Cool Systems For Hot Cities

Source: Professional Roofing
By: Hashem Akbari and Sarah Bretz

On a blistering summer day, Los Angeles, Calif., is about 6 to 8 F (3 to 4 C) hotter than its surrounding areas. The same is true of Baltimore, Md.; Phoenix, Ariz.; Washington, D.C.; and Tokyo, Japan. During the past several decades, dark buildings and pavement replaced trees and shrubs in these cities, absorbing more of the sun's heat. This created urban heat islands (i.e., differences in temperature between urban and rural areas) and resulted in increased air-conditioning costs, energy use and pollution.

Scientists with the Heat Island Project at Lawrence Berkeley National Laboratory (LBNL), Berkeley, Calif., have been studying the effects of roof system color and type on the energy used to cool a building. The results of this research indicate that roofing professionals should consider the reflectance (i.e., albedo) and emittance (i.e., how well a material releases heat it absorbs) of the roof systems they install.

The reasons

Using light-colored roof systems to keep buildings cool is not a new concept. In fact, throughout the 1960s, homes in the southern United States often were built with white shingle roof systems. But as air conditioning became widespread, priorities shifted—there no longer was as great a need for light-colored roof systems. It became popular to use darker roofing shingles, which resembled wood shingles and better concealed dirt and algae.

Much of the extra heat from these roof systems makes its way into an attic and then the house, though the heat transfer is slowed by attic insulation. A cool roof system—one that reflects solar radiation and emits thermal radiation well—keeps a building cooler and helps reduce air-conditioning costs. Researchers at LBNL and the Florida Solar Energy Center (FSEC) have measured cooling energy savings of up to 60 percent for individual homes where white roof coatings were applied to dark roof systems.

Homes with the highest energy savings were those that had cooling ducts running through the attics and little or no attic insulation. For these homes, hot attics have the most detrimental effects. For instance, supply ducts pick up heat from an attic and distribute warmer air throughout the house. If return ducts are located in a hot attic, leaks in these ducts will suck in hot attic air and bring it back to the air conditioner to be cooled. Both these conditions will make an air conditioner work harder than it should.

In addition, a small amount of insulation (e.g., R-5) allows much of an attic's heat to transfer directly to the house below. But for a moderately insulated building, roof color will not make a large difference in energy savings.

Cool roof systems also are beneficial because they can save money and energy during peak cooling periods. Because the need for air conditioning peaks during the hottest part of the day, a utility company brings on its most expensive generating capacity to meet this high demand. Reflective roof systems are most helpful at cooling buildings during these times. This benefits electric utilities and, ultimately, all utility customers, who will see reductions in their cooling costs and the heat-island effect.

During warm afternoons in Los Angeles, for example, the demand for electric power increases nearly 2 percent for every degree Fahrenheit (0.5 C) the daily maximum temperature rises. Computer modeling of Los Angeles' heat island indicates that lightening the colors of roof systems and pavement, as well as planting trees, could lower the average summer afternoon temperature by 5 F (3 C).

In turn, cooler urban temperatures reduce pollution because more smog is produced at higher temperatures. Smog is created by photochemical reactions of air pollutants, and these reactions are more likely to intensify at higher temperatures. This is one of the reasons there is little smog in winter, though the pollutants that cause smog still are present.

In Los Angeles, for every degree the temperature rises above 70 F (19 C), the incidence of smog increases 3 percent. LBNL researchers estimate that if all the buildings in the greater Los Angeles area had cool roof systems, the total energy and smog savings (i.e., lower hospital bills and fewer lost workdays caused by smog inhalation) would be about half a billion dollars per year.

The potential for significant energy, comfort and pollution savings from cool roof systems is not limited to southern states. In fact, about half the U.S. population lives in heat islands. Of course, white roof systems will save more in hotter climates, such as Phoenix and Los Angeles. But for most building types, cool roof systems will have net savings in colder climates as far north as Chicago, Ill.

LBNL projected savings by computer model in 11 cities (see Figure 1). The projections accounted for a combination of factors: In warmer areas, there are larger savings per square foot (0.09 m^2) for air-conditioned buildings, and these savings are multiplied by the population.

As shown in Figure 1, Los Angeles has less energy savings than Phoenix because it has fewer air-conditioned buildings and less cooling energy per square foot (0.09 m^2) despite being seven times more populous. It also appears, according to LBNL studies, that roof systems tend to be about 5 percent darker on average in the North as in the South, which increases the opportunity for savings in the North.

Electricity costs also affect potential savings. The high price of electricity in New York, N.Y., (16 cents per kilowatt-hour [kwh]) compared with Atlanta, Ga., (8 cents per kwh) causes dollar savings in New York to be almost twice as much as Atlanta.

In general, the best candidates for white roof systems in any city are buildings with high air-conditioning bills (e.g., bills more than $30 per 1,000 square feet [90 m^2]), low insulation levels (e.g., less than R-11 ceiling) or ducts running through the attics. But a cool roof system will benefit most buildings in areas with hot, sunny summers.

Concerns

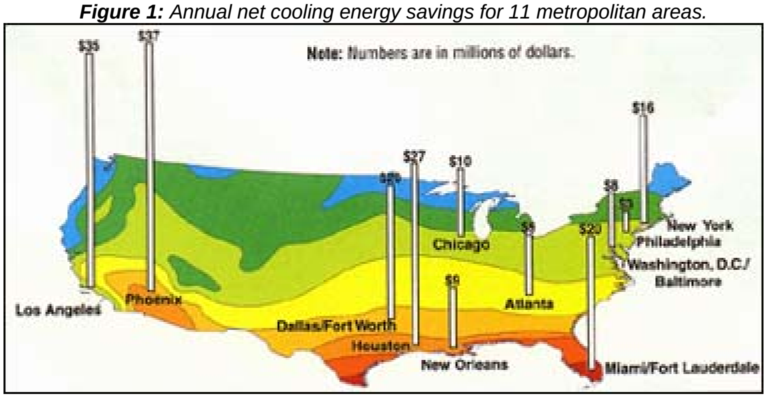
Because cool roof systems reflect the sun's heat in winter, too, they can cause heating costs to rise. But this usually is not significant. Computer models accounted for the winter "energy penalty" and still found net savings from light-colored roof systems in the 11 cities studied.

Of course, there are areas where reflective roof systems' summer savings are less than the increased heating costs in winter. These are cold climates, such as Detroit, Mich., and Minneapolis, Minn., or cloudy areas with cool summers, such as Seattle, Wash., and San Francisco, Calif.

Cool attributes

There are two properties that help a roofing material stay cool. The first is how well a material reflects sunlight. Lighter-colored materials, such as white tile, have high reflectances, which keep heat from entering a building.

Figure 1: *Annual net cooling energy savings for 11 metropolitan areas.*



The second property is a material's emittance. Most roofing materials have high emittances, which allow them to release heat quickly. Unpainted metal roof systems and some metallic coatings, however, have low emittances; this causes more heat to be retained on a roof system's surface and ultimately transferred into a building.

A roofing material's shape also affects how well it sheds heat. For instance, curved-tile and wood roof systems usually allow air to circulate between tiles or shakes, helping remove solar heat.

Researchers at LBNL, Oak Ridge National Laboratory and FSEC have measured the solar reflectiveness of various roofing materials. Their studies have shown that a roof system cannot always be judged by its color. Although lighter-colored roof systems generally are more reflective, there are significant differences among roofing material types. For example, white composition shingles are much less reflective than white coatings.

The researchers are looking for the best ways to increase the reflectances of several roofing material types (i.e., composition shingle, single-ply, built-up, metal, modified bitumen and tile). Following are brief descriptions of these materials' reflectances (values are for newly applied materials). Ideally, materials should have 80 percent reflectances.

1. *Composition asphalt shingles.* These tend to absorb more solar radiation than other materials. The reflectance of conventional composition shingles ranges from 5 to 25 percent, depending on a shingle's color. Even white asphalt shingles reflect only about 25 percent of sunlight—low compared with the reflectances of white tile or unpainted standing-seam metal roof systems.

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White composition shingles have low reflectance because of the granules' low pigment content, rough texture and black substrate. With current technology, it is possible to increase the solar reflectance of white composition shingles to 35 percent by increasing the granules' pigment amount.

2. *Single-ply membranes.* Many single-ply membranes are available in white, with reflectances of 70 to 80 percent. For some single-plies, such as EPDM, using a dark membrane with a white coating allows the same reflectance without compromising a roof system's durability. It should be noted that a coating may degrade as much as 20 percent depending on how it was applied.

3. *Built-up roof (BUR) systems.* The reflectances of BUR systems vary considerably—from 5 to 80 percent, depending on the surfacing used. The best way to maximize a BUR system's reflectivity is to surface the system with a reflective coating.

Many BUR systems are surfaced with aggregate. The reflectance of aggregate ranges from about 10 percent for dark aggregate to nearly 50 percent for white marble chips.

If a contractor uses dark aggregate, covering it with a white (e.g., cementitious) coating can increase its reflectance to roughly 55 to 60 percent. Using a highly reflective coating (e.g., a white coating) instead of aggregate can yield an even higher reflectance of almost 70 percent.

Some BUR systems are covered with mineral-surfaced cap sheets. Similar to white asphalt shingles, a white, mineral-surfaced cap sheet has a reflectance of only 25 percent. Adding a reflective coating increases a cap sheet's reflectance to 65 percent. A contractor can eliminate the cap sheet and surface a BUR system with a reflective coating to achieve a reflectance closer to 70 percent.

The remainder of BUR systems are smooth-surfaced. A white coating's initial reflectivity on a smooth surface is about 70 percent. Aluminum coatings range from 30 to 60 percent, and black coatings are about 5 percent reflective. According to research results, even aggregate is an improvement over a smooth-surfaced, uncoated BUR system, which has a solar reflectance of about 5 percent. A white coating gives the maximum reflectivity to an uncoated BUR system.

4. *Metal.* These roof systems typically are available in white, which raises their solar reflectances to about 65 percent. Unpainted metal should be covered with a white coating to increase its emittance.

5. *Modified bitumen.* According to studies published by FSEC and LBNL, modified bitumen's reflectance ranges from 5 to 25 percent (depending on a system's initial color). It is possible to increase reflectivity to roughly 65 percent by adding a white reflective coating.

6. *Concrete and clay tile.* Concrete and clay tile may be obtained in white, increasing the solar reflectance to about 70 percent vs. 20 to 30 percent for red tile.

Aesthetics

Many low-slope roof systems, such as BUR and EPDM, have inherent variations (e.g., birdbaths) that catch dirt. Although common to all low-slope roof systems regardless of color, these depressions are more visible on light-colored systems. Fortunately, dirt does not indicate an actual problem with a roof system's integrity, but a contractor may need to allay a building owner's concerns.

Another issue is color. Although people at ground level usually can't see the tops of low-slope roof systems, many owners prefer dark colors when a roof is sloped and visible from the ground. Presently, only light colors are solar-reflective, but it is possible to increase the reflectivities of nonwhite materials by increasing nonvisible radiation's reflectance.

Because the human eye detects only the visible portion of the spectrum, half the sun's heat arrives as invisible radiation in the near-infrared part of the spectrum. Therefore, it is theoretically possible to have two shingles that appear identical but have different solar reflectances— it may be possible to increase the reflectance of near-infrared radiation on shingles without changing their visible color.

Effectiveness

A light-colored roof system's reflectance will decrease as it gets dirty. LBNL scientists found that most of the loss in reflectance caused by dirt on a roof system's surface occurs within the first year of application. They estimate the reduction in reflectance to be about 20 percent during the first year—a safe assumption for coatings that perform well. Low-quality products that blister and peel off a roof system within a few years obviously will lose effectiveness.

A contractor also must ensure coatings are compatible with roof systems' surfaces. Because of their smooth surfaces, metal shingles and concrete and clay roof tiles should have less than 20 percent degradation because they are more resistant than coatings to dirt buildup.

Other studies by FSEC have indicated that rough-surfaced, low-slope roof systems (e.g., aggregate-surfaced) are more susceptible to loss of reflectance from dirt accumulation than smooth, steep-slope systems (e.g., metal).

Scientists also are working with roofing products manufacturers to develop a new generation of cooler shingles and tiles. Titanium dioxide typically is used as the white pigment in coatings or shingles. Because white surfaces are discolored easily by algae, these shingles also will need to have an algicide coating. When fabricated with a smooth surface, these shingles will self-wash and stay cool for their entire service lives. The increase in albedo of such shingles can be more than 35 percent.

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Informing consumers

The Cool Roof Rating Council (CRRC) is composed of roofing manufacturers, government officials, utility companies and researchers. CRRC is focused on establishing a fair, accurate and credible rating system for roofing materials. The council's main goal is to provide information, not endorse particular products. For different roofing products, the group will provide information about initial reflectivity, durability of reflectivity, product durability, life-extension properties of coatings, and installation and compatibility issues.

The U.S. Environmental Protection Agency (EPA) also is developing a label that would show consumers whether the roof systems they are considering meet EPA's criteria for a cool roof system. Roofing professionals should note that EPA criteria differ among roofing products