An Introduction To Cool Roof

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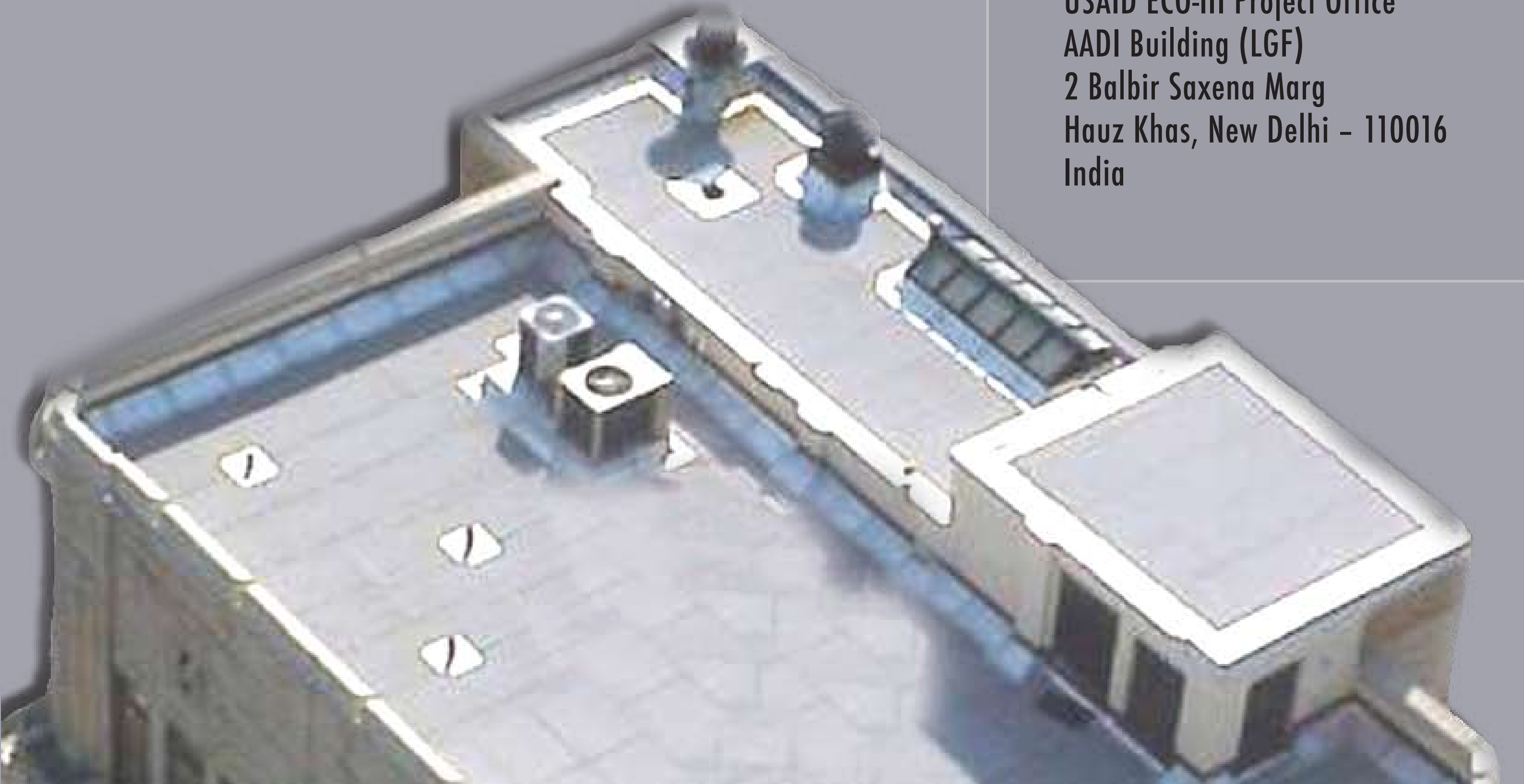


COOL ROOF

(A WAY TO SAVE ENERGY)

INTRODUCTION TO TECHNOLOGY

Modern urban areas have typically darker surfaces and less vegetation than their surroundings. Collectively, dark surfaces and reduced vegetation warm the air over urban areas, leading to the creation of urban "heat islands." The additional air-conditioning use caused by this urban air temperature increase is responsible for 5–10% of US urban peak electric demand, at a direct cost of several billion dollars annually. Summer heat islands increase system-wide cooling loads and smog production because of higher urban air temperatures. Smog is created by photochemical reactions of pollutants in the air; and these reactions are more likely to intensify at higher temperatures.

Use of solar-reflective (cool) urban surfaces and the planting of urban trees are inexpensive measures that can reduce summertime temperatures. At the building scale, a dark roof is heated by the sun and thus directly raises the summertime cooling demand of the building beneath it. A reflective roof is typically light in color and absorbs less sunlight than does a conventional dark-colored roof. Thus, reflective roofs reduce air-conditioning (a/c) energy use and increase occupant comfort level. The magnitude of energy savings depends upon building type, level of roof insulation, ventilation rate between roof and ceiling, a/c size and efficiency, and of course, roof solar reflectance. Cool roof technologies include coatings, membranes, tiles, and shingles.

The primary intent of cool roof technology is to reduce the amount of energy absorbed by a roof surface. New advanced coating materials allow for the selective absorption and reflection of various spectral wavelengths. This allows for the design of roofing systems with visual coloring that can enhance a building's character while still reflecting a good deal of the total incident solar energy, of which a significant portion extends beyond the visual wavebands to include infrared and ultraviolet light. The net result is that a lower fraction of the incident solar energy (only about 20% or less) is absorbed by the structure. This reduces the cooling load on the building's HVAC as well as significantly increases the expected life of the building's roof. The environmental benefits of cool roofs are that they can decrease the urban heat island effect by reflecting some of the incident solar energy back into space as opposed to absorbing the heat and releasing it to the surroundings.

Light-colored building surfaces are a time-honored technique of staying cool in the Mediterranean, the Caribbean, and other sun-drenched locales. Roofing materials with high reflectance, or high albedo, can reflect up to 85 percent of incident solar radiation, compared to normal surfaces which may reflect only 20 percent. For commercial applications, flat, poorly insulated roofs are the best candidates for high-albedo materials. Although wall color can also affect cooling load, the roof is a much more significant solar receiver and is typically more difficult to cool by shading.

Thermal benefits of cool roof technology	
Conventional Roof	Cool Roof
Reflects 30 to 60% of incident solar	Reflects 80% of incident solar
Absorbs 40 to 70% of incident solar- (heats top roof adding to cooling load and urban heat)	Absorbs nearly 20%

THE PHYSICS BEHIND THE COOL ROOF

Absorptance and reflectance of building materials are usually measured across the solar spectrum, since they will be exposed to that range of wavelengths and these are the major characteristics responsible for urban heat gain/ loss. The emissivity of building materials, on the other hand, is usually measured in the far-infrared part of the spectrum, since most building materials don't get hot enough to radiate at the shorter near-infrared, visible, and UV wavelengths.

Installation of high-albedo roof coatings or paint is most cost-effective if done during new construction or when buildings are scheduled for re-roofing. Reflectance (albedo) is measured on a scale of 0 to 1, with 0 being a perfect absorber and 1 being a perfect reflector. The complement of reflectance is absorptance; whatever radiant energy incident on a surface that is not reflected is absorbed. Absorptance is also rated from 0 to 1, and can be calculated from the relation: reflectance + absorptance = 1. An ideal exterior surface coating for a cooling climate would have reflectance near 1.0, absorptance near zero, and infrared emissivity near 1.0 to radiate absorbed heat back to the sky. White plaster very nearly achieves this combination, as shown in table below.

SPECTRAL CHARACTERISTICS OF BUILDING MATERIALS

Even though many metals have a high solar reflectance, if emissivity is low the material will not reject heat effectively. For example, polished aluminum foil has a very high solar reflectance, but its emissivity is low, so it retains heat. Note its placement in the lower portion of the graph. The best performing materials for cooling load reduction have both high albedo and high emissivity, and are in the upper left hand section.

Source: Florida Solar Energy Center [43]

Buildings typically have solar reflectance in the 0.20 to 0.35 range, although dark roofs can be as low as 0.05. Both walls and roofs can be treated with light-colored paints or other finishes increasing reflectance to about 0.70. Walls can be treated with exterior grade latex paints (which are unsuitable for roofs), and special compounds formulated and marketed specifically for heat load reduction are available for roofs. The differences between standard paints and "specialty paints" are relatively small, and relate more to durability, fire protection, application ease, waterproofing and crack-sealing performance than to cooling load reduction. Aluminized roof coatings are also available; they are less effective than white coatings at reflecting incoming radiation and reducing roof temperature.

A basic rule of thumb is that metallic objects have low emissivity and nearly everything else is high. For example, there is a slight difference in emissivity between black and white paints (0.95 versus 0.90), but they are nearly equal when compared to bare metal at about 0.35. Ceramic content, paint base, and other factors don't matter much, although the inclusion of metal in paints, as in aluminized roof coatings, may reduce emissivity. Surfaces that are most promising for albedo increase meet all of the following criteria:

- dark or metallic existing surface
- poor insulation
- high solar insolation
- large ratios of surface area to enclosed volume

- cooling season dominates energy considerations

In April 1997, DOE and EPA introduced two labels for roofing materials. The first is a quantitative "Solar Reflectance Index" and will be similar to the yellow Energy Guard appliance labels. The second is Energy Star, which will mark the coolest one-third of the products on the market. Traditional roofing materials have SRIs of five percent (brown shingles) to 20 percent (green shingles). White shingles with SRIs of around 35 percent were used in the 1960s, but were discontinued because they appeared dirty. Today, manufacturers treat white shingles with a fungicide to prevent discoloration. Smooth "self-washing" shingles have SRIs of up to 62 percent.

MEASURED ENERGY SAVINGS IN A LARGE OFFICE/TRAINING CENTER

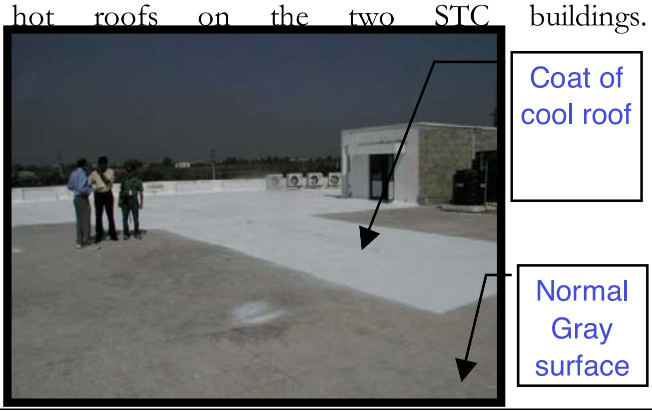
(CASE STUDY: SATYAM TECHNOLOGY CENTER (STC), HYDERABAD,, INDIA)

In a recent (2006) demonstration, installing a white roof coating reduced the average summertime daily maximum roof-surface temperature of a two-storey office building at the training center of the Satyam Technology Center (STC), Hyderabad,, India from 52°C to 32°C. The total air-conditioning (a/c) energy use was thereby reduced by 30 kWh/day (5% on hot days and 8% on average days). At Rs 5 per kWh, the coating on this 700-m2 (7,000-ft2) building is estimated to save about Rs 450,000 over the 10 year life of the roof. Significant cost-effective a/c electricity and peak load savings and increased comfort level can be realized by installation of such cool roofs on industrial and commercial buildings – malls, hospitals, offices, hotels, etc. and residential buildings in India.

The cool roof technology is also being tested on passenger vehicles and rail cars in the US and Japan. A similar reflective pavement can reduce pavement surface temperature by 10°C, which would make urban air cooler. Together, cool roofs and pavements can reduce temperature-dependent urban air pollution.

We also carried out a preliminary study to investigate the effects of heat-island mitigation measures (cool roofs, cool pavements, and urban vegetation) on reducing the ambient temperature in Hyderabad and surrounding areas. The simulation results show a maximum temperature reduction of up to 2.5°C and 3.5°C for the moderate and aggressive heat island mitigation measures, respectively.

The demonstration was sponsored by the U.S. Agency for International Development (AID), and conducted by the Lawrence Berkeley National Laboratory (LBNL) and International Institute for Information Technology (IIIT) Hyderabad. Thermoshield, a US company, provided the material and labor for installation of the cool and hot roofs on the two STC buildings.



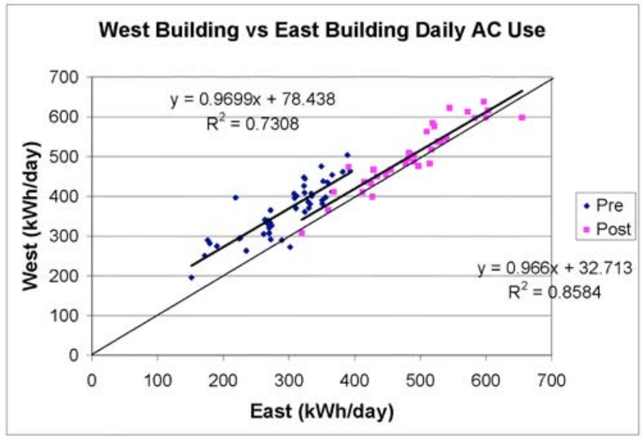
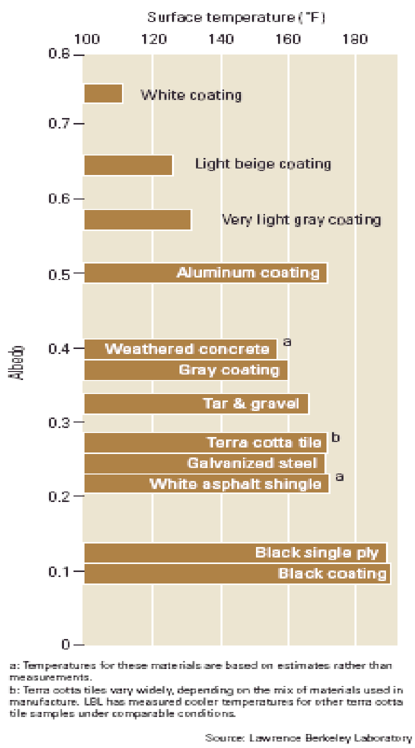


Figure 1. Installation of cool coating on the concrete roof, and kWh consumption with respect to outdoor and indoor temperature difference

SURFACE TEMPERATURE AND ALBEDO OF COMMON ROOFING MATERIALS AND PAINTS



Temperatures were measured in August in central Texas, with an ambient temperature of 90°F and clear sky conditions. Materials were applied to two-inch polyurethane foam.

CASE STUDY (FIELD TESTS)

Field tests confirm that reducing high roof temperatures will reduce cooling load in both humid and dry climates. In the mid-1980s, the Mississippi Power Company found that a reflective white elastomeric coating on the roof of a commercial building reduced air conditioning by about 22 percent compared to an identical neighboring building.47

In an LBL study, two Sacramento school buildings saw energy savings ranging from 40 to 69 percent and peak demand reduced by an average of 33 percent. Two identical, freestanding school classrooms with roofs insulated to R-19 were measured. The control classroom had yellow walls and a metal roof. The other classroom had its roof and southeast wall first painted dark brown and measured for two weeks, then painted white with an elastomeric coating. The whitened building used only 50 percent of the daily cooling energy that the brown building did, and only 35 percent as much as the identical control building. Thus, even dark paint reduced the cooling load of the metal-roofed classroom.

RESULTS OF LBL SCHOOL BUILDING TESTS

Test site	Albedo before	Albedo after	Cooling energy savings	Peak demand reduction
White coating on metal roof, plus white coating on yellow southeast wall	0.34*	0.70	50%	40% (450 W)
White coating on brown metal roof, plus white coating on brown southeast wall	0.08	0.70	40%	30% (500 W)

* Emissivity was low

Source: Lawrence Berkeley Laboratory

In this study, two identical school buildings, with metal roofs insulated to R-19 and attic ducts, were used. The first case shows how albedo changes from adding a white polymer coating on an unpainted metal roof and to a yellow southeast wall. The second case adds a white coating to a brown metal roof and to a brown southeast wall.

PERFORMANCE CLAIMS FOR HIGH-ALBEDO PAINT

As with radiant barriers and some other gainreduction technologies, manufacturer performance claims for albedo-increasing paint must be carefully examined. A common brochure statistic is that the product can "insulate" like R-19 fiberglass batts. Of course, the paints do not work by insulating at all, but by dealing more effectively with incoming solar radiation. Similarly, some manufacturers claim their products reduce total energy costs by up to 40 percent. If you live or work in a small, unshaded, uninsulated metal shack with no internal loads, that may well be true. But roof temperature reduction for most buildings removes only a relatively small component—10 to 20 percent—of total cooling load. Promotional literature for some roof coating products shows space shuttles screaming through the atmosphere or men holding torches to piles of powder in their hands. These advertisements effectively demonstrate the high emissivity and low conductivity of the ceramic paint base, but in these properties the specialty paints differ little from standard paints. However, Hashem Akbari of LBL points out that emissivity is in fact an important factor to consider in cooling load reduction:

Place three metal sheets in the sun. Paint one white, paint another black, and leave the third as bare metal. The metal sheet will reach the highest equilibrium temperature— even though it has higher reflectance than the black sheet— because its low emissivity doesn't allow the absorbed heat to be reradiated to the surroundings. So the bottom line for cooling is: paint your metal.

POTENTIAL SAVINGS FROM COOL ROOF - ECONOMICS

The cost of materials and labor for a high-albedo roof, installed during construction or reroofing, will not differ significantly from a conventional roof, making application of highly reflective roofs a no-cost or low-cost option. Table 3-6 shows estimates of the comparative costs of some high-albedo and regular roofs. For a residential roof, the cost premium of cooler shingles is less than $25.

Approximate installed costs for flat roofs (1993 $)

	Reroofing applications					Retrofit
Roof material	Built-up asphalt w/ dark gravel	Built-up asphalt w/ reflective paint	Built-up asphalt w/ white gravel	Modified bitumen w/ white gravel	Single-ply white polymer roofing	White acrylic roof paint (2 coats)
Installed total cost/ft[2]	$1.30	$1.30	$1.30	$1.05	$1.15	48¢
Albedo (est. new)	0.05 – 0.10	0.70 – 0.80	0.50 – 0.60	0.50 – 0.60	0.70 – 0.80	0.70 – 0.80
Albedo (est. weathered)	0.50 – 0.20	0.60 – 0.70	0.40 – 0.50	0.40 – 0.50	0.60 – 0.70	0.60 – 0.70
Expected life (years)	20	20	20	20	20	5 – 10
Annualized cost/ft[2]	12¢	12¢	12¢	10¢	11¢	8¢

Source: Lawrence Berkeley Laboratory [48]

TECHNOLOGY AND APPLICATION IN NON BUILDINGS STRUCTURES[1]

1) **USES:** Suitable for application on mobile homes, metal roofs and buildings, recreational vehicles and trailers, RR boxcars, trucks and transportation vehicles.

2) **SPECIFICATIONS**

- **Colors**: Standard: White (May be tinted but not recommended if heat reduction is primary.)
- **Certification**: Formulated without lead, mercury.
- **Surface Preparation**: Surfaces must be clean and free of dirt, mildew, grease, excess chalk, loose or scaling paint.
- **Paint will not stick to a chalky surface.** For best results, it is recommended to wash the surface with Hy-Tech House Wash. Mildew should be washed with a solution of 1 Qt of household bleach and 3 Qts of water, rinse well and allow drying.
- **Recommended Primers:**
  a) Aluminum and galvanized metal, #15 Aqua-Prime
  b) Rusted metal: Clean,wire brush and apply one coat #18 Metal Prime or # 17 Rust Cure

[1] Hy-Tech Thermal Solutions, **"A NASA Technology Spinoff Company"**

c) Wood: Unpainted should be primed with # 16 Stain blocker.

d) Masonry/ Concrete: New and previously painted, remove all traces of form releasing agents, Prime

e) all chalky surface areas prime with Chalk Locker #10 or #50 Shields All.

- **Joints, Seams and Cracks:** Apply one (1) coat of Hy-Tech Elasto-Patch elastomeric patching compound to all horizontal or vertical seams. Seal around all flashing, openings, and joints with Polyester membrane- or Fiberglass Mesh and Elasto-Patch other mastic type compound. Follow ridge contour or depressions of the seam, do not bridge the area. Smooth over with brush or roller to insure complete wetting and to leave finish free of stretches of creases in the membrane. Allow to dry two (2) to four (4) hours allowing for weather conditions. Apply a second coat of Elasto-Patch on top and allow to dry two (2) to four (4) hours before continuing.

3) **APPLICATION:**

a) Stir thoroughly before use. Apply 2 full generous coats by brush, roller or spray gun. Roller: ¾"-1-1/2" nap depending on surface texture. Spray: Remove all filters, tip size .021-.035, and pump size 2 Gal per Min.

b) Avoid over spreading. First coat should be allowed to dry overnight before applying the second coat. Do not thin or add other paints or solvents. Clean brushes, rollers and other painting tools in warm soapy water after use

c) LIMITATIONS Do not apply when temperature of air and surface is below 50° F (10° C), nor on damp and rainy days. CLOSE CONTAINER AFTER EACH USE. Store in a clean, dry place. KEEP FROM FREEZING

4) **TECHNICAL DATA**

a) Color: Bright Tintable White Vehicle Type: 100% Acrylic Emulsion

b) Finish: Low Velvet Sheen

c) Solvent: Water

d) Recommended numbers of Coats: Two WEIGHT PER GALLON: 11.5 lbs.

e) Drying Time Touch: 1 Hour Recoat: 8-12 hrs FLASH POINT:N/A

f) Coverage: 125-150 square feet per gallon Percent Solids By Vol.43.0% ± 2%

g) Dry Film Thickness 6.0 mils @ 125 SFPG

h) Voc Level: < 48 gms/ ltr Complies with all Federal, State and Local VOC standards.

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