Cool Metal Roofing – An Emerging Hot Topic

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In the United States, buildings are responsible for almost two-thirds of national electricity consumption and more than one-third of total primary energy use. As a result, the current energy crunch has made conservation measures within these structures more important than ever.

Heating and cooling costs are generally the major expenses associated with the operation of a building. Therefore, any reduction in these costs through the use of energy efficient building envelope components makes sense. Unfortunately, the roof can be the least energy efficient component of a building envelope. Is it any wonder, then, that cool roofing has become such a hot topic?

Cool roofing is gaining in popularity due to its ability to reduce cooling and heating energy usage. Utility companies are also interested in cool roofing because it can help reduce the peak demand in electricity during the afternoon hours of summer months, preventing power disruptions. And, from an environmental point of view, cool roofing can also help to mitigate a phenomenon known as the heat island effect.

Coming to Terms with Cool Roofing

Cool roofing is based on the premise of minimizing heat gain through the roof surface. To understand how this happens one must look at the solar energy spectrum as shown in Figure 1. Ultra violet (UV) energy in lower wavelengths amounts to only 3% of the total energy striking the earth's surface. Visible light energy is 40% and infrared (IR) energy in the longer wavelengths accounts for the largest percentage of the spectrum. When IR energy strikes the earth's surface, we feel it as heat.

Cool roofing is described by two main terms: solar reflectance and thermal emittance. Total solar reflectance (TSR) is the percentage of all solar radiation that is immediately reflected from a surface. Any energy that is not reflected from a surface is absorbed by the material. Some of this is transferred to heat which can be removed by convective transfer from air flow over the surface. Some of the heat can be conducted through the surface. More importantly, some of the heat can be re-emitted to the night sky in the form of infrared wavelength energy. The latter phenomenon is known as thermal emittance (TE). The combination of solar reflectance and thermal emittance properties of a material determine the surface temperature of a roof and its ability to act cool.

Some typical radiative properties of common roofing materials are shown in Table 1. Metal roofing has a wide range of solar reflectance and thermal emittance values. In the unpainted condition, a metallic surface has a very low TE but a relatively high TSR. When a paint system is applied to the surface, the TE is very high regardless of the color. However, the TSR can vary depending on the color and/or pigmentation used.

Table 1. Roofing Material Radiative Properties

	Solar	Thermal

	Reflectance	Emittance
Metal (unpainted)	0.60-0.80	0.04-0.10
Metal (painted)	0.10-0.75 *	0.80 +
Comp Asphalt Shingles	0.05-0.25	0.90
Single Ply Membranes	0.70-0.80	0.85+
Built Up Roofing	0.05-0.80	0.90
Modified Bitumen	0.05-0.25	0.90
Concrete/Clay Tile	0.20-0.70*	0.90

* depending on color Source: ORNL and LBNL

Metal Roofing More Reflective Than Ever

Metal roofing continues to grow in today's construction industry. In the residential sector, for example, metal's share is small but increasing faster than any other product. In commercial roofing, metal's share exceeds 30%, depending on actual applications. Certainly, cool roofing is an ever-increasing segment.

A 2006 survey in *Metal Architecture* magazine revealed that almost 29% of architects across the nation stated that cool roofing qualities influenced their use of metal. An even higher percentage responded in the Southwest, Pacific and Northwest regions.

Metal roofing is available in a variety of surface finishes, profiles, textures and substrates. Prepainted metal roofing is popular because of the aesthetic appeal and designs that become possible with color. One of the main ingredients in exterior paint systems is pigments which impart color to the surface. A blue paint looks blue to the naked eye because the pigments used in that paint film absorb all of the visible wavelengths of colors except for blue which is reflected back to our eyes.

In general, dark colors absorb most of the visible light striking the surface while lighter colors reflect most of that solar energy. This would suggest that color is an indication of how much solar visible energy will be reflected. The amount of infrared energy that is reflected is often a function of the color as well, but recently new pigment technology has been introduced to change that assumption. New IR reflective pigments in paint systems allow for darker colors to actually reflect more total solar energy.

Cool metal roofing that is painted is available with special paint systems that feature a new pigment technology that increases TSR with corresponding lower surface temperatures. More importantly, these cool pigments do not affect the color of the product, meaning that traditional colors can be matched with identical colors of the new paint systems with higher TSR values.

Many Research Studies Completed or Underway

Over the past five years, many research programs have been conducted to characterize roofing products in the area of cool roofing. Oak Ridge National Laboratory (ORNL) conducted a three-year evaluation of a variety of metal roofing products installed in low slope and steep slope orientations and in a variety of environments. The results from this work were used to develop whole building energy savings calculators for low and steep slope roofing. An example of the output from this calculator is shown in Figure 2.

The ORNL study also showed differences in metal roofing compared to other types of roofing materials in terms of durability and degradation of TSR over time. Prepainted metal roofing was found to retain its initial TSR values by 95% over as much as 30 years exposure. In comparison, the research showed some membrane products lost 40% of its TSR after only 3 years due to dirt retention. Findings also showed that metal roofing's minor loss in reflectance was similar across all climates in the USA.

The Florida Solar Energy Center (FSEC) has been evaluating the energy efficiency of roofing materials for some time now. Their test facility allows for full size roofing panels to be exposed, allowing for measurement of temperatures and heat transfer into the space beneath.

An example of the performance of roofing materials with regard to roof temperatures is shown in Figure 3. Note that the white painted metal roofing showed excellent performance. In the latter part of the afternoon, the metal roof surface cools below that of tile roofing, due to the difference in thermal mass between the two products. This translates into lower air conditioning costs over the course of an entire day.

Using that information, Florida Power & Light, in cooperation with Habitat for Humanity and FSEC, conducted a real-world experiment with homes featuring different roofing materials, including painted metal. The results showed that the metal roof saved 23% in cooling energy, which was the highest level of savings among the roof systems tested.

In the residential sector, a cooperative research program, involving the California Energy Commission (CEC), Lawrence Berkeley National Laboratory (LBNL), ORNL and the roofing industry is sponsoring research on residential roofing products that incorporate cool pigment technology. This program involves monitoring of energy savings on homes in the Sacramento area of California with roofs in a variety of materials. Metal roofing is part of this program. Results from this program are expected later this year.

Variety of Voluntary and Mandatory Programs

In addition to the obvious energy saving benefits of cool roofing to a building owner, its use is also influenced by codes, standards, rebate/incentives, or marketing programs. And, in this regard, the landscape is bursting with an ever-increasing list of cool roofing programs and initiatives.

These policies can be national and local programs, each with their own unique criteria and definitions of cool roofing. Most of the programs are voluntary, but some have mandatory criteria. They often pertain to both low and steep slope roofing. Figure 4 shows some of these policies and indicates the requirements for compliance.

The Environmental Protection Agency (EPA) expanded into the cool roof arena with the introduction of its Energy Star Roof Products Program in 1998. EPA has determined that an Energy Star labeled roof product can help lower energy costs for the home, lead to favorable mortgage lending programs, meet utility incentives and qualify for some government rebates.

EPA estimates that an Energy Star labeled roof can lower a roof temperature by as much as 100º F. The lower surface temperature translates into lower heat flow into the attic space below the roof and reduces the load on the air cooling system. To date, more than 60% of the products listed on the Energy Star labeled directory are metal roofing products or coatings used specifically in the metal roofing industry.

The Cool Roof Rating Council (CRRC) was established in 1998 as a non-profit organization to develop a methodology for evaluating and labeling all types of roofing products. Its program was launched in 2002. This organization is comprised of roofing manufacturers, distributors, suppliers, trade associations, contractors, consultants, government agencies, educational institutions, code bodies, energy suppliers and independent laboratories. The CRRC is now recognized by the CEC as the sole entity responsible for labeling roofing products that are allowed in the California Energy Code Title 24. It is important to note that the CRRC does not establish criteria or definitions for cool roofing.

California is leading the way with an energy code as part of its overall building code. The latest version of its state building and energy code, Title 24, became effective in October 2005. For the first time, this version of the energy code contains language specific to cool roofing requirements.

Compliance in Title 24 is based on meeting prescriptive requirements of 0.70 TSR, 0.75 TE and being a CRRC-listed product. Compliance can also be achieved using a method of building component tradeoffs and energy budgets. The current code pertains only to non-residential conditioned buildings with a low slope roof. The impact on metal roofing is that unpainted metal such as Galvalume® sheet can not comply with the prescriptive criteria. However, compliance using the tradeoff calculations is possible, but costly.

Metal Roofing Can Contribute to LEED Credits

Another program gaining in popularity in the construction industry is the US Green Building Council's Leadership in Environmental and Energy Design (LEED) program started in 2000. This is a whole-building design program that encourages an integrated design and construction process whereby points are awarded for the use of sustainable products or building practices.

The flagship for LEED has been its New Construction (NC) program. Other programs include Existing Buildings, Commercial Interiors, Core and Shell Projects, Neighborhood Development, Homes and Schools. Four levels of LEED certification are possible based on a graduated system of points awarded. An increasing number of LEED certification requirements for federal, state and local public building construction projects are being mandated.

A 2005 survey in *Metal Architecture* magazine showed that 12% of architects pursued LEED project certification at least once in 2004. The number of LEED certified projects, registered projects and accredited professionals is growing exponentially.

Metal roofing can contribute to the LEED-NC certification point system in several categories. Its high recycled content can be used to raise the overall building's average recycled content in order to receive up to 2 points. Supplying a metal panel from a location within 500 miles of a jobsite can contribute to a point for regional manufacturer. The fact that metal is 100% recyclable helps with the waste management section of LEED. One credit can be awarded for metal in the Heat Island Roof section where cool roofing is defined.

In the recently launched version 2.2 of LEED-NC, a credit is available for a roof system whose Solar Reflective Index (SRI) meets the values in Table 2 for a system that covers a minimum of 75% of the roof surface area. Using the calculation of SRI according to ASTM E1980, this LEED requirement means that prepainted metal roofing with a solar reflectance value of 0.66 or greater would comply for low slope, and prepainted metal roofing with a solar reflectance value of 0.30 or greater would comply for steep slope roofing. This allows a wide variety of colors to be LEED compliant when metal roofing is specified.

Table 2. LEED version 2.2, Sustainable Sites Credit 7.2: Heat Island Effect: Roof

Roof Type	**Slope**	**SRI** (minimum)
Low-Sloped Roof	≤ 2:12	78
Steep-Sloped Roof	> 2:12	29

In addition, many states, cities and local jurisdictions are developing their own cool roof rebate/incentive programs. At the federal level, for example, the recently signed Energy Policy Act of 2005 provides a tax credit for contractors and homeowners who use a reflective or cool metal roof. The language in the new law is specific to metal roofing as it defines a building envelope component to include "...metal roofs with appropriate pigmented coatings which are specifically and primarily designed to reduce the heat gain of a dwelling when installed in or on such dwelling...".

Metal Roofing a "Cool" Choice for Any Building

As the cool roof movement continues to grow in the wake of rising oil, gas and electricity costs, metal roofing is poised to become the product of choice. With its wide range of TSR/TE properties, it can be engineered to optimize the energy efficiency of a roof system depending on the climate and application.

For cooler climates where heating dominates, a lower TE may be desirable which can be met with an unpainted metal roof. In contrast, in warmer climates where cooling loads dominate, a high TSR and TE is desirable which can be met with a prepainted metal surface using lighter colors and/or IR reflective pigmentation. This design flexibility, combined with the sustainability, strength, durability, and low life cycle cost makes metal roofing a cool choice for any building.

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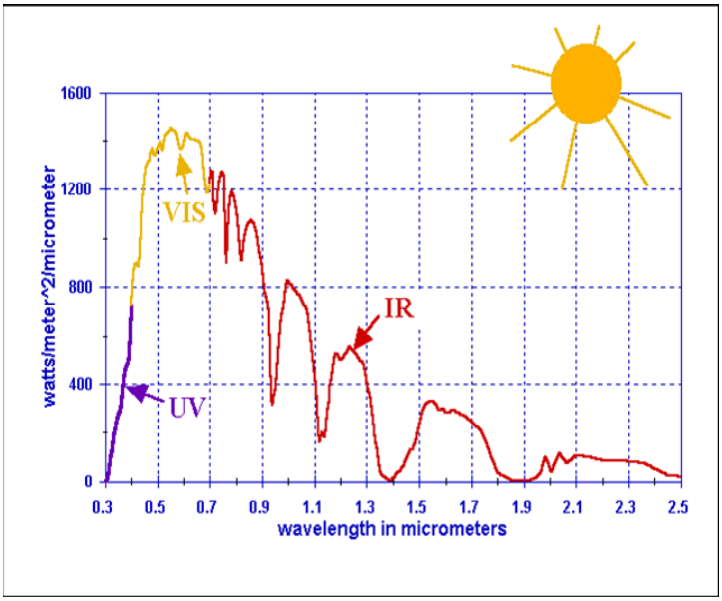
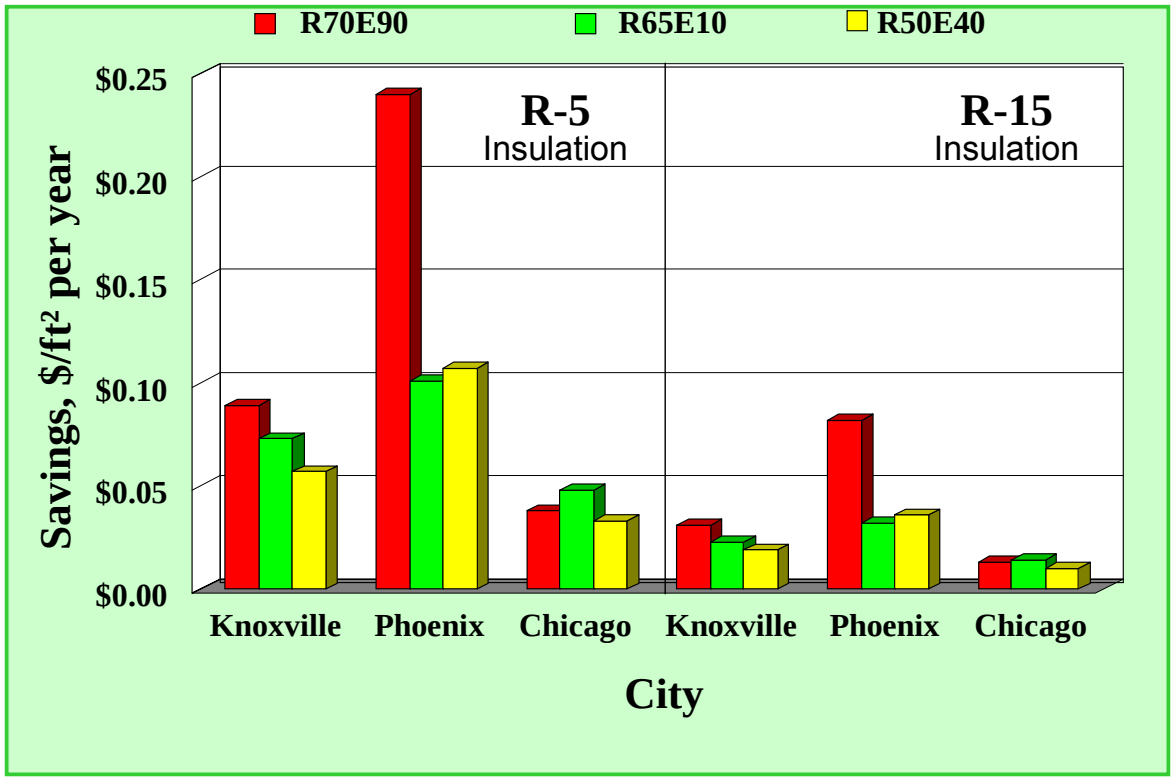
Figure 1. The Solar Energy Spectrum



- Ultraviolet (UV)
  - 3% of total energy
  - Responsible for sunburn
- Visible (VIS)
  - 40% of total energy
  - Visible light
- Infrared (IR)
  - 57% of total energy
  - Felt as heat!

Figure 2. Example of Roof Energy Savings from ORNL Calculator



Note: Roof materials designation:R70E90 = 0.70 Reflectance, 0.90 Emittance

Figure 3. FSEC Data on Roofing Materials' Effect on Attic Temperatures

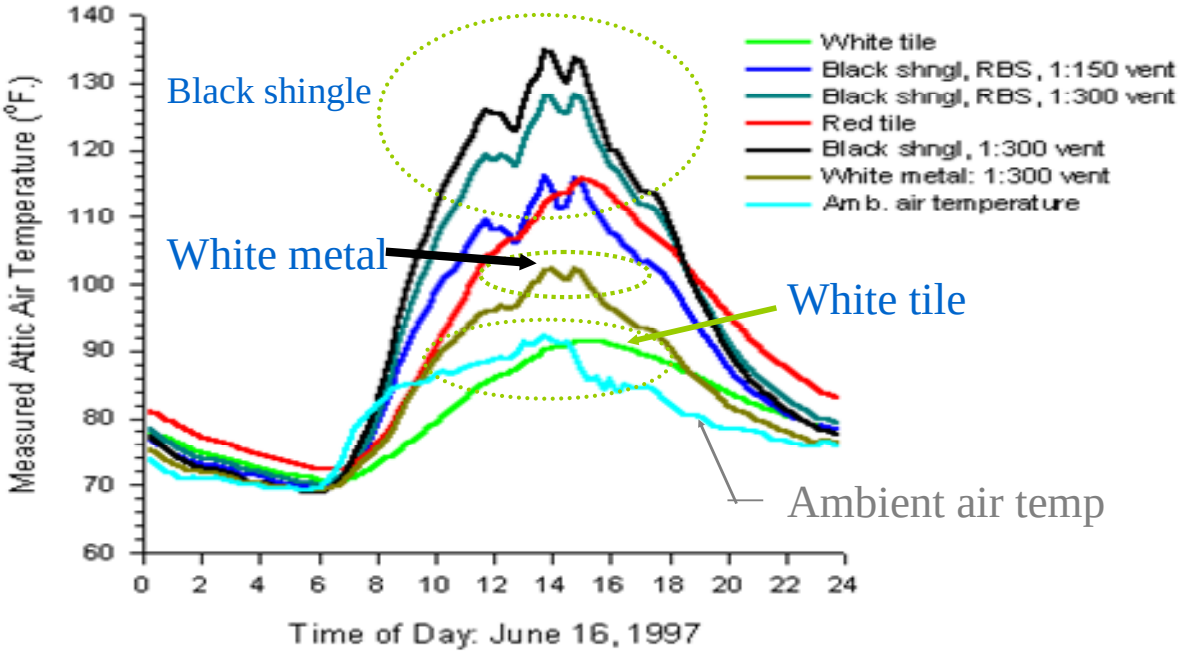


Figure 4. Cool Roof Policies

Policy [1]	Policy Requirements	Minimum Initial Solar Reflectance	Minimum Aged Solar Reflectance	Minimum Emittance
Energy Star				
low slope (< 2:12)	N/A	0.65	0.50	none
steep slope (> 2:12)	N/A	0.25	0.15	none
California Energy Code (Title 24)	Required	0.70	none	0.75
Florida State Energy Code				
Commercial	Required	0.65	none	0.80
Residential	Credit	0.65	none	0.80
Georgia Energy Code	Credit	0.70	0.75	none
Chicago Energy Conservation Code				
low slope (<2:12)	Mandatory	0.25	0.25	none
mod slope (2:12 - 5:12)	Mandatory	0.15	0.15	none
LEED	Credit	0.65	0.50	0.90
ASHRAE				
90.1 Commercial	Credit	0.70	none	0.75
90.2 Residential		0.65	none	0.75
IECC	Credit	0.70	none	0.75
Canadian Energy Code	Credit	none	none	none
California State/Utility Cool Roof Rebate Programs	Mandatory	0.65	0.50	none

[1] Mandatory refers to policies where cool roofs must be used to comply
Required refers to policies where cool roofs are not mandatory, but an energy penalty is given if one is not used
Credit refers to policies where cool roofs are not mandatory, but an energy credit is earned if one is used

Source: Eley Associates, 2003

Material performance reference

MATERIAL	INITIAL TSR	INITIAL TE
Asphalt Shingle	0.09	0.91
Built-up roof	0.05	0.90
CT Galvalume	0.78	0.06
Galvalume Plus	0.68	0.08
HDG	0.66	0.06