Presentation to the Alternative Technology Association
Melbourne Branch

Cool Roof Coatings

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Introduction

- I am Managing Director of Nutech Paint Pty Ltd & Director of Nutech Paint LLC in the US.

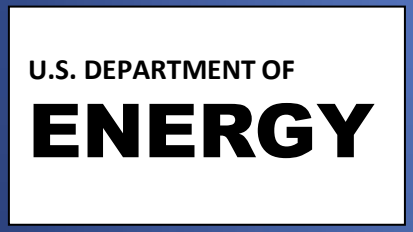
- Today I will discuss cool roof coatings and discuss the economic life cycle and cost/benefits of cool roof coatings compared to conventional roof coatings.

- I will also discuss a 2011 US study which suggests that cool roofs could contribute to global warming.

Who is Nutech Paint Pty Ltd

- Nutech Paint is Australia's oldest and largest specialised roof coating manufacturer with 40 years experience.
- Nutech has supplied coatings for more than 800,000 roofs world wide covering 128 million square metres of roof area.
- Nutech has been developing insulating and cool roof coatings for 15 years and has one of the worlds leading cool roof coatings called NXT Cool Zone®.


NXT
COOL ZONE



Nutech's is involved with organisations such as the US Cool Roof Rating Council (CRRC) Product Rating Program, Energy Star®, Department of Energy, California Energy Commission's Title 24 and the Reflective Roof Contractors Institute and combined with 40 years specialised industry experience and a leading Research and Development program this makes Nutech an industry leader in cool roof coatings.

Why should we use cool roofs

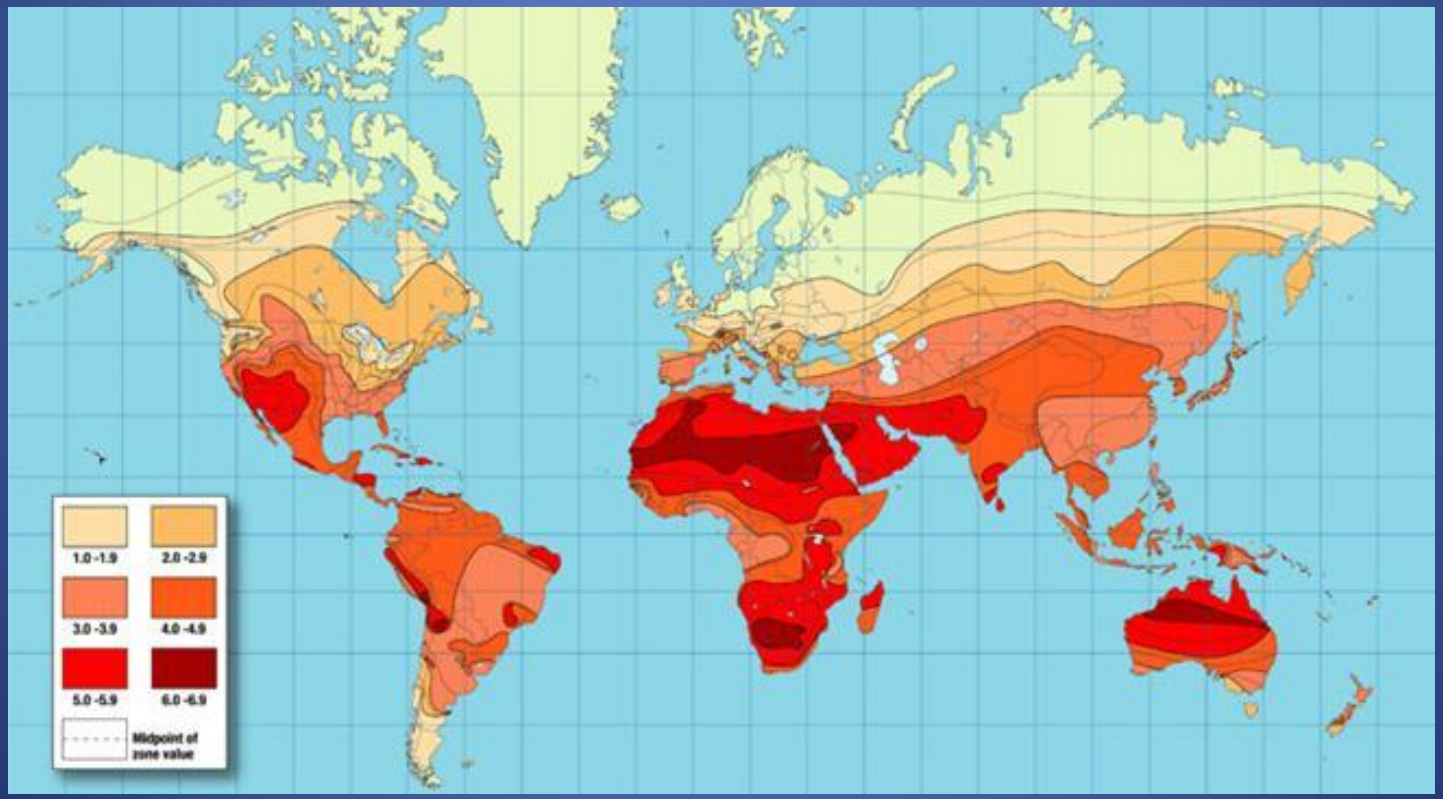
- Dark coloured roofs soak up the Sun's energy getting hotter and hotter as the day progresses.
- The roof space can become superheated up to 90°C on a 35°C day and the temperature of rooms below becomes unbearable, even with insulation.
- Air conditioning is overworked and temperature extremes affect the durability life of the whole roof structure.
- Dark heat absorbing and bare metal roofs make up more than 75% of the colours used in our suburbs. Insulation helps, although once the heat is inside the roof space, ceiling insulation only delays the heat transfer process.
- The best method is to prevent the roof space heating up in the first place by reflecting heat away from the roof surface. Rooms below are kept cooler reducing air conditioning energy consumption over the life time of the building.
- Air conditioning adds to greenhouse emissions and uses valuable natural resources damaging our environment. Cooling is becoming increasingly expensive due to rising energy costs, servicing and maintenance, so cost and resource savings in this area are very important.
- Hot buildings add to the Urban Heat Island effect

Benefits of Cool Roofs

- Water savings from reduced evaporative air conditioning
- Reduced electricity usage conserving energy and valuable resources and saving money
- Reduced peak electricity demand due to summer airconditioning
- Lower urban heat island build up resulting in reduced ozone and healthier living
- Encourages recycling of older viable roof structures
- Cooler buildings mean reduced chemicals and pollution for healthier cities
- Cooler buildings mean less dehydration and chemical emissions
- Encourages recycling of older viable roof structures and extends roofing lifecycle

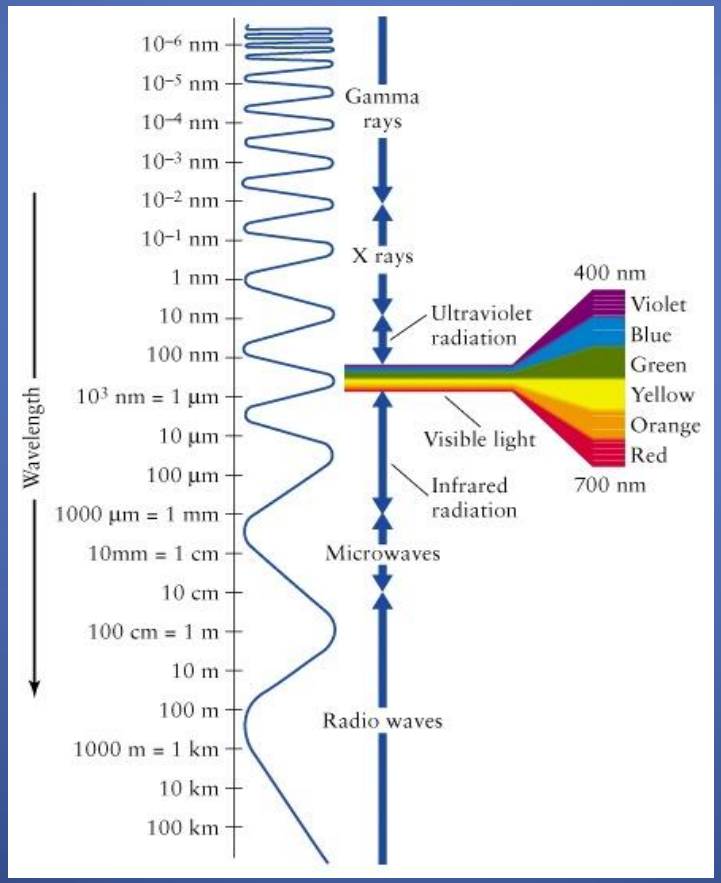
Why we need cool roofs in Australia

Solar Insolation refers to the amount of energy radiated from the sun onto a given surface in a given amount of time. This map shows that cool roofs are suited to Australia's hot summer climate.



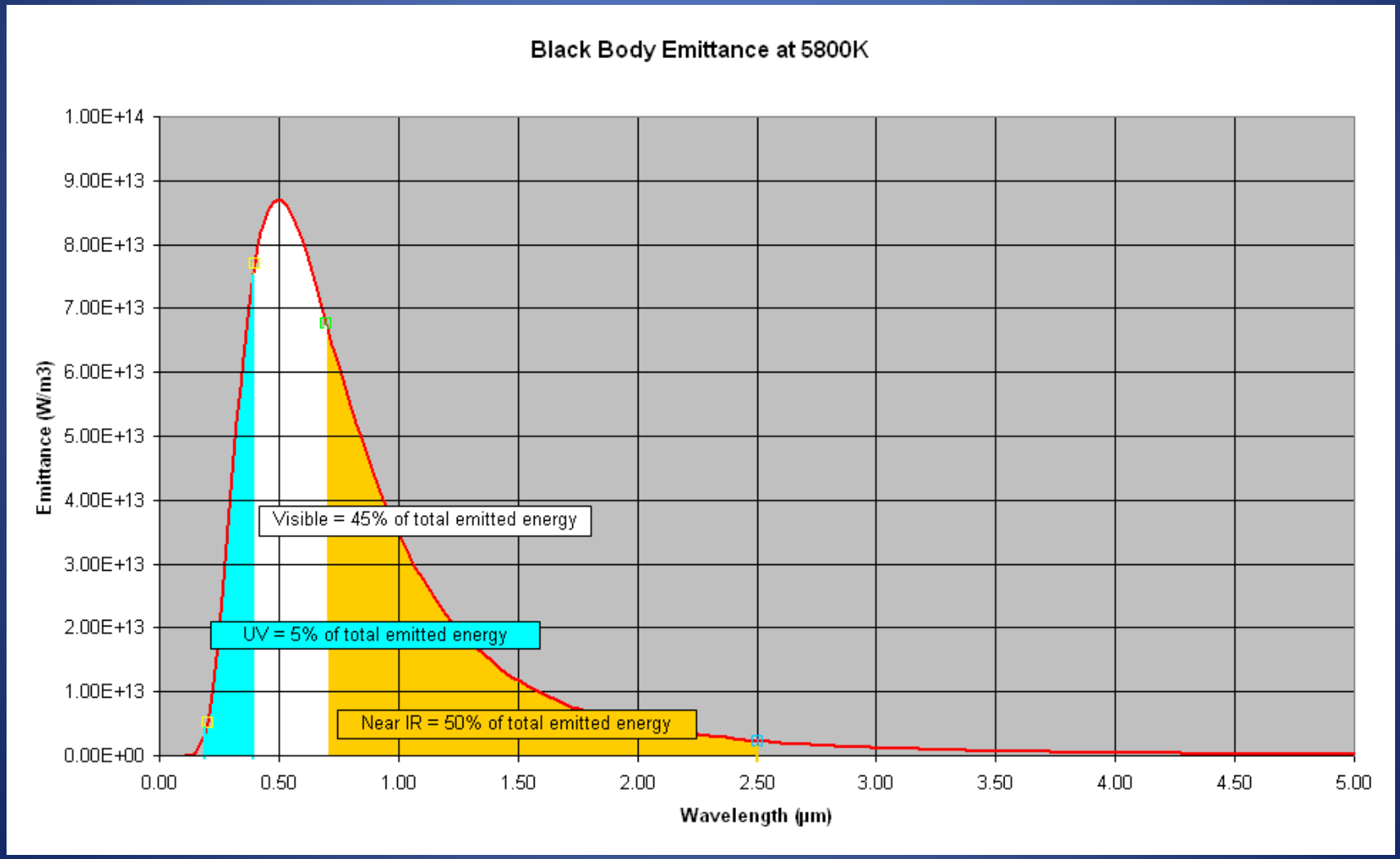
Wavelength of Sun's Energy

Infrared light from the Sun accounts for 49% of the heating of the Earth, with the rest being mostly caused by visible light and ultraviolet light that is absorbed then re-radiated at longer wavelengths.



Primary heat source from the Sun's Energy

Visible Light 45% Ultraviolet Light 5% Near Infrared Light 50%



Heat Island Effect

The term Heat Island describes cities that are hotter than rural areas. According to the US EPA "the annual mean air temperature of a city with 1 million people or more can be 1–3°C warmer than its surroundings. In the evening the difference can be as high as 12°C.

Heat islands affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality.

The main cause is heat radiation from buildings and pavements. Other causes are people, industry and reduced evapotranspiration due to lack of vegetation and development.

This diagram illustrates the temperature increase over a city caused by a heat island.

The US EPA has stated that cool roofs and pavements significantly help reduce urban Heat Islands.

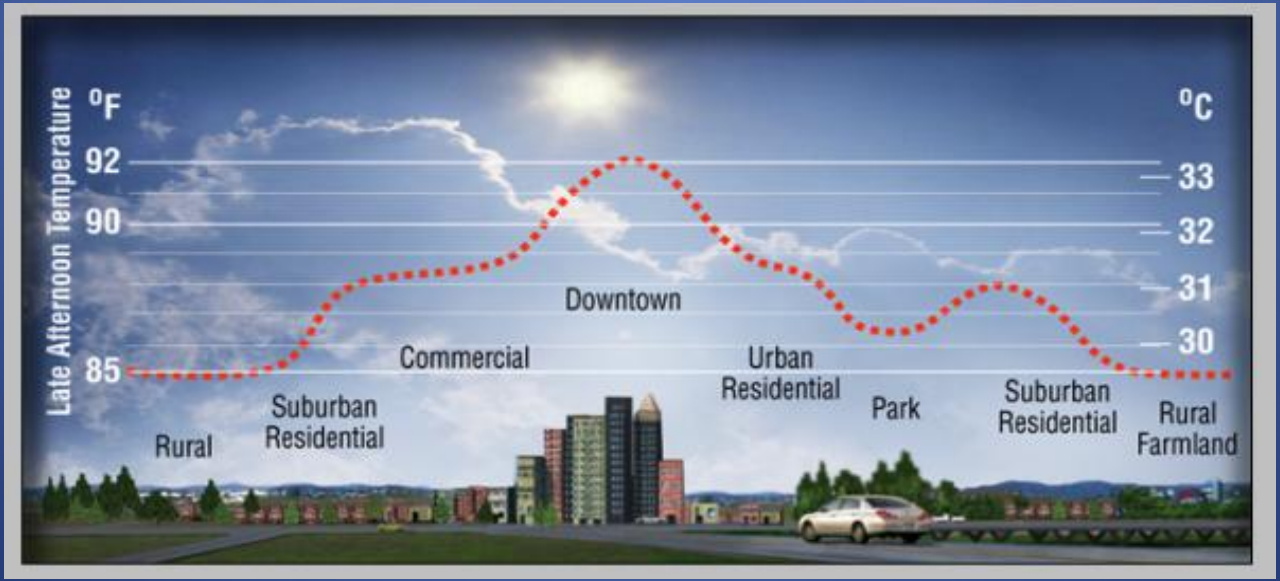


Image courtesy of Heat Island Group, Lawrence Berkeley National Laboratory

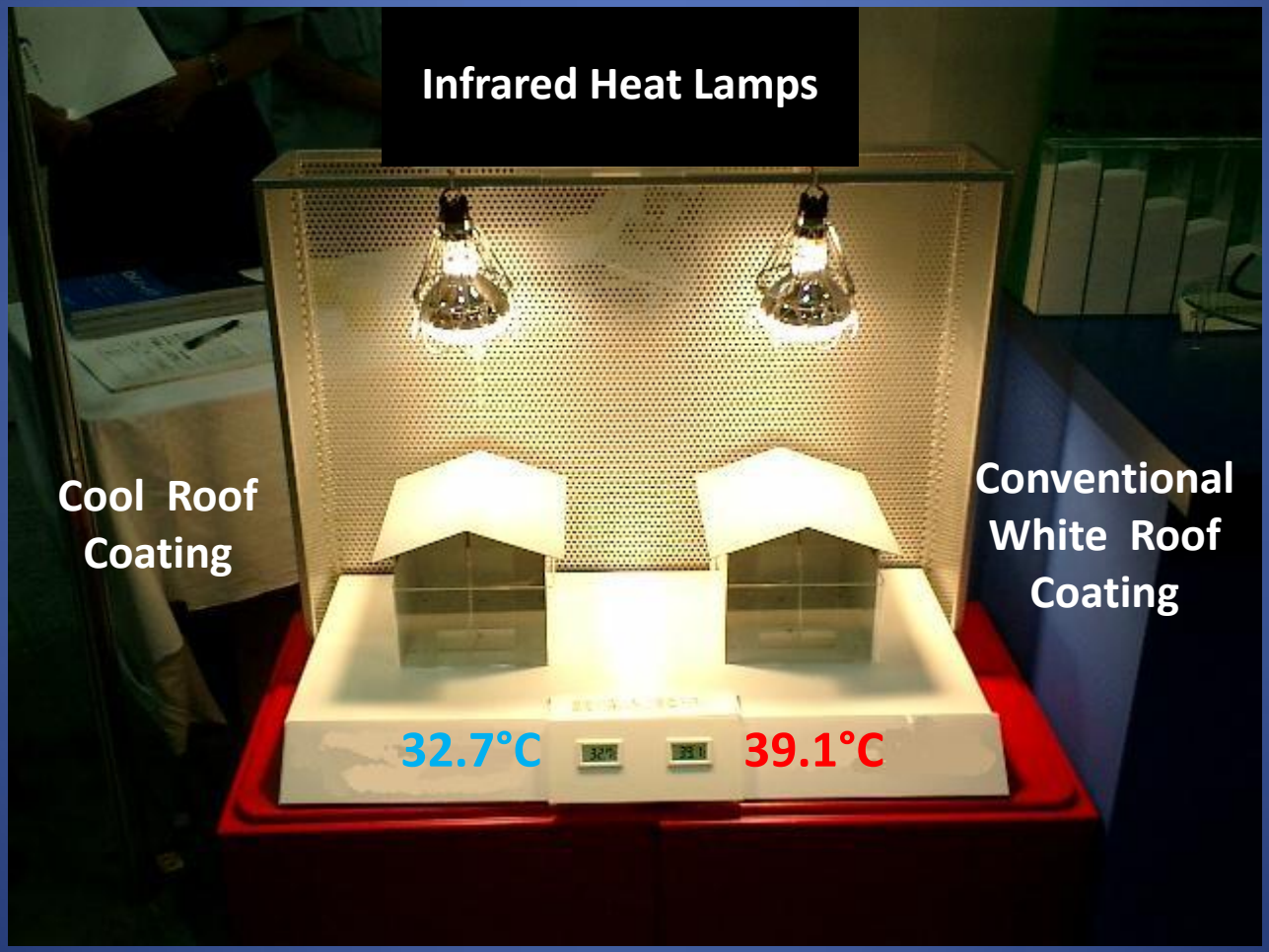
Benefits of Cool Roof Coatings

The use of reflective coatings on roof surfaces is a simple solution construction professionals can specify to increase building endurance and save money for building owners. Below is a list of benefits:

- Reduces interior temperature by 6-10 degrees
- Applies toward LEED credit
- Reduces roof surface temperature by 20 to 60 degrees
- Increases effective ‘R’ value
- Extends life of airconditioning systems
- Reduces energy consumption
- Can reduce the size of original airconditioner design system
- Creates a more comfortable and healthier interior environment
- Helps reduce heat islands
- Can be applied over almost any roof surface
- Extends life of roofing systems & therefore reduces waste disposal
- Easier installation when compared to other alternatives
- Reduces the carbon footprint of the building and the city

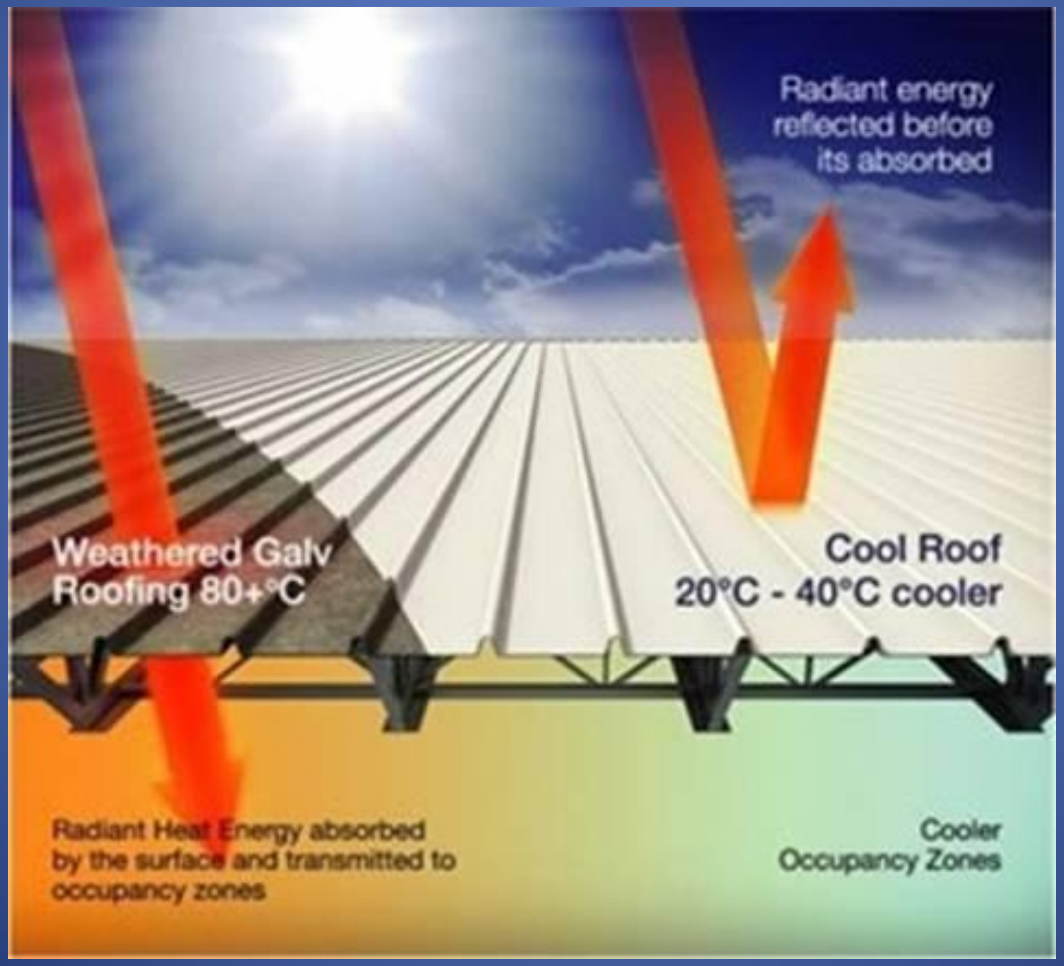
How effective are cool roof coatings?

Testing Cool Roof Performance



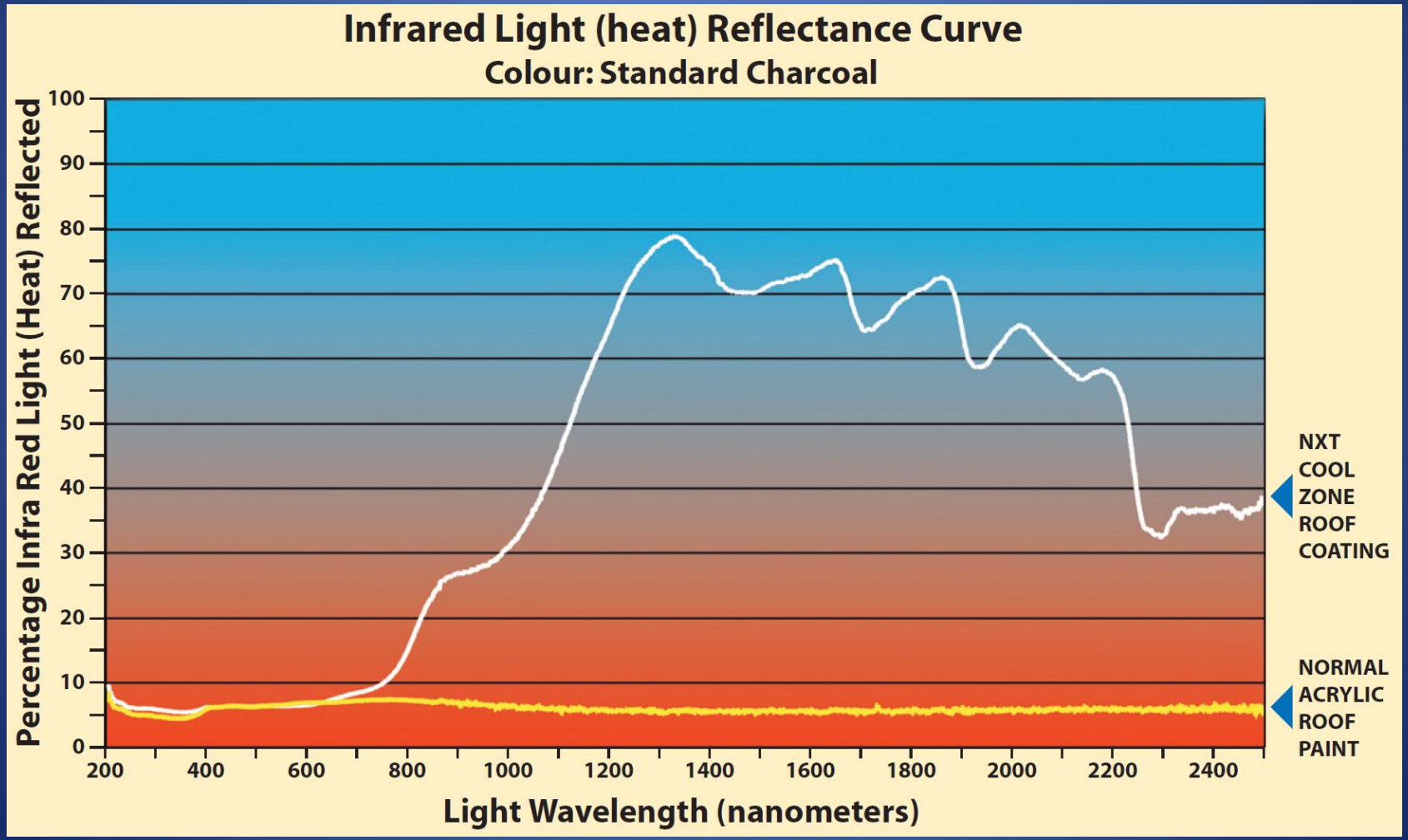
Galvanised Metal Roof – heat reflectance from Cool Coating

+90°C hotter than ambient

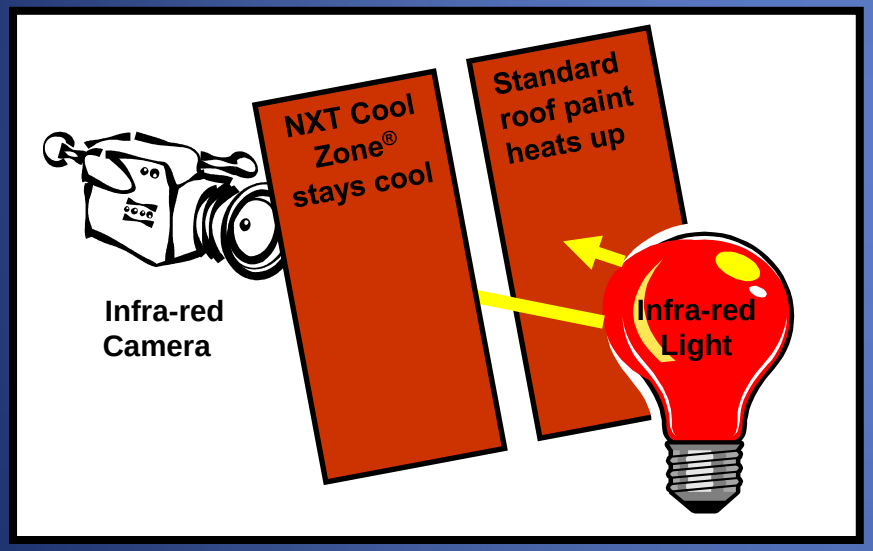


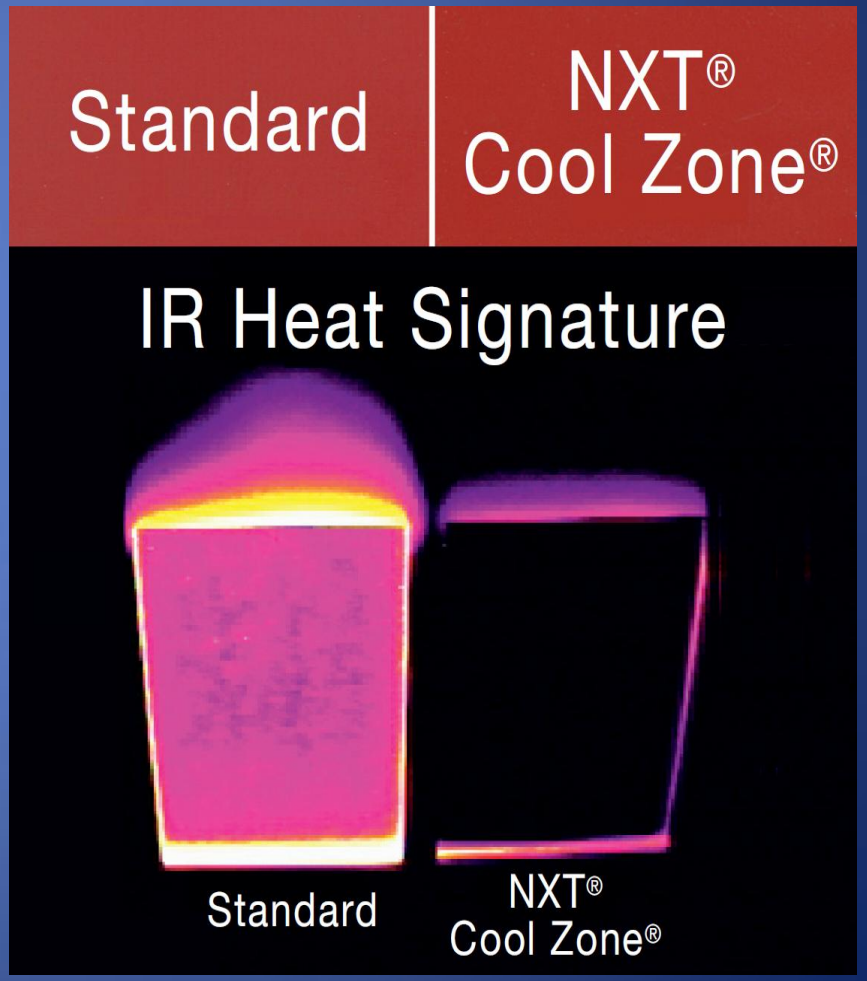
20-40°C cooler than uncoated

Infrared Reflectance - Cool Roof vs Conventional Paint



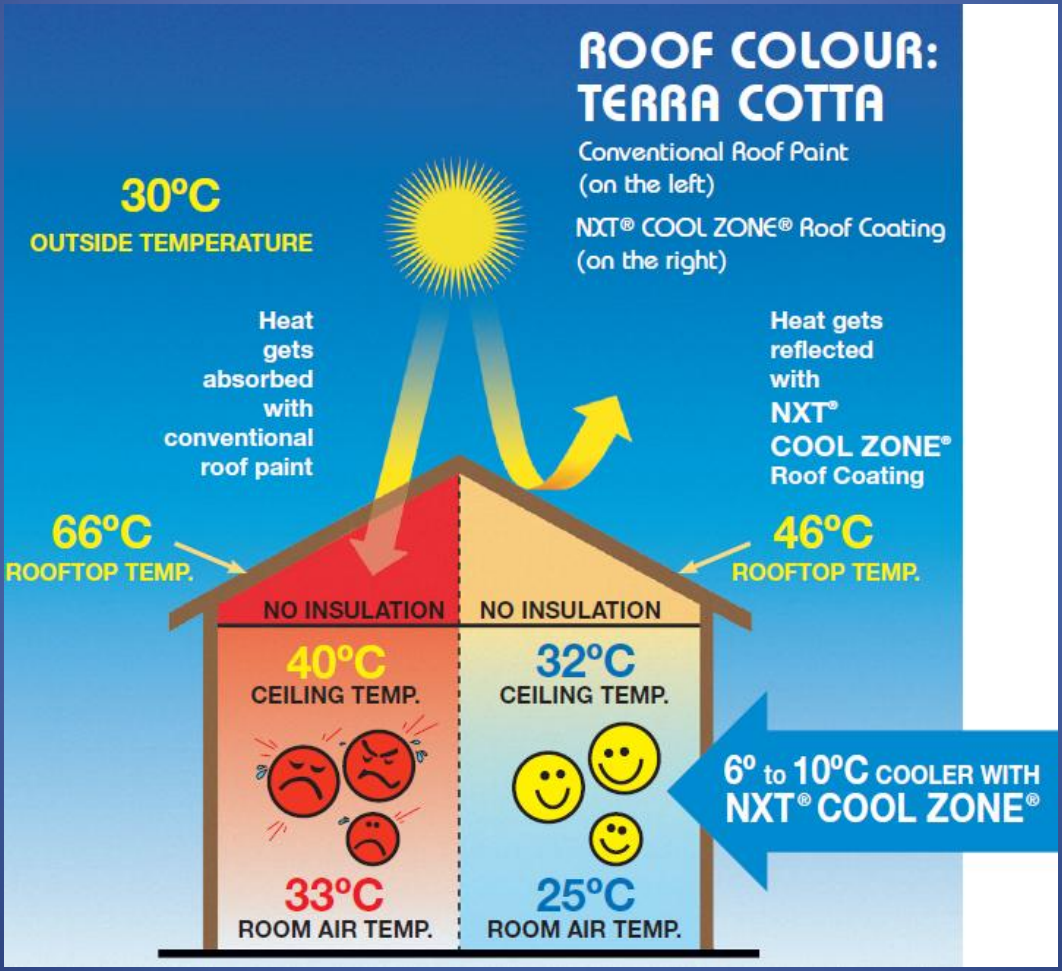
NXT Cool Zone Performance





NXT Cool Zone Performance

Based on Nutech field testing in 1998



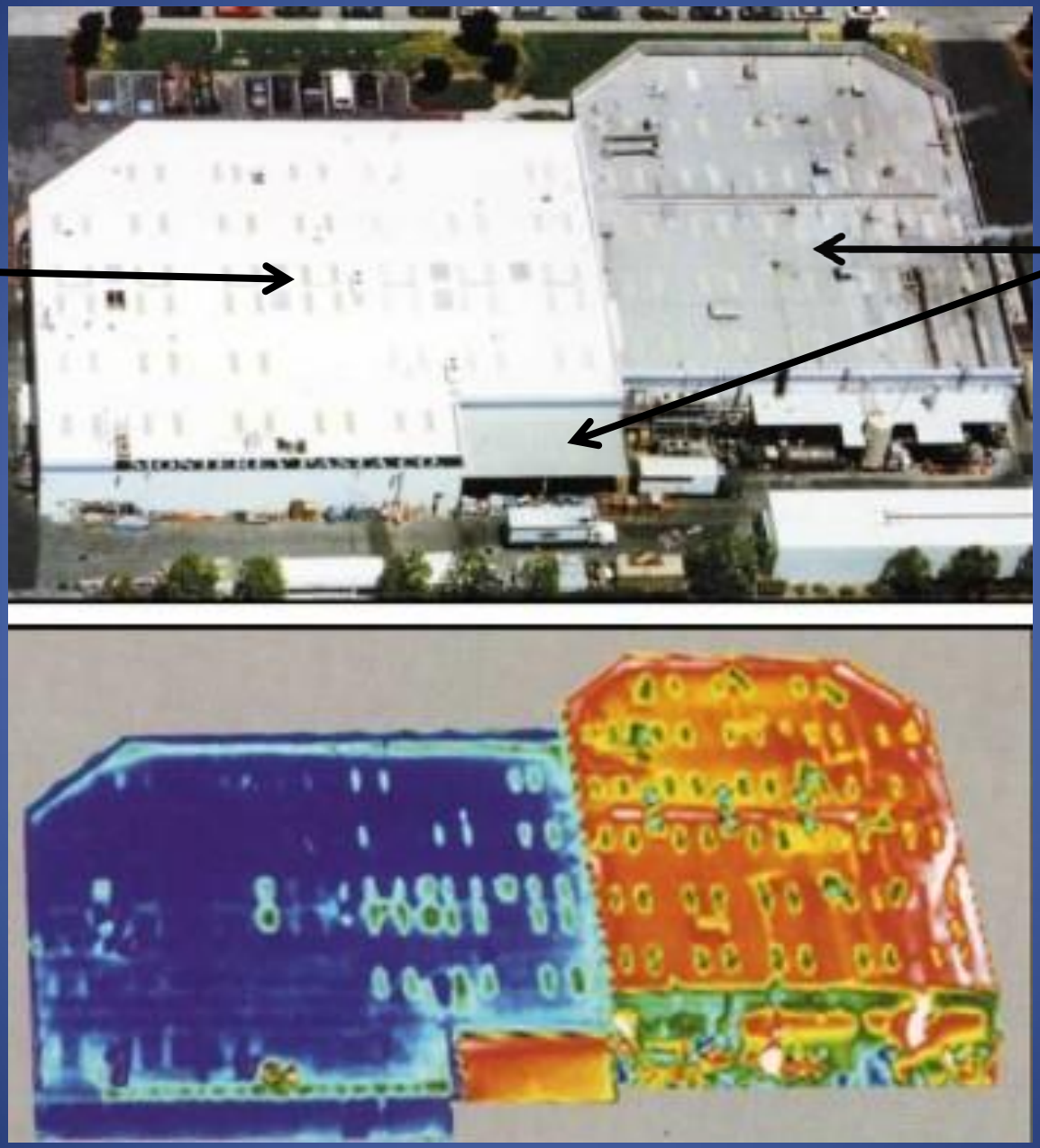
Examples:

- Malaysian shopping centre roof top lift machine rooms

- 3 x 3kW airconditions and insulated walls and ceiling – internal Temp +45°C on hot days.
- Lift motors cutting out due to thermal overload 2 to 3 times per day.
- After NXT White coating applied to roof and walls only 1 airconditioner required and temp < 25°C.
- No thermal overloads.

Cool Roof Coating on Galvanised metal roof

Dirty Galvanised Iron Roof uncoated



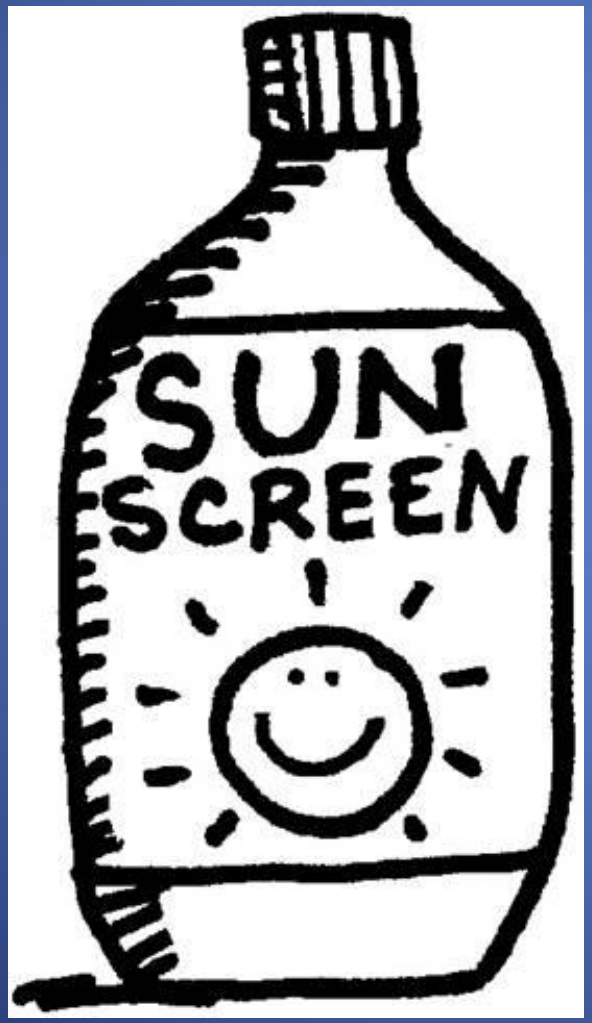
Cool
< 30°C

Hot
> 70°C

Emerald Cities™ cool paving

The temperature of new conventional black asphalt in parking lots averages 66-72°C from June through September in California. Emerald Cities™ Solar Reflective Cool Pavement is proven to reduce the surface heat of asphalt parking lots by 17-28°C. Heat absorbed by asphalt in the daytime is re-radiated at night increasing city heat by 5.5°C.

Sunscreen for your roof?



How do Cool Roofs work?

- Sunscreens protect against sunburn and skin damaging ultraviolet rays.
- Cool roof coatings protecting roofs in similar ways to reflect ultraviolet, infrared and visible light.
- Cool roof coatings consist of a binder blended with pigments and other additives that reflect the sun's energy and also provide a number of other benefits including protecting roof surfaces, waterproofing, contributing to longer roof service life and reducing air conditioning costs.

How do cool roof coatings reflect heat?

Cool roof coatings use a combination of organic and inorganic chemistry, like sunscreen to reflect, scatter or absorb radiation (sun light)

WHITE COATINGS

- Contain inorganic ingredients like zinc and titanium oxide to reflect or scatter infrared and ultraviolet radiation.
- Can have a high gloss finish to reflect visible light.
- Can also contain organic ingredients to absorb UV radiation.

*** The challenge is how to keep white surfaces clean to maintain a high TSR

COLOURED COATINGS – PASTEL & DEEP COLOURS INCLUDING BLACK

- **Contain c**omplex inorganic coloured pigments reflect the portion of sun's energy called near infrared between 700nm-2500nm comprising nearly 50% of the sun's radiation that reaches the earth's surface.
- Do not contain conventional organic or inorganic iron oxides which mostly absorb radiation or organic oxides which either absorb radiation or are invisible to infrared radiation.

Some Useful Terms

- TSR – Total Solar Reflectance is the fraction of solar energy that is reflected by the roof surface. A roof surface with high TSR will reflect thermal energy and remain cooler than one with a low TSR.
  (where TSR 0 = 0% reflectance & TSR 100 = 100% reflectance)

- TE - Thermal Emittance is the relative ability of the roof surface to radiate absorbed thermal heat (far infrared) back into the atmosphere (where TE 0% = 0% emittance and TE 100% = 100% emittance). A roof surface with a high TE can radiate heat it back into the atmosphere more readily than one with low TE.

A cool roof should have both high TSR and high TE

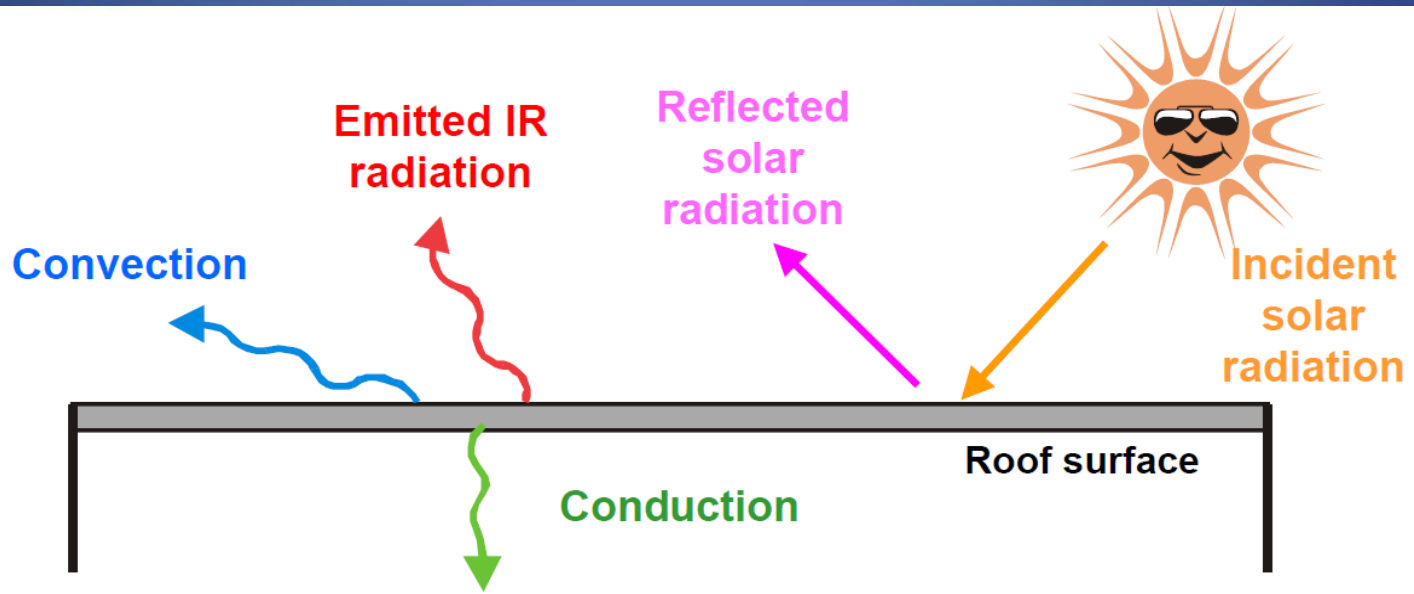
- Substituting a cool roof for a warm roof reduces conduction of heat into the building, convection of heat into the outside air, and thermal radiation of heat into the atmosphere. This benefits our buildings, our cities and our planet.

SRI – Solar Reflective Index

- SRI is a new term for considering the radiative properties of roofing materials. SRI is defined by ASTM Standard E1980-01 and is a calculation that uses solar reflectance and thermal emittance.

- SRI is a measure defined by the Lawrence Berkeley National Laboratory as the roof's ability to reject solar heat. It is defined so that the SRI of a standard black is 0 (reflectance 0.05, emittance 0.90) and a standard white is 100 (reflectance 0.80, emittance 0.90). Due to the way SRI is defined, particularly hot materials can have slightly negative values, and particularly cool materials can even exceed 100.

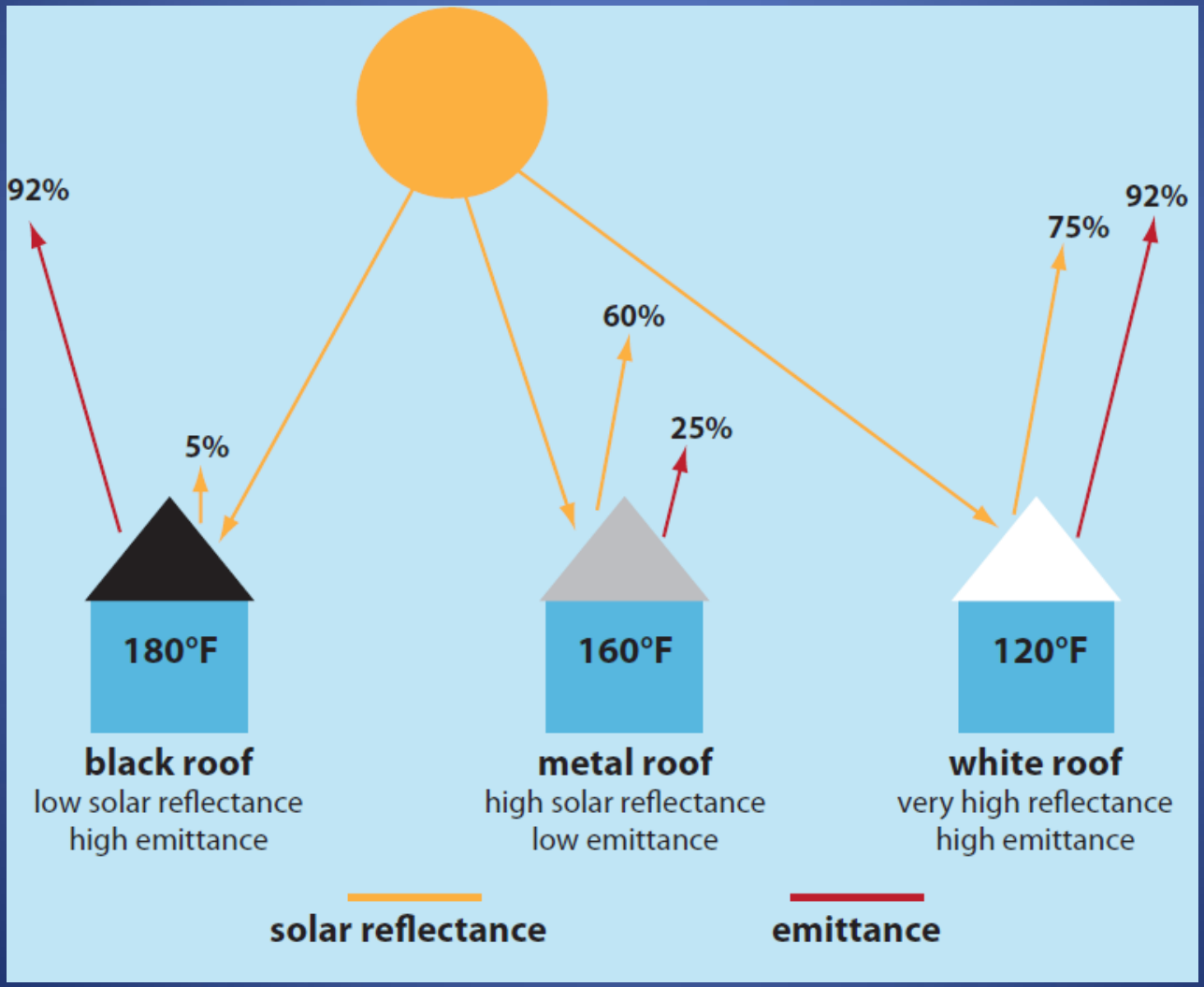
Cool roofs need high reflectance & emittance



To keep a roof cool in the summer, the roof surface should have:

- high solar reflectance
- high infrared emittance

Reflectance & Emittance of roofs



Spectrophotometer & Thermal Emissivity Meters

Measures TSR & TE to ASTM Standard E1980

TSR of standard Nutech NXT colours

Colour	TSR%		Colour	TSR%	
	Standard	NXT		Standard	NXT
Paperbark	47.5	61.7	Headland	25.2	38.1
Wheat	45.8	60.9	Sunset	28.0	38.0
Sandbank	38.4	53.8	Manor Red	17.5	32.3
Sandstone	35.5	52.0	**Indian Red**	**10.0**	**26.3**
Coral	42.1	55.6	Burgundy	20.9	30.9
Beige	26.7	48.1	Oxide Red	18.4	31.0
Dune	35.6	53.2	Saddle Brown	9.5	28.7
Sahara	22.1	42.7	Chocolate	6.0	24.8
Raccoon	16.6	37.7	**Mission Brown**	**5.9**	**24.2**
Pale Eucalypt	30.7	39.5	Light Grey	33.7	51.7
Wilderness	15.6	33.0	Earl Grey	22.3	41.8
Mid Brunswick Green	**6.5**	**24.0**	Bluestone	8.0	28.8
Bushland	19.4	39.3	**Charcoal**	**6.6**	**26.1**
Woodland Grey	10.0	29.6	Midnight	6.5	23.7
Ironstone	8.7	28.0	**Black**	**4.3**	**24.0**
Blue Ridge	15.0	33.0	**White**	**75.0**	**91.0**
Deep Ocean	**8.2**	**28.1**	Surfmist	61.9	71.8
Plantation	11.9	30.0	Shale Grey	42.5	57.4
Grecian Terracotta	28.4	42.1	**Gunmetal**	**12.0**	**35.0**
Terracotta	25.3	34.6	Jasper	14.0	33.1
Sienna	24.3	40.2			

Solyndra Testing of NXT

- In 2009 NXT Cool Zone was approved by the US Solyndra solar panel company as a cool reflective roof coating under its innovative solar arrays.
- Solyndra tested more than 400 cool roof coatings world wide. NXT Cool Zone recorded the highest Solyndra "reflectance" of any coating they have tested – 98.4%.

Emittance of Common Surfaces

• NXT Cool Zone	0.96
• Asbestos board	0.96
• Charcoal Paint	0.95
• Red Paint	0.91
• White painted surface	0.80 to 0.96
• Brick, fireclay	0.75
• New Aluminium Paint	0.27
• Steel Galvanised New	0.23
• Steel Galvanised old weathered	0.65
• Zincalume New	0.045
• Aluminium Foil	0.04
• Cadmium & Polished Silver	0.02

Where 0.0 Emissivity = no radiation of heat
1.0 Emissivity = 100% radiation.

Alternative approaches to current Cool Roof Technology

- White and light pastel coatings using Titanium Dioxide - poor to medium performance
- White & conventional coloured top coats using an InfraRed reflective white primer coat – poor performance due to heat conduction
- Heat reflective Inorganic pigments for White, pastel and dark colours – poor to medium performance
- Combination of organic, inorganic and insulative chemistries in top coat/primer systems to offer white, pastel and full colour range – maximum performance (Nutech R&D focus)

What are some of the challenges?

- There is a high usage rate of Titanium Dioxide in cool roof coatings.
- Titanium Dioxide is known as a primary cause of Photocatalysis resulting in radical degradation of paint binders – in the US its common to use ablative cool roof coatings where the rough surface continually chalks and erodes to expose a cleaner surface, however these very low gloss coatings usually only achieve 70% TSR or less. Nutech NXT White has an initial TSR of 91% and 3 year aged of >80%.
- This issue is a strong focus for Nutech R&D.

Photocatalysis

BHP metal coil roof sheet coating damaged by sunscreen containing $Ti0^2$

Other Challenges

- **Understanding cool roof performance specific to location is very important** .
  Aged performance of roof coatings in the southern and northern hemisphere are quite different. Temperature, humidity and rainfall significantly affect cool roof performance. Coatings from Europe and the US usually perform very badly in Australia because they contain copolymers including PVA and Styrene which are not durable in the southern hemisphere.

- **The durability of a paint affects its cool roof performance.**
  As the surface of a coating is damaged it loses its visible and UV light reflecting properties and has increased dirt pick up. This lowers the TSR of the coating over time.

- **Not all colour tinters and white pigments are durable.**
  Some colour tinters commonly used in the northern hemisphere such as carbon black and many organic pigments are not long term colour stable in the southern hemisphere. Many grades of titanium dioxide also do not perform well in high UV conditions. This affects cool roof performance and aged results in the southern hemisphere.

- **Membrane coatings are not necessarily the answer for Asian climates**
  The US focus on elastomeric membrane coatings is not as relevant in the Australasian markets. We have very different roof structure types in Australia and Asia compared to the US – for example we have very few timber shingle, BUR, polyurethane foam, asphalt shingle and composite tile roof. In the US > 80% of roof coatings are termed Elastomeric Membranes and need to remain flexible below 0 Degrees C. This is not required in Australia.

- **Testing field applied coatings, rather than laboratory prepared samples is essential**
  All cool roof rating testing in the US is based on samples prepared under Manufacturer Laboratory conditions rather than on site. Testing of field applied coatings is much more important and relevant. There is also a push by the CRRC for 1 year rather than 3 year aged coatings results for TSR. This may be suitable in the US but not in Australia where TSR declines over 3-5 years

Keeping a roof coating clean is difficult

Stained white cool roof

Regional differences affecting performance

Several years ago Bunnings sold Nippon Solaflect claiming 5% Infra-red reflectivity. The product was developed and manufactured in Asia. Based on our testing there were 3 serious problems with TESTED product;

- Charcoal coloured Solaflect was purchased from Bunnings. After application, the paint remained extremely soft and plastic for a number of days. Dirt pick up was extreme in Australian warm/dusty conditions, which detrimentally affects short and long term coating durability. The Polymer Resin Tg was too low and the paint continued to pick up dirt in hot conditions. It did not adequately wash clean with rain. Based on our testing Solaflect Charcoal would not satisfy the Energy Star criteria of 80% TSR retained after 3 years.
- Dirt pick resulted in loss of infra-red reflectivity very quickly and the dirt on the surface of the coating absorbed infrared heat and heated the sample surface by conduction, causing a further increased in temperature even if a white or light colour is used. As an example based on NXT testing, adding 3% conventional black pigment or similar surface dirt pick up can result in a loss of 97% infrared reflectivity in white paint.
- The Solaflect charcoal was manufactured without using conventional iron oxide or carbon black pigments. The colour was achieved using a combination of standard low infrared absorbing red/green/blue colours. However this made the coating relatively transparent to infrared light and almost all infrared light will penetrate through 2 to 4 coats of Solaflect. If the Solaflect Charcoal is painted over a dark substrate, infrared light will simply heat the substrate causing a rise in building temperature, as with normal paint.

How do you maintain high TSR in aged roof coatings ?

- Regular surface washing to remove contamination (Conventional coatings) – not practical or safe except under certain circumstances (commercial)
- Chemical treatment post application – with or without washing, costly and not practical or safe except under certain circumstances (commercial)
- Ablative white roof membranes are commonly used in the US – the surface continually sheds to expose cleaner coating sub surface (USA) – not practical & causes unsightly staining
- Effective in-film coating biocidal controls – very effective & low cost
- Highly durable coating formulations using correct binders & low surface friction (nano technology) to reduce dirt pick up (Nutech R&D focus) – premium performance

Cost Benefit Analysis of a Cool Roof

A	B	C	D	E	F	G	H	I	J	K	L	M
State	Ducted Split system Reverse Cycle	Estimated running cost 3 months	Estimate of Annual Operating Cost per State $	Period	Maintenance Cost $ Per Year	Air-conditioner Price New	Running & Maintenance Cost $ per Annual	12 Years	Saving estimate 50% operating Cost & 25% new price	Cool Roof Coating Cost $/ 18 sq. home	Potential Cost Saving $ over 12 Years	Conventional Roof Coating + Airconditioning Costs
QLD	15 kW	$ 951	$ 1,902	6 months	$ 250	$ 10,000	$ 2,152	$ 25,824	$ 15,412	$ 7,500	+$ 7,912	$ 32,574
NSW	10kW	$ 497	$ 746	4.5 months	$ 225	$ 7,500	$ 971	$ 11,652	$ 7,701	$ 7,500	+$ 201	$ 18,402
VIC	10kW	$ 472	$ 629	3 months	$ 200	$ 5,000	$ 829	$ 9,958	$ 6,229	$ 7,500	-$ 1,270	$ 16,708
									(			

Assumptions

Airconditioner running 8 hours per day

QLD = 6 months per year NSW = 4.5 months per year VIC = 3 months per year

Average single story 18 square house with cement roof tiles or metal roof = 210 square metre roof

Roof Coating Cost @ $35.00 per sq.m. material & labour cost (recoat 12-15 years required)

Conventional roof paint recoat required 6-19 years

Additional Cost Cool Roof Coating All States +$750

C = AGL estimated equipment operating costs 2011

F = Manufacturer quoted cost estimate 2012

G = Manufacturers quoted price installed average 2012

H = Service provider costs D + F

J = Nutech experience based observations 2010

K = Contractor Quoted Cost 2012

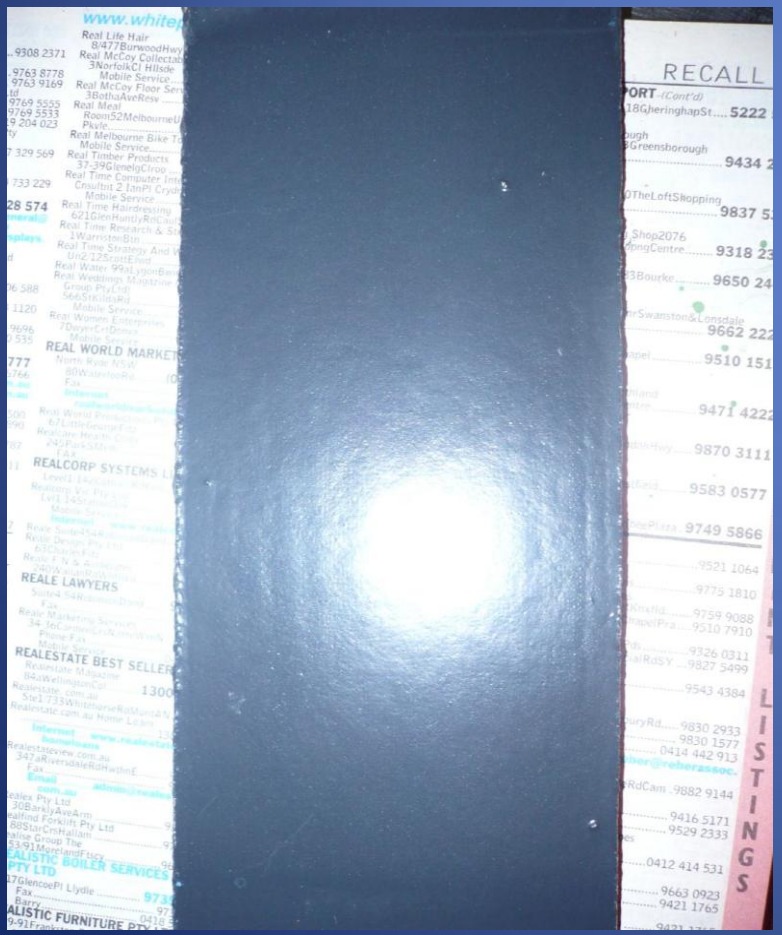
M = Material cost additional only for 18 squares (210 sq.m. roof)

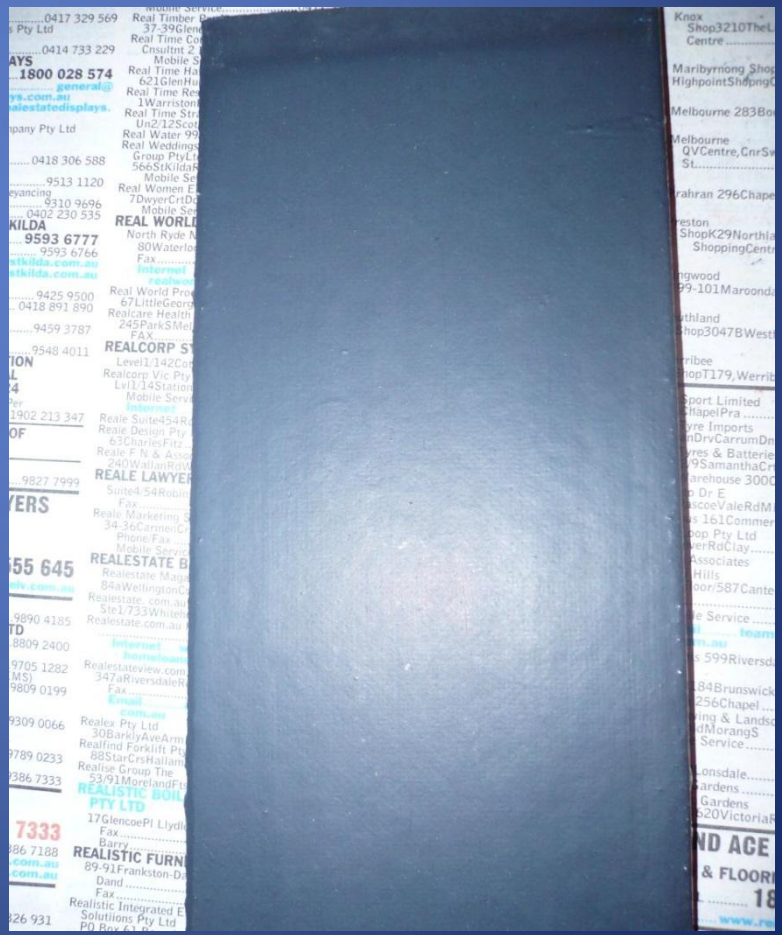
***** Does not take into consideration rebates that may be applicable and costs based on 2011 electricity prices**

Are cool roof coatings durable?

NXT Cool Zone Exposure Series

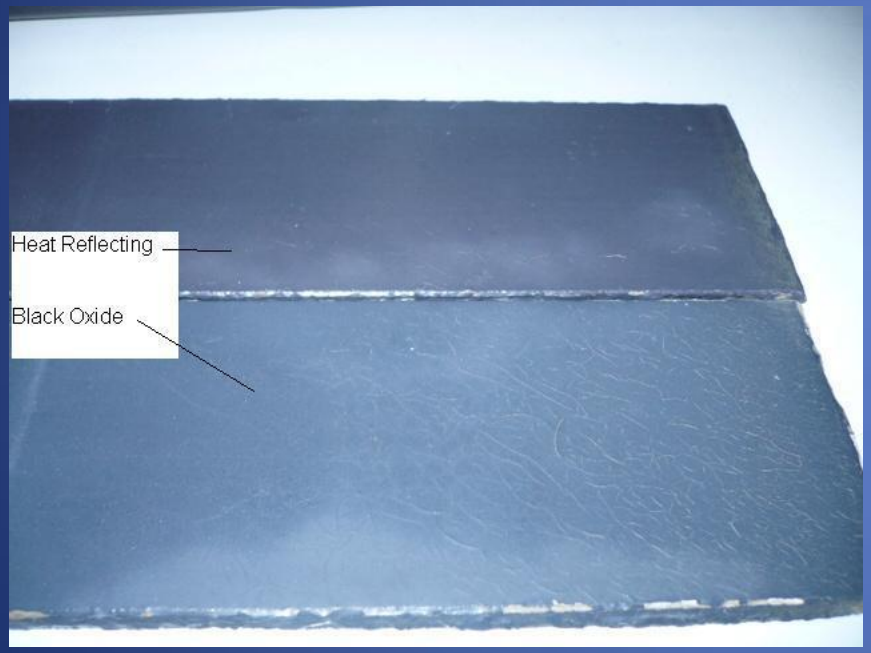
48 months exterior exposure = 120 months QUV exposure





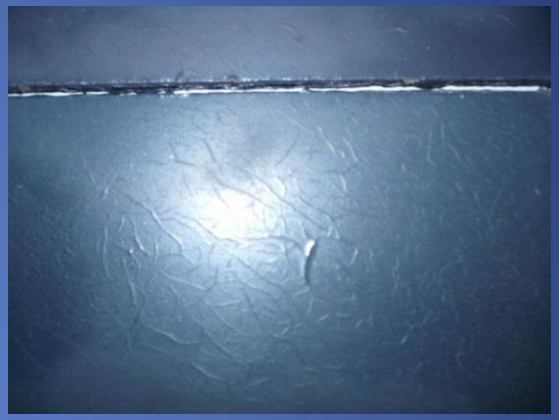
Coating Performance Comparison

Comparing conventional roof coating performance containing standard iron oxide pigments with NXT Cool Zone containing premium binder and heat reflecting pigments



Nutech NXT Cool Zone Charcoal – 10,500 hours exposure QUV Accelerated weather testing

- Sunlight exposure for 1 year = approximately 2100 hours QUV Accelerated Weather Testing



Conventional roof coating with iron Oxide Pigments (polymer damage and colour variation)

Nutech NXT Cool Zone with Heat Reflecting Pigments (no polymer damage or colour change)

Examples of Roof Coating Problems

Thin flaking tile coating


Delaminating cool roof coating on polyurethane foam
Goodman


Peeling and bubbling tile coating


Wrinkled metal roof coating


Weathered coating
Original coating


Peeling metal roof coating

Extreme mud cracking of cool roof coating on asphalt roof

Are Roof Easy to Paint

Contamination


Moss & lichen


Extensive surface rust


Very steep difficult access


Dangerous asbestos sheeting

Performance & Durability of Cool Roof Coatings

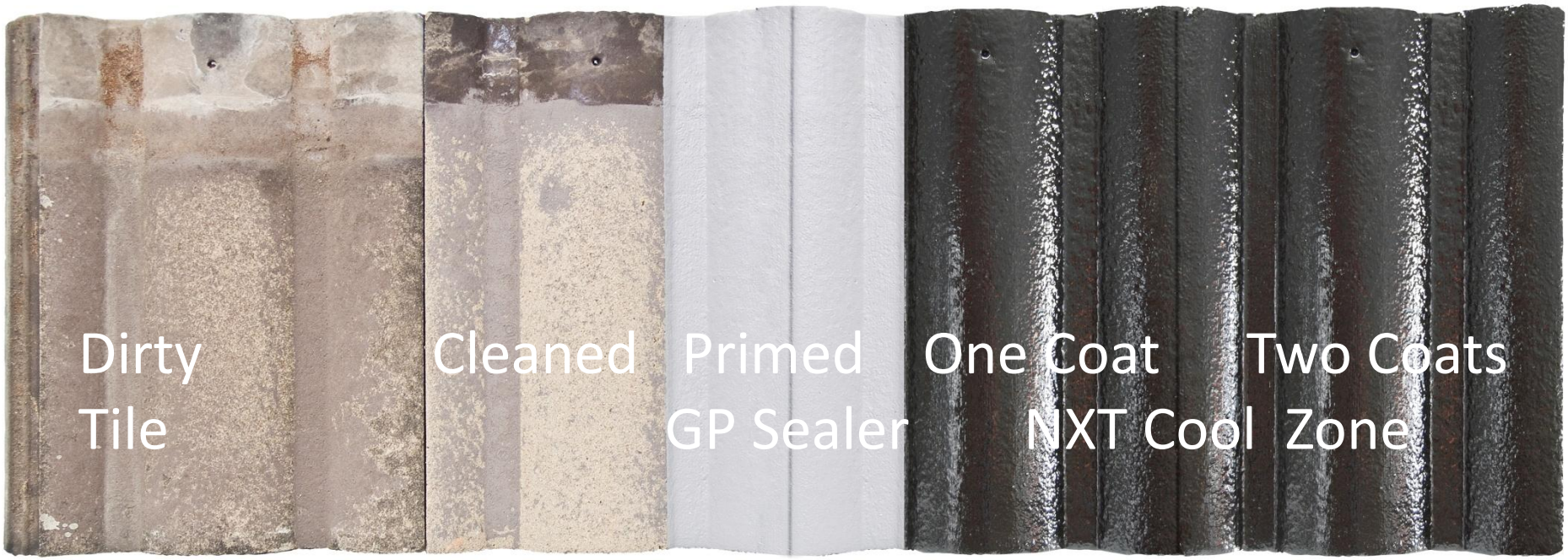
1. Coating Adhesion
2. Coating Durability
3. Coating Functionality

Coating Adhesion

- Correct surface preparation
- Correct primer selection
- Correct primer & top coat application
- Correct weather conditions during and immediately after application

The best cool roof coating in the world will perform no better than a cheap paint unless the surface preparation, primer selection, product application and weather conditions are suitable

Figure 1. Cement Roof Tile Coating Process



Coating Durability
Primary Factors

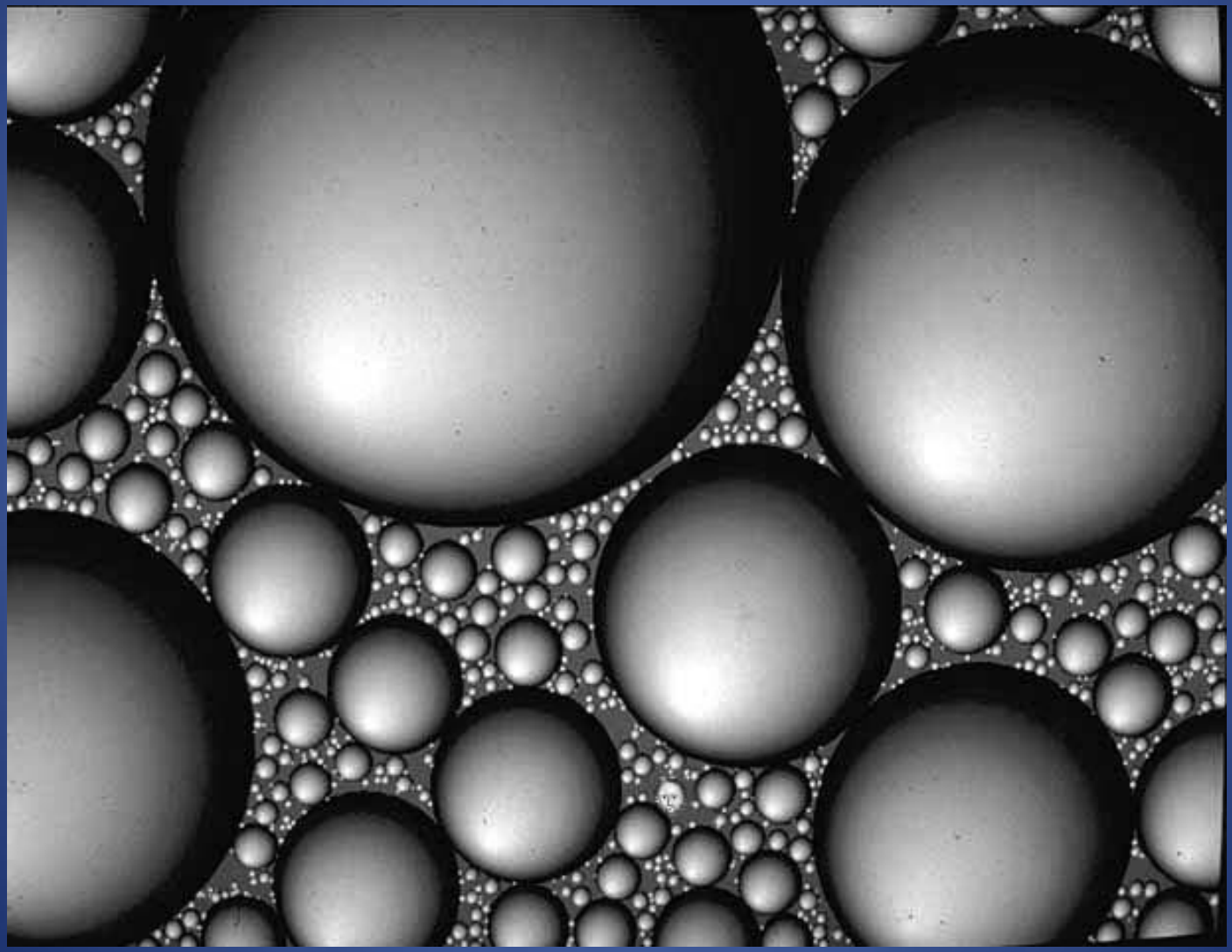
- The durability of a roof coating is determined primarily by the type, quality and quantity of the binder and pigments in the coating.

- Durability is also determined by the application process, the weather conditions during and after application, the suitability and quality of the primer and the total applied coating thickness.

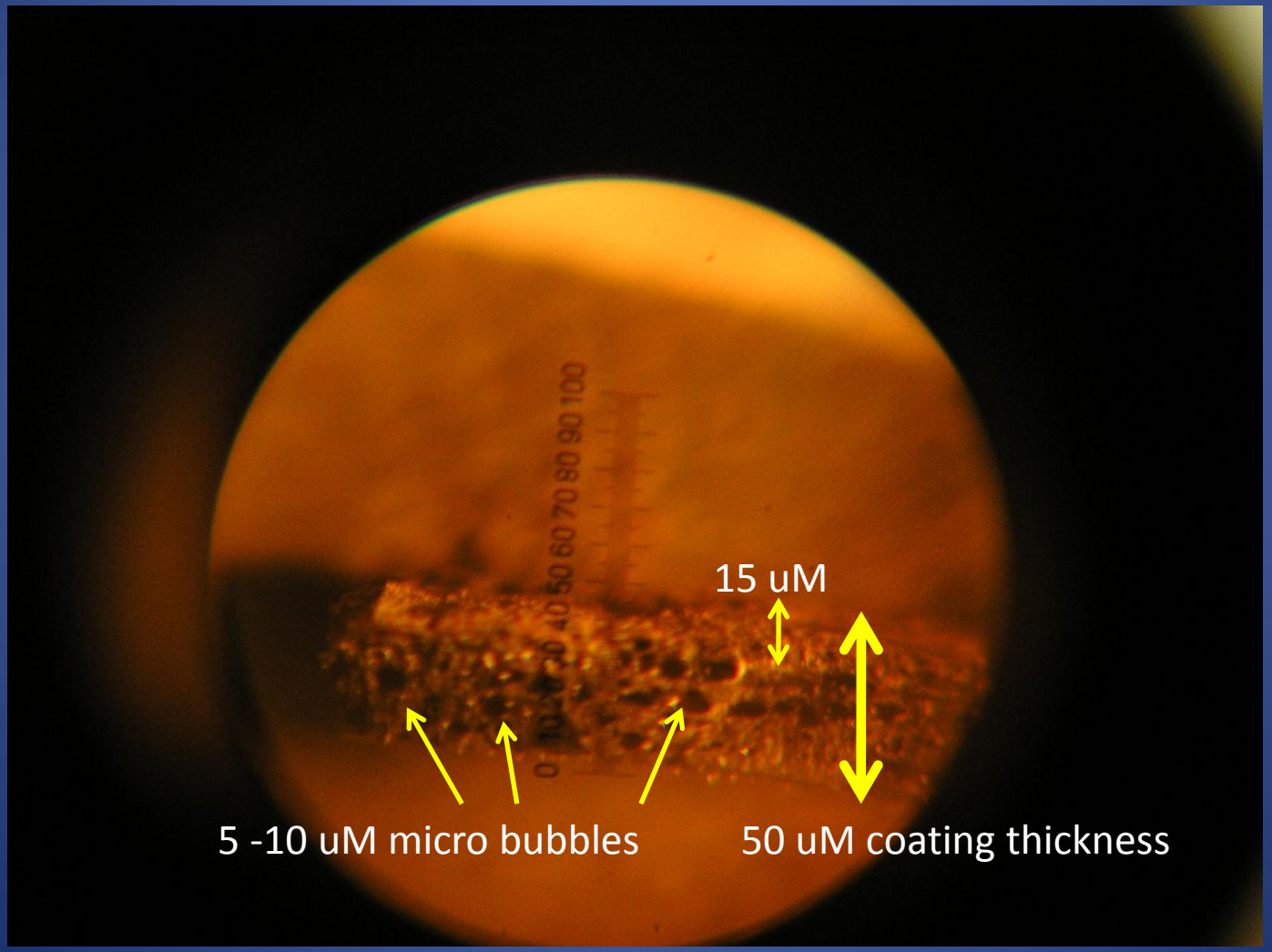
Coating Durability
Secondary Factors

- Paint rheology additives including thickeners affect application and dry film properties.
- Micro foam causes major durability problems in field applied airless spray applications.
- Gloss coatings are more durable and have higher solar reflectance than semi gloss, low sheen or flat coatings due to dirt moisture and surface light refraction.
- Biocide performance is critical for coating durability, surface contamination and therefore also cool roof performance.

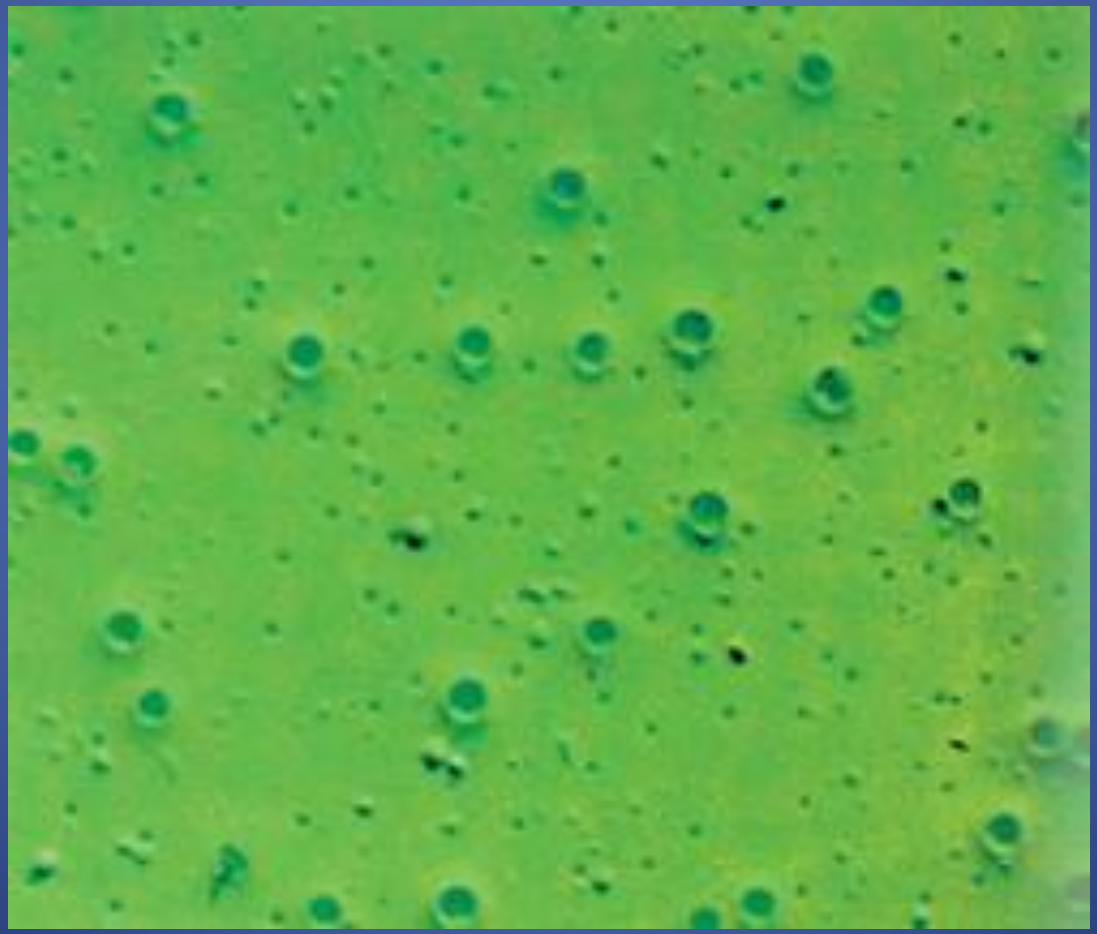
Micro Bubbles from airless spray application



5-10 micron air bubbles in a 50 micron thick coat of roof paint



5uM – 20uM air bubbles in the surface of a roof coating



Coating Functionality

- Anti corrosion metal sheet coatings
- Water proofing membranes for flat roofs
- Anti condensation for metal sheet
- Anti mould/fungus for high humidity areas
- Anti bacteria for contaminated & high humidity areas
- Sealer binder primer for loose fibrous asbestos cement surface or powdery oxidised loose surface.

Examples of Cool Roof Coatings on Commercial Buildings

NXT Cool Zone on shopping centre roof in California US


NXT Cool Zone on TipTop factory roof in Queensland

NXT Cool Zone on Exhibition Centre Roofs in China

NXT Cool Zone on McDonalds Roof in Scotland UK

NXT Cool Zone in Idaho US

NXT Cool Zone in Idaho US With Solyndra solar panels

Very large factory roofs in Califoria US

Do cool roofs cause global heating?

- In 2011 Jocobson and Ten Hoeve from the Department of Engineering at Stanford University in the US released a study titled “Effects of Urban Surfaces and White Roofs on Global and Regional Climate”

- Their first assumption was that dark asphalt shingles dominate in cities around the world. This assumption is incorrect as clay, concrete and slate tiles are predominately used outside the USA.

- Based on evaluation of very technical and theoretical modelling they hypothesised that although white roofs may reduce local energy demand and reduce local temperatures, their local ground cooling could stabilise surface air, reducing vertical heat fluxes and therefore reduce local cloudiness increasing local surface solar radiation, which could offset some of their local cooling benefit.

- They also stated that local cooling due to white roofs may reduce energy demand and thus other emissions as well, a factor not accounted for in their modelling. They stated that this feedback should be considered in any final assessment of the effects of white roofs on climate.
-

Consideration of this Modelling

- A subsequent study by the Heat Island Group at Lawrence Berkeley National Laboratory in November 2011 raised concerns about the validity of the Stanford Study citing the uncertainty acknowledged by the authors, statistically insignificant numerical results and insufficient analysis of local contributions to global feedback.
- They concluded that white roofs provide a sensible low-cost solution that significantly reduce energy needs and costs in a wide variety of climates and that a growing body of work suggests that selective use of white roofs may also reduce heating of the Earth's surface.
- A new observational and modelling study currently underway by Berkeley will compare surface-based and satellite-retrieved data of radiative fluxe and temperature from cool and dark roofs rather than using theoretical modelling to analyse the effect of cool roofs.
- Berkeley concluded that selective use of white roofs makes sense as part of an integrated strategy for a more sustainable human existence on Earth.
- A subsequent 2012 study by researchers at Concordia University included variables similar to those used in the Stanford study (e.g., cloud responses) and estimated that worldwide use of cool roofs and pavements in cities would generate a global cooling effect equivalent to offsetting up to 150 Gigatonnes of carbon dioxide emissions - enough to take every car in the world off the road for 50 years.

Summary

- Cool roof coatings can be highly durable
- Cost benefit analysis shows that cool roof coatings in Australia are an attractive investment
- Cool roof coatings are good for the environment, and our health
- Using cool roof coatings most likely do not add to the global warming effect

Keeping cool is not easy !!

Thank you