Tropical Environment Radiative Cooling Applications

A case study into the science and performance of SkyCool, a spectrally selective radiative cool roof coating, in a humid tropical environment.

It has been possible for the past 25 years to cool a building's outer sun-facing surfaces to several degrees below the ambient shade temperature throughout the day in relatively dry climates.

This study will examine the effects of radiative cooling in the challenging tropical environments. Thermal images will demonstrate the performance of radiative cooling on both the exterior and interior of buildings. It will also examine how this type of cooling compliments the air-conditioning required to maintain desired set points.

Case Study Site

The site for this case study is the Hypermart in Cianjur Indonesia, located south east of Jakarta. This Site measures approximately 10,000m^2

HYPERMARKET CIANJUR INDONEISA

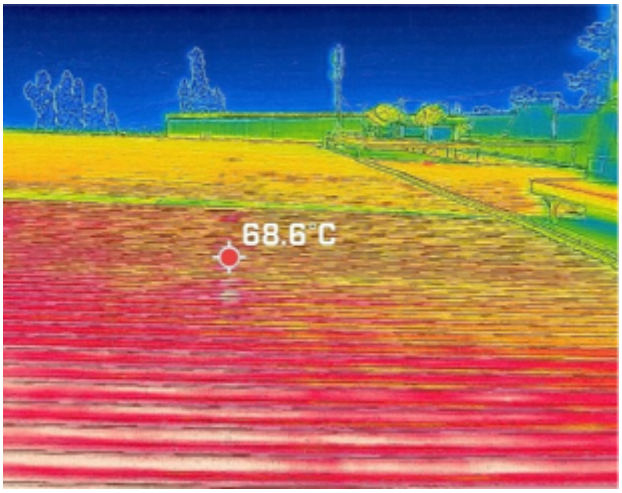
Site Goals

The Hypermarket operators were seeking to reduce the air conditioning power consumption and in turn increase the sites profitability and overall customer comfort level.

To achieve these goals it was anticipated that an application of SkyCool to the upper metal roof surface would lower the air-conditioning power required to maintain temperature set points.

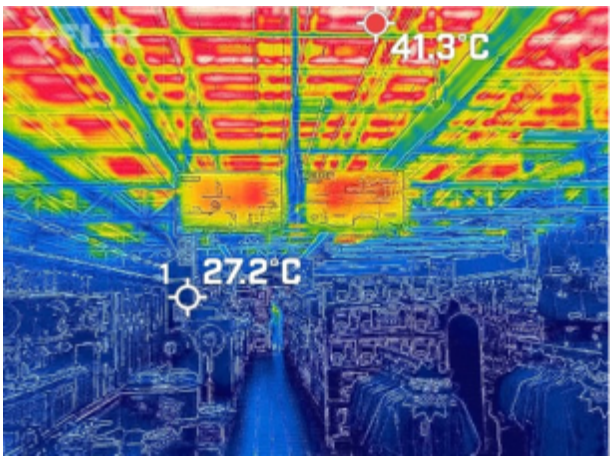
The application was made during July 2024, being the driest period for this region. Temperatures fluctuated between 34ºC during the day and 22ºC at night.

Prior to the commencement of works external and internal temperatures were recorded using a FLIR thermal imaging camera to visually demonstrate the base line conditions.



THIS IS TWICE THE AMBIENT TEMPERATURE

A NON-THERMAL FOR COMPARISON

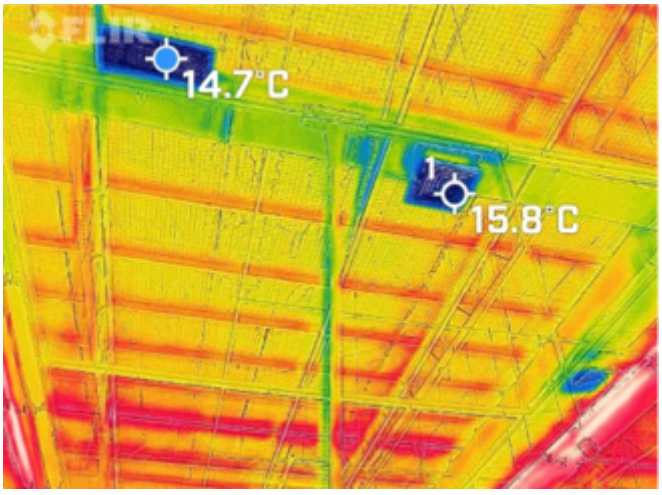


With an exterior surface temperature of 68.6ºC the internal temperature remains at 41ºC, this is with the air-conditioning plant operating at full capacity. It could be concluded that the sub roof steel is absorbing a portion of the cooled air, and this causes the internal steel to stay several degrees lower than the upper heated side

The client advised that the desired set point of 24ºC could not be met without a major mechanical plant upgrade.

The store had no more than 10 people in there at this time during the day, thus, it would be safe to say the solar load was by far the main heat load.

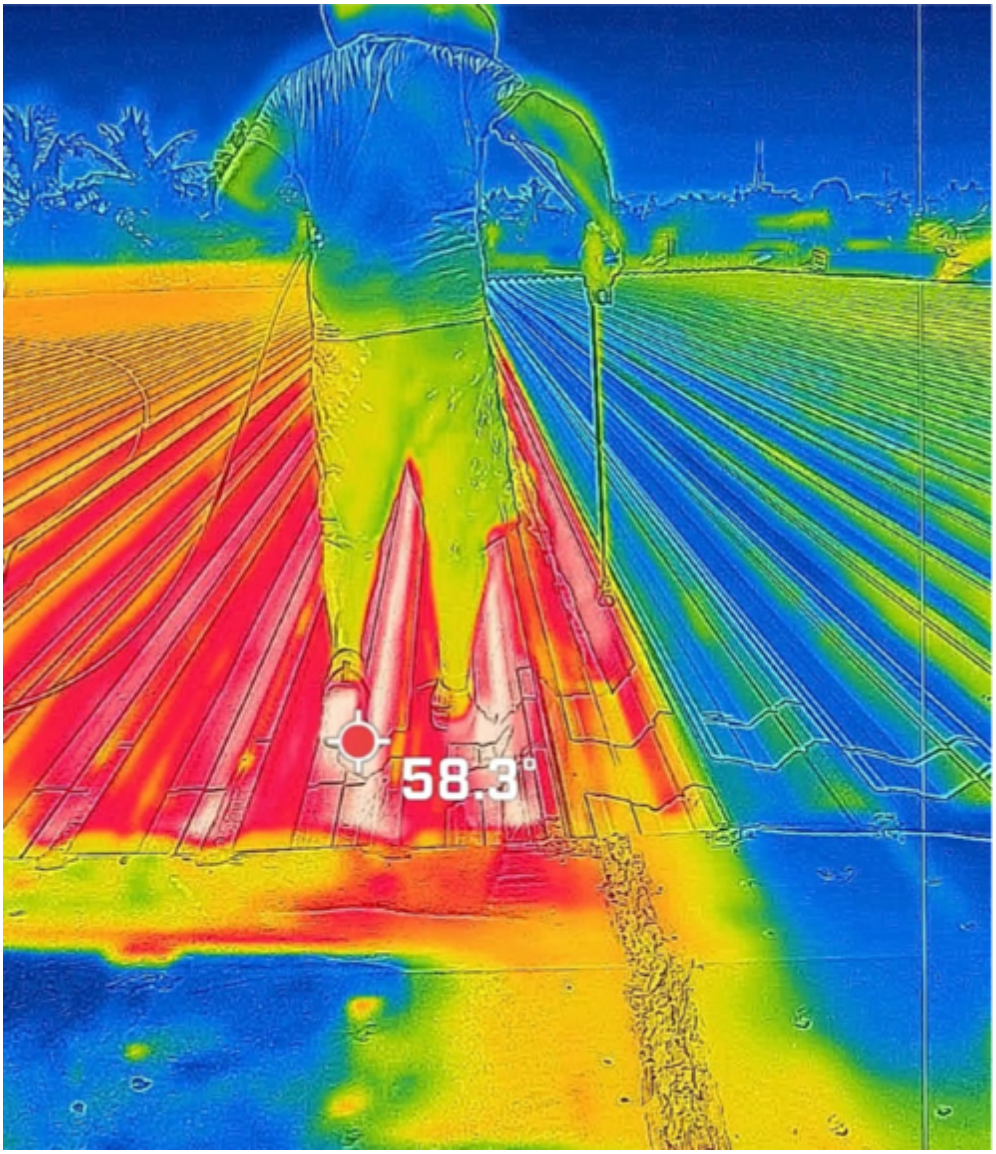
These pictures show the incoming chilled air temperature from the HVAC plant in normal and thermal imagery.



The Application

Following initial evaluation the roof surface was cleaned to prepare it for the application of SkyCool.

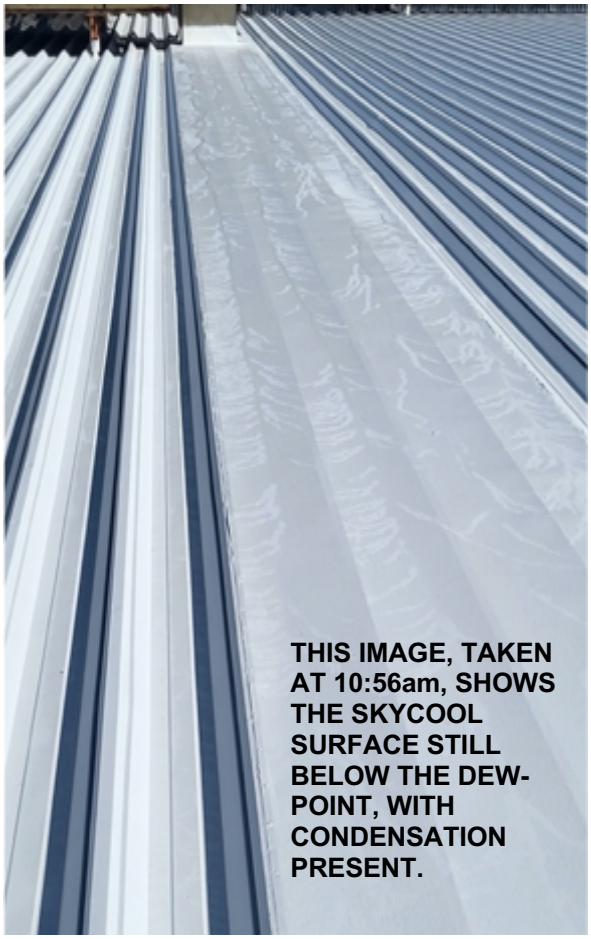
The 58.3ºC temperature steel is immediately cooled as the first coat is being applied.



During the application the client was invited to inspect the progress and to feel the cooling difference once an area was completed. On one such day the image on the following page was taken. Several of the staff were lying down on the cooled roof surface while their manager took photos, this was while the sun was directly overhead heating the air to 33ºC. The uncoated steel measured about 68ºC at that time.

This image shows the results of night time cooling. As there is an out-flow of energy with zero incoming solar load the surface continues to cool to a lower temperature.

On clear nights the surface temperature will fall by up to 13ºC below the ambient temperature in the tropics. This causes condensation to accumulate on the upper surface. SkyCool is hydrophobic by design and will prevent dirt from adhering to its surface. When the condensation forms it will lift the dirt and allow it to flow to the lower edge, effectively washing the surface and helping to maintain a clean surface. The internal temperature will depend upon on the level of sub roof insulation below the metal surface.



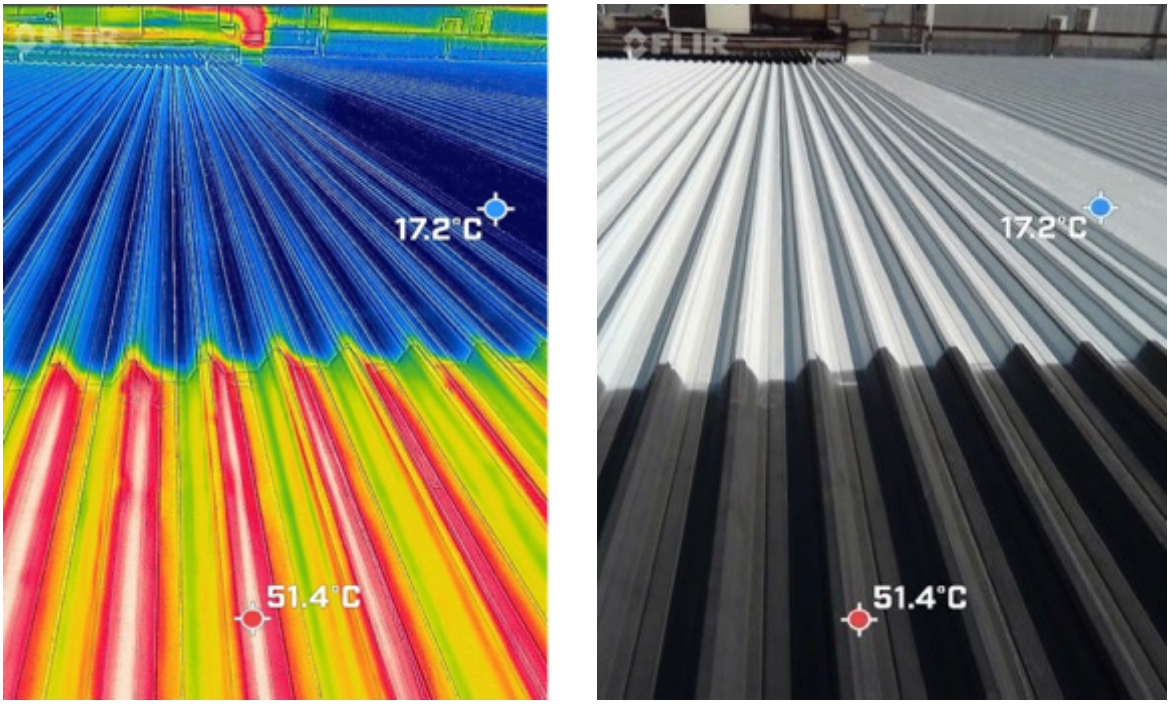
THIS IMAGE, TAKEN AT 10:56am, SHOWS THE SKYCOOL SURFACE STILL BELOW THE DEW-POINT, WITH CONDENSATION PRESENT.

Insulation slows the rate of heat transfer from the interior to the steel roof surface since it was originally designed to retain warmth within a building in colder climates. In warm climates sub-roof insulation is partially working against the performance of SkyCool.

The coated surface has been measured to have up to 40 watts/m^2 of energy outflow to the sky over night while the day time surface temperature is generally around 5°C below the shaded ambient air temperature. Normally, the conducted heat load from within a building as well as the solar load will dramatically increase the uncoated surface temperature.

SkyCool's unique performance is its ability to tune the outgoing radiation to the 8-13micron frequency window, such that the rejected heat does not warm the surrounding air.

See UTS report on SkyCool - https://www.skycool.net.au/uts. and
https://www.sciencedirect.com/science/article/abs/pii/S0306261918318373



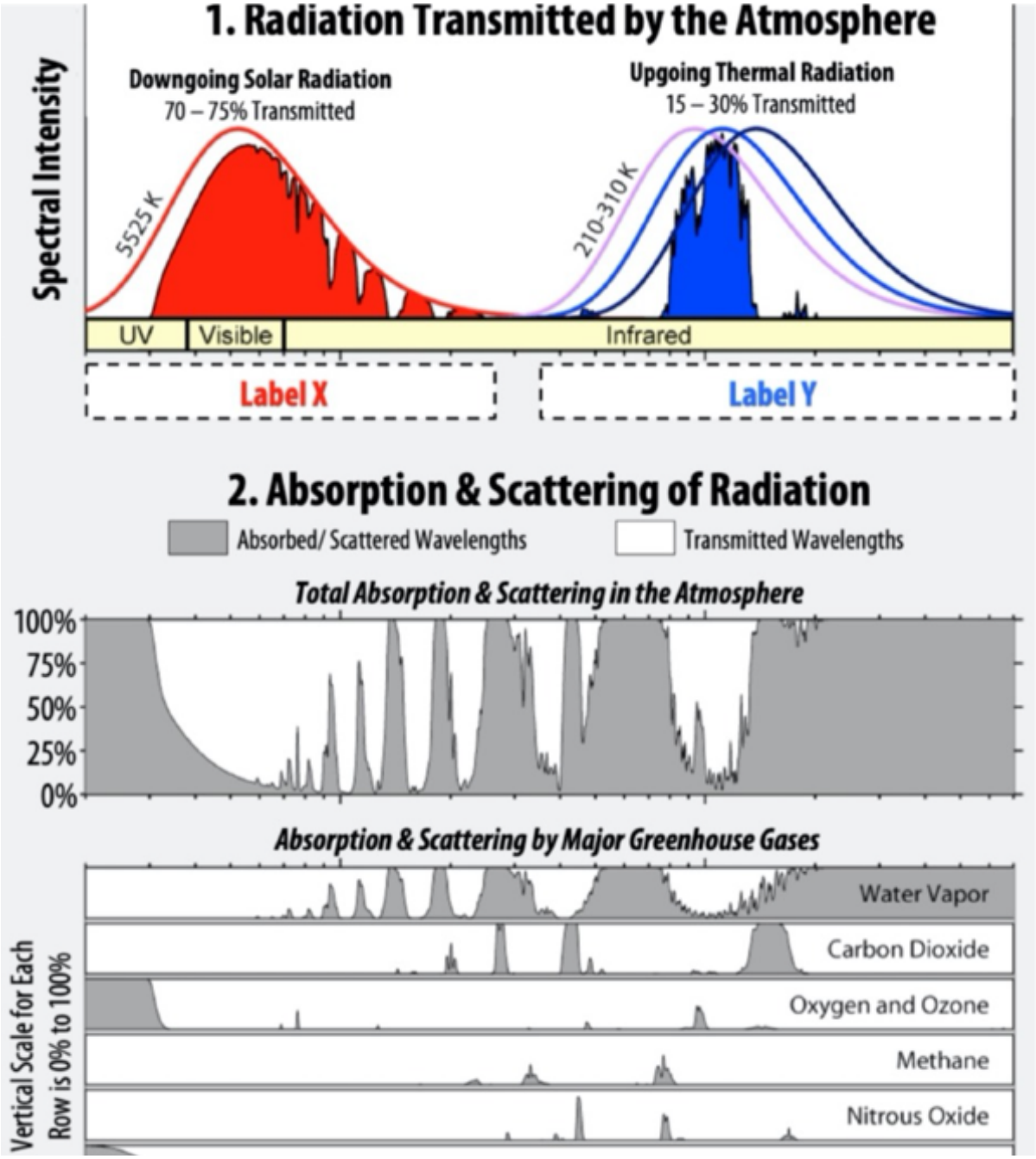
SkyCool cooled the black roof from 51.4°C down to 17.2°C.

The material is known to be a "spectrally selective surface", as explained in the above link to the University of Technology Sydney report. Unlike all other materials, which radiate heat across the infrared spectrum, SkyCool will focus its out-going energy through the "atmosphere-to-space" window.

SCIENTIFICALLY:

The chart below shows the red incoming radiation which is 90% reflected. The blue section is where all the absorbed solar and the conducted internal heat is radiated out to space with UTS-measured 96% efficacy. This is the tuned spectral radiation unique to SkyCool.

The greenhouse gas that blocks this natural cooling effect is water vapour, typically, clouds.



Results

Upon completion of the application, where two coats were applied to a thickness of 300 microns, these images were taken with a FLIR thermal camera.

The ceiling-mounted screens and customers are now the hottest items within the building.

The cable tray (point #2) is the same temperature as the floor and the sub roof that was over 40ºC (see page 2) while being cooled via the AC is now nearly 20ºC lower. It is also interesting to note in these pictures that the building now has only 1.5ºC of difference between the ceiling and floor.

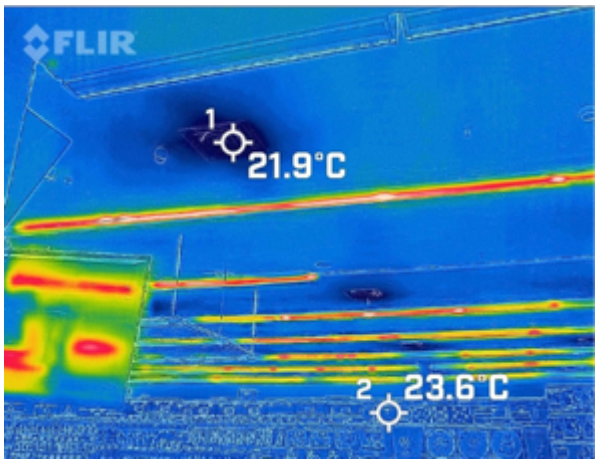
The effect on air-conditioning

To compare the incoming conditioned air temperature another nearby store was chosen. This store, pictured on the following page, has an internal ceiling separating it from the external roof with air-conditioning outlets positioned so that a room temperature difference and air outlet temperature could be easily seen.

The images on the following page were taken around 2pm to allow sufficient foot traffic within the area and so that the highest temperatures could be captured.

This store had an air-conditioned set point of 24ºC.

With a 1.7ºC temperature difference between the SkyCool-ed building and the benchmark building, the air-conditioning is almost not working under SkyCool. That results in huge energy savings.



These results demonstrate that SkyCool is capable of cooling an entire building in a 33ºC climate, very close the normal AC set point. This will enable the reduction of electricity consumption to such a degree that it's only required to cool the incoming air for ventilation.

These results were confirmed when this message was received from the client some six months after the application was completed.