perpendicular to the roof battens.
2. Ensure a 50 mm overlap into the gutter and a nominal 40 mm sag between battens is achieved.
3. Allow 150 mm overlap at joins (50 mm is adequate when joins are to be taped - please refer to brochure "Kingspan Insulation Tape" for further information).
4. End joins should be overlapped by 600 mm if not taped.
5. Staple or tape to battens to hold in place until roofing is fixed.

Under Batten Installation

1. Starting at the gutter, roll out the *Kingspan* **AIR-CELL** Insulbreak® 65 across the rafters with the anti-glare side up, and ensuring a 50 mm overlap into the gutter is achieved.
2. Fix to rafters.
3. Allow 150 mm minimum overlap for joins (or 50 mm is adequate if joins are to be taped - please refer to brochure "Kingspan Insulation Tape" for further information).

Fig. 1: Extract from Kingspan AIR-CELL Insulbreak reflective insulation brochure [7]

The R-value achieved for a metal roof with Kingspan AIR-CELL Insulbreak reflective insulation shown in Fig. 1 ("Thermal Performance") still appear short of the 3.1 m^2.K/W NCC required R-value even for roofs with solar reflectance < 0.4 in zone 1. However, it should be noted that the R-values in the Fig. 1 show reflective insulation can provide a very different

R-values in down and up direction[4]. For a non-airconditioned building in a hot climate this is a desirable property, as the lower R-value in up direction assists the cooling of the building during night time, particularly when the roof thermal mass of the construction is low.

8. Effective R-value for walls

As already mentioned in Section 6, no R-value credit appears to be given for walls painted with solar reflective paint in the latest NCC 2019. To some extend this is understandable, as sidewalls, unlike the roof, receive less solar radiation and sometimes are completely shaded, say by a neighbouring building or a tree. However, as already discussed in Section 6 the NCC 2019 allows for a 0.4 m^2.K/W reduction in R-value requirements for walls that receive some shade form direct sunlight from a roof overhang (see Fig. 3.12.1.2 NCC 2019). This acknowledges that benefit may be derived from reduction in the solar radiation absorption.

In this section the maximum benefit of solar reflective wall paint in a building is investigated. This benefit may apply to buildings that do not receive any shade from surrounding buildings, trees or roof overhangs and that are in high solar radiation and temperature environment such as zone 1 in Australia.

Leaving aside the thermal mass of a wall, which is likely to be larger than for a metal roof, the equations of the previous section should also apply for walls, except that the solar radiation on an unshaded wall usually is lower than the solar radiation incident on a roof. An estimate of the solar radiation received by a wall may be made by comparing the clear sky solar radiation received on a horizontal surface compared to that on an East and a North oriented vertical walls. Figure 2 shows a plot of the approximate clear sky radiation incident on an equinox day at latitude 30^o for 0.2 ground reflectance.

[4] The R-values from the NCC 2019 preview for the roof construction shown in Fig. 1 with reflective insulation (emissivities of 0.2 outer and 0.05 on the inner surface) appear to suggest lower R-values than those in Fig. 1 (e.g. 1.93 instead of 2.7 m^2.K/W for the downward direction and 0.80 instead of 1.3 m^2.K/W for the upward direction for a ventilated roof with flat ceiling). However, the higher R-value of the AIR-CELL reflective insulation may be due to the extra air space created by the reflective insulation, the extra thermal resistance provided by the AIR-CELL insulation layer sandwiched between the reflective surfaces (0.20 m^2.K/W for AIR-CELL Insulbreak 65) and conservative values by the NCC 2019. This issue has not been further investigated.

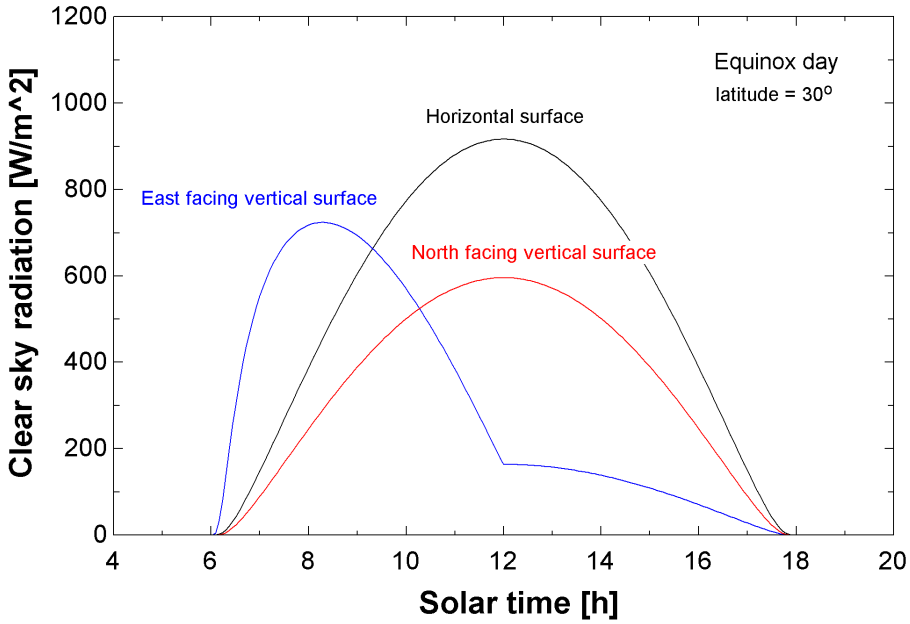

Fig. 2: Approximate clear sky radiation incident on a horizontal surface and east and west facing walls during an equinox day (20/21 March or 22/23 September) at a location with latitude of 30° for 0.2 ground reflectance.

In Fig. 2 the solar radiation on the east facing vertical surface will receive no direct solar radiation after solar noon and only receive diffuse solar radiation in the afternoon (sky and ground diffuse radiation). However, to keep the calculation for the relatively small diffuse radiation component simple, the shading for ground reflected solar radiation of the East facing vertical surface is neglected. This will overestimate the ground reflected diffuse radiation received in the afternoon for this surface. The calculated clear sky radiation values and the ratio of radiation relative to a horizontal surface are shown in Table 3.

Table 3: Approximate clear sky radiation incident on a horizontal surface and east and west facing walls during an equinox day at a location with latitude of 30o and the ratio of the radiation received on the vertical surfaces relative to the horizontal one.

	Clear sky solar radiation [MJ/day]	Ratio to horizontal surface solar radiation
Horizontal surface	23.42	1
Vertical North facing surface	15.08	0.644
Vertical East facing surface	13.07	0.558

To take some account for the overestimation of the ground diffuse clear sky solar radiation on the East facing vertical surface, the ratio to horizontal radiation is reduced from 0.558 to 0.5 for subsequent calculations

Using the approximate average daytime solar radiation of 500 W/m^2 for the roof surfaces in northern Australia, the ratio in Table 1 can now be used estimate the effective R-value also for a wall. To limit the length of the report the calculation is only performed for an east facing vertical wall. By symmetry the same result is obtained for a West facing wall.

Moreover, using the below sample calculation and result in Table 1 it should be easy to repeat the calculation for a north facing vertical surface.

(c) Solacoat "white" East facing unshaded vertical surface

For <u>new</u> surface conditions Solacoat "white" should provide about:

$$\frac{R_{ref} - R}{R_{ref}} = 1 - \frac{\left(6.5 + \frac{0.23 \times 0.5 \times 500}{25}\right)}{\left(6.5 + \frac{0.60 \times 0.5 \times 500}{25}\right)} = 0.296 \qquad (14)$$

of the required R-value for inward heat transfer, i.e. provide for about 30% of the required R-value when it is in new condition. The question that now arises is what is the solar absorptance of a vertical surface once it has been exposed to the elements? Clearly dust and dirt will not settle anywhere near as readily as it does on a horizontal surface. The author of this report is not aware of any data about this issue and it will now be assumed that the reflective surface will approximately retain its original solar absorptance value of 0.23 so that relative benefit of the wall painted with solar reflective paint in Eq. (14) should still apply for the weathered wall surface.

Using 2.8 m^2.K/W reference R-value for an unshaded wall coated with an average paint (see NCC 2019 preview), this translates into an effective R-value provided by the solar reflective Solacoat "white" paint of:

$$R_{ref} - R = 0.296 \times R_{ref} = 0.296 \times 2.8 = 0.83 \text{ m}^2\text{.K/W} \qquad (15)$$

i.e. the R-value benefit of the solar reflectively surface when a total resistance of 2.8 m^2.K/W is required is about 0.83 m^2.K/W.

(d) Solacoat "cream" East facing unshaded vertical surface

The measurement by R&D Services suggest the solar absorptance for Solacoat "cream" is 0.151. Therefore, for <u>new</u> surface conditions Solacoat "cream" should provide about:

$$\frac{R_{ref} - R}{R_{ref}} = 1 - \frac{\left(6.5 + \frac{0.151 \times 500}{25}\right)}{\left(6.5 + \frac{0.60 \times 500}{25}\right)} = 0.359 \approx 0.36 \qquad (16)$$

of the required R-value for inward heat transfer, i.e. the Solacoat cream surface in new conditions may substitute for about 36% of the required wall R-value when the surface exposed and there is inward heat flow.

Again using 2.8 m^2.K/W reference R-value for an unshaded wall coated wall with an average paint (see NCC 2019 preview), this translates into an effective R-value provided by the solar reflective Solacoat "white" paint of:

$$R_{ref} - R = 0.359 \times R_{ref} = 0.359 \times 2.8 = 1.01 \text{ m}^2\text{.K/W} \qquad (14)$$

i.e. the R-value benefit of the solar reflectively surface when a total resistance of 2.8 m^2.K/W is required is about 1.01 m^2.K/W.

The results for the vertical East facing wall are summarized in Table 4

Table 4. R-value fractions and R-values for Rref = 2.8 m^2.K/W provided by Solacoat "white" and "cream" for a wall in Northern Australia. Note 'alpha' denotes the solar absorptance of the paint.

Surface	alpha	alpha ref	R-value fraction provided by paint	R-value provided by paint for Rref = 2.8 m^2.K/W
Solacoat white new	0.230	0.60	0.296	0.83
Solacoat cream new	0.151	0.60	0.359	1.01

9. Discussion and Conclusions

The above calculations suggest that solar reflective paint on the roof and walls of a building can provide significant benefits in a hot and sunny climate. For buildings that are exposed to both high outside temperatures and high solar radiation the reflective paint can not only reduce the heat flow into the inside of a building, but also can prevent it from ever becoming as hot as a building coated with average paint during a prolonged exposure.

This report only estimates the reduction of heat flow through the reflective paint compared to an average paint for airconditioned and non-airconditioned buildings. The extra benefit that a non-airconditioned buildings (e.g. a shed) remains relatively cool when coated with a solar radiation reflective paint, but reaches higher interior temperatures after a prolonged exposure when coated with a solar radiation absorbent paint (no matter how substantial the insulation) is not readily quantified.

Solar reflective paint may act as low cost substitute for some of the required building insulation. However, the benefits need to be carefully stated and depend on the environmental conditions of the location. In this analysis it was assumed that the average daytime solar radiation is that 500 W/m^2 and that the daytime outside to inside building temperature difference $\overline{\Delta T}$ = 6.5 K. The reflective paint is only a partial substitute for insulation, particularly for buildings that are permanently air-conditioned, but can play a most valuable contribution.

The average daytime 500 W/m^2 solar radiation assumption is approximately satisfied for Northern Australia where the average daily solar radiation can reach 22 to 23 MJ/day (see Fig. A1 in AS/NZS 4234:2008) It is noted that 500 W/m^2 approximately corresponds to an average solar radiation of 21.5 MJ/day and corresponds to a full day average of 250 W/m2.

The average daytime outside to inside building temperature difference of $\overline{\Delta T}$ = 6.5 K, on the other hand, depends on the location and time of year. This daytime temperature difference is about twice the full day average temperature difference reported in ref. [3] for some

northern Australian locations (see Table 2 in ref [3]) and what is suggested by the Australian Bureau of Meteorology average annual cooling degree days for northern Australia (see BOM, climate data online). Since both the annual average *daytime* radiation and the temperature difference are about twice the annual average *full day* average values, this suggest that the daytime values are approximately consistent with the full day values, i.e. the daytime value approximately produce the same result from Eq. (3) as obtained from full day average values. Note a lower $\overline{\Delta T}$ value increase the effect of the reflective paint, while a higher one decreases it.

The effect of reflective paint on the heat flow reduction is best described in relative terms (e.g. saying that weathered Solacoat "cream" can provide for approximately 35% the total R-value required for a roof). This relative statement is independent of the actual total R-value required for the roof at a particular location. However, when quoting an actual equivalent R-value of the reflective paint it is important that that this value is quoted together with the reference value R-value to which the equivalent R-value relates (e.g. by saying that weathered Solacoat "cream" can provide 1.42 m^2.K/W of the 4.1 m^2.K/W in total R-value required for a roof of average colour in zone 1 of Australia).

It is noted once again that any of the benefits calculated in this report for particular paints and building roofs or walls are information only and that cannot be used in Australia as a substitute for NCC requirements. In particular it is noted that the values calculated for the vertical walls relate to maximum benefits that would only be achieved if the walls are unshaded and located in a hot and sunny location such as in northern Australia. Any shade through neighbouring housed or trees will immediately reduce the benefits.

References

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[4] National Construction Code (2016), Volume 2, Table 3.12.1.1a, Australian Building Codes Board.

[5] National Construction Code (2019 preview), Volume 2, Table 3.12.1.1a, Australian Building Codes Board.

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