Cool Colors, Cool Roofs

Source: Science Beat
By: Allen Chen

Roofs, and the rainbow of colors used in roofing materials, are getting cooler and cooler, thanks to research by Berkeley Lab's Environmental Energy Technologies Division (EETD). The cooler roofs get, the more energy and money they save. A new program in cool materials will soon result in the first cool shingle for residential roofs becoming available on the market.

Since the mid-1980s, Berkeley Lab researchers have studied the effects of increasing the solar reflectance of roofs. "Cool" roofs, which reflect more of the sun's radiation than conventional roofs, keep houses and other structures cooler, lower their air-conditioning energy use, and reduce the "urban heat island effect," in which air temperatures in urban areas are higher than surrounding rural areas.
Since dark surfaces are better heat absorbers, traditional cool roofs are white. Berkeley Lab research has demonstrated that raising the solar reflectance of a roof from about 20 percent (dark gray) to about 55 percent (weathered white) can reduce cooling energy use by 20 percent.

Flat-roofed commercial buildings are often fitted with white roofs, but U.S. homeowners typically demand nonwhite roofs. Cool-colored, nonwhite roofs meet that need. It is possible to create a nonwhite cool roof by using colorants or pigments that reflect the invisible, near-infrared radiation that accounts for over half of the energy in sunlight.

Home owners whose houses have pitched roofs prefer darker colors for roofing.

"Our research estimates that the potential net energy savings in the U.S. achievable by applying white roofs to commercial buildings and cool-colored roofs to houses is more than $750 million per year," says Hashem Akbari, an EETD researcher and head of the Heat Island Group.

The Heat Island Group's research has shown that, regionally, widespread application of cool roofs can reduce ambient air temperatures and retard smog formation. Cool roofs can also reduce peak electrical demand in the summer, which helps reduce strain on the aging electricity grid when relief is most needed. Lower temperatures on the roofs may also increase the life of a roof, according to preliminary research by the group.

Thanks to the work of Akbari's team, the roofing industry in recent years has adopted voluntary industry standards for measuring the reflectance of roofing materials and has set up the Cool Roof Rating Council to develop labels that inform buyers about the relative coolness of various products used in roofing — that is, their ability to reflect solar energy and release heat through thermal radiation.

The building-materials industry has brought a number of products to the marketplace that help increase the reflectance of roofs, including elastomeric coatings, single-ply membranes, tiles, and metal roofing. And the Environmental Protection Agency's Energy Star program certifies cool roof products with its voluntary labeling; EPA maintains a web-based guide to Energy Star roofing products.

However, technical barriers to getting cool roofs on homes still remain. Existing white and nonwhite cool coatings are fine for the low-slope roofs of commercial and industrial buildings and apartment structures, where white is acceptable. But on the high-slope roofs of single-family homes, which can been seen from the street, the market is dominated by colorful shingles, tiles, metal products, and wood shakes. Most homeowners don't want white roofs. Asphalt shingles account for 47 percent of the roofing market for residences in the western states, according to industry sources.

To bring cool roofs to the high-slope residential market, research was needed to identify cool color pigments and a different way of manufacturing asphalt shingles. Thanks to a research project funded by the California Energy Commission and the U.S. Department of Energy, consumers will soon see a variety of new cool-colored roofing products to help them save energy and increase the comfort of their homes.

Cool-colored roofing materials in a variety of styles, resembling those in this digital image by Tom Marlin of Marlin Studios (www.marlinstudios.com), will soon be on the way for the residential market.

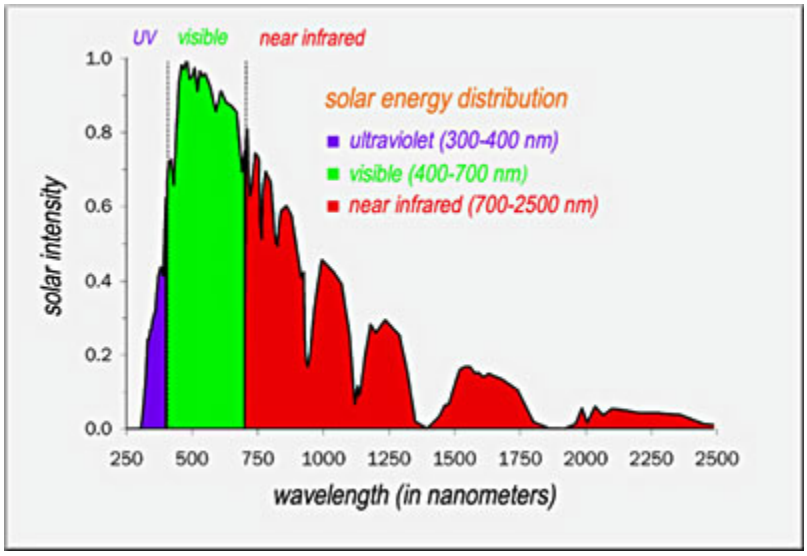
Berkeley Lab is working with Oak Ridge National Laboratory, two pigment manufacturers, and ten roofing manufacturers who collectively produce about 90 percent of the residential roofing products in the United States. The industrial partners are 3M, American Roof Tile Coating, BASF, Custom-Bilt Metals, Elk Manufacturing, Ferro, GAF, Hanson Roof Tile, ISP Minerals, MCA, Monier Lifetile, and Shepherd Color Company.

"Most commercially available roof shingles are optically dark," says Akbari. "Their solar reflectances range from 5 to 25 percent, depending on color. Even the majority of nominally

'white' roof shingles are grayish, and have a solar reflectance of about 25 percent, which is much lower than the 70 percent solar reflectance of white tiles or white metal panels. Since many homeowners prefer nonwhite roofs, we are working to develop cool-colored roof products."

Cooler pigments

Building a cooler color shingle starts with finding cooler pigments. EETD's Hashem Akbari, Paul Berdahl, and Ronnen Levinson have been testing commercially available pigments to measure their solar spectral reflectance — their reflectance versus wavelength over the solar spectrum. For a given color, the ideal pigment is one that reflects as much as possible of the invisible radiation in the near-infrared range.



Cool colors are formulated to reflect more sunlight at near-infrared wavelengths.

The research team has developed a pigment database with a variety of colors, including browns, blues, purples, greens, and reds, that are highly reflective to near-infrared radiation. When tiles colored with standard pigments were compared with tiles colored with cool pigments, the solar reflectance of the cool pigments was from 15 to almost 40 percent better than color-matched conventional pigments. And with metal roofing panels, while to the eye a cool brown and a standard brown may appear almost the same color, the cool brown is almost 20 percent more solar-reflective than the conventional brown (27 percent versus 8 percent).

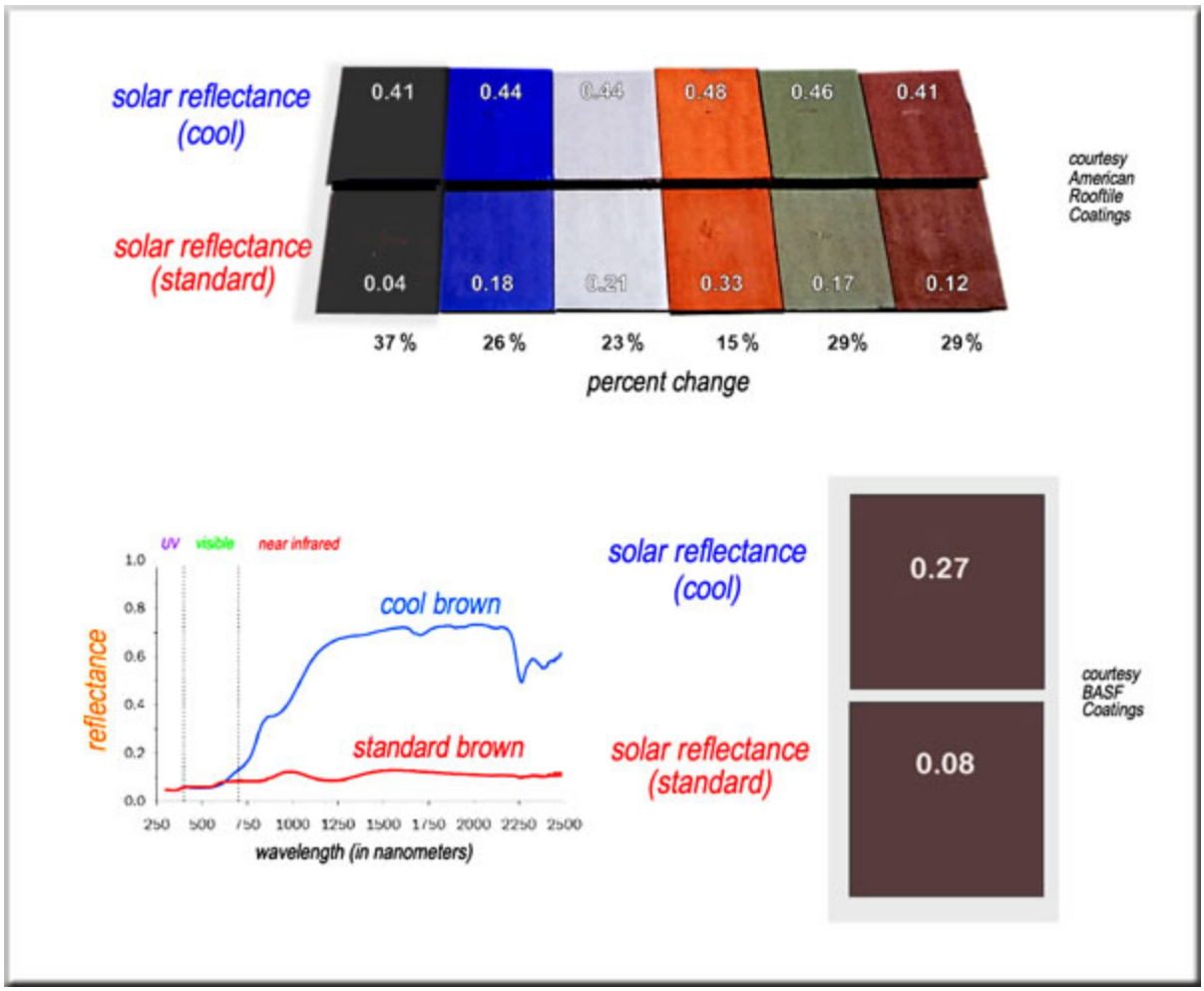
In addition to testing materials in the lab, Levinson, Berdahl and Akbari have adapted a mathematical model to describe how pigments scatter and transmit light. They will apply the model to develop more reflective cool-colored roofing materials.

Using the pigment database and the model, the team is now developing design software for the roofing industry dealing with cool-color coatings. The software estimates the reflectance of the coating using the absorption and scattering properties of the pigment as well as coating

composition and geometry. It provides recipes for manufacturing pigmented coatings that maximize the solar reflectance for a given color.

Cooler tiles, panels, and shingles

The next step is to figure out how to apply pigments to relatively simple roofing products such as tiles, metal panels, and wood shake. The team has identified a number of cool pigments appropriate for use in coating metal panels and concrete and clay tiles. Tile roofs are a growing preference in more expensive houses of the western and southern states.



Roof tiles made with cool-color pigments are far more reflective than standard tiles in the same colors (top), as are metal tiles coated with cool pigments, like the brown tiles at bottom.

One manufacturer of metal roofing has already switched most of its product line to these cooler pigments, since the cost was about the same, and it added value for their customers. The team's current efforts focus on asphalt shingles, a more challenging technical problem.

Shingles are produced in a multi-step process. Roofing granules (small crushed rocks) are manufactured, and color is applied to them; the granules are then used to coat asphalt-saturated fiberglass sheets.

Cool shingles require cool granules. The Berkeley Lab team and its industrial partners have developed a two-layer system for manufacturing cooler roofing granules. In their process, granules are precoated with an inexpensive pigment that is very reflective at near-infrared wavelengths. In the second step, the cool color pigment is applied. The first pigment helps increase the reflectance of granules — it reflects even more light than the cool color pigment would by itself, reducing the amount of near-infrared light absorbed by the granule's dark surface.

The industrial partners have now manufactured more than 50 prototype cool shingles, 30 tiles and tile coatings, and 20 metal panel prototypes, including a cool black shingle — 18 percent reflective, well above the 4-percent reflectance of conventional black shingles.

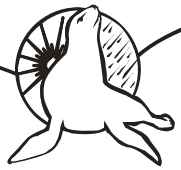
Field testing and market acceptance

To test the field performance and durability of these coatings, Berkeley Lab has teamed with Oak Ridge National Laboratory. The Oak Ridge team has set up a steep-slope assembly test apparatus on its grounds in Oak Ridge, Tennessee, where they are evaluating a variety of samples from the manufacturing partners. Andre Desjarlais, William Miller and their associates have installed representative cool roofing materials at the Oak Ridge roof testing facility. They are measuring the changes in physical and chemical composition of the samples as a result of ultraviolet light, weathering, and temperature changes.

At Oak Ridge National Laboratory, cool-color roofing materials are tested with the Envelope Systems Research Apparatus.

The joint Berkeley Lab-Oak Ridge team has also set up weathering panels throughout California to monitor the performance of roofs using test materials from the manufacturing partners. There are seven test sites located throughout the state, in six different climate zones, ranging from mild to severe. Sites are located from the far north of the state, in McArthur, to Meloland at the California-Mexico border. The project team is also collaborating with the Sacramento Municipal Utilities District to measure energy savings and changes in temperature and humidity inside test houses in Sacramento.

A number of the new cool coatings are already available on the market through the manufacturing partners. "Since the start of this research," says Akbari, "the solar reflectance of commercially available clay and metal products has increased from the 5 to 25 percent range to the 30 to 45



percent range. Working with our industrial partners, we hope to produce shingles with a solar reflectance of 25 percent or higher, qualifying for an Energy Star cool-roof label." He adds that "some of the products resulting from this research will also qualify as cool roofs in the California building energy code," the 2005 Title 24 California Building Energy Efficiency Standard.