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ARCHITECTS TURN TO COOL METAL ROOFING IN NORTH AMERICA

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ABSTRACT

Today's headlines about escalating energy costs and environmental concerns are changing how builders and architects select building materials and how they design for energy performance. Since the roof can be the least energy efficient component of the building envelope, "cool roofing" has come to the forefront. Builders and architects are now learning how advances in coatings and finishes have qualified metal roofing as a recognized "cool roofing" product.

Reflective or cool roofs can directly save up to 40% in energy costs by lowering building envelope cooling loads. Cool metal roofing is available with several different treatments, ranging from unpainted metal to oven-baked painted finishes to granular-coated surfaces. Reflected solar energy allows the metal roof surface to remain cooler, which means less heat is transferred into the building and thus less heating load for the HVAC system.

Cool metal roofing is one way to mitigate the urban heat island effect. Roofs with higher reflectance have lower surface temperatures, which help reduce ambient air temperatures. This improves air quality since less smog is formed. Also, air pollution associated with burning fossil fuels at utility plants is reduced because of less peak load demand.

In addition to being energy efficient, metal roofing is a sustainable building material for several other environmental reasons. As a "green" building product, metal roofing is rightfully becoming more popular in the architectural community.

INTRODUCTION

According to the United States Department of Energy (DOE), there are over 80 million buildings in the US, and another 38 million are expected to be built by the year 2020. The DOE also reports that buildings use 2/3 of all the electricity and 1/3 of all primary energy consumed in the country. The challenge to the construction industry is to build these structures smarter to reduce the impact on our environment and to reduce energy consumption.

In many cases, the type of roof system on a building can have a significant impact on the energy use of a building in terms of cooling and heating energy requirements. Reflective roofing can directly save up to 40% in cooling and heating energy costs. (Heat Island Group, 2003). Research by laboratories such as Oak Ridge National Laboratory (ORNL) and Lawrence Berkeley National Laboratory (LBNL), and the Florida Solar Energy Center (FSEC) continues to focus on cool roofing characteristics.

Metal roofing is used in commercial and residential sectors of the roofing market - for low slope applications where hydrokinetic conditions require the roof system to be watertight and for steep slope applications where hydrodynamic conditions allow for the roof system to shed water. In addition to the excellent service life of metal, this type of roofing product offers design professionals and building owners flexibility in the choice of color, shape, texture, strength and style.

COOL ROOFING

Roofing systems can be designed to help reduce the heating/cooling energy costs for a given building. Metal roofing is no exception, having properties that make it a "cool roof". Cool roofs are those with radiative properties that reduce the surface temperature, minimize the amount of heat transferred into living space below, and reduce the heat released from the surface to the ambient air. Total solar reflectance and infrared emittance are the two main properties that affect the energy efficiency of a cool roof. These physical properties of a roof material are a result of a phenomenon occurring at the outer surface; a fraction of a micrometer in thickness within the irradiated roof surface.

The solar radiation that strikes a roof is comprised of a spectrum of energy levels. Visible light is only a small part of the overall spectrum. The ultraviolet and infrared radiation that hits a roof can be either reflected or absorbed. The fraction of incident solar radiation that is reflected from the surface is the Total Solar Reflectance. The absorbed energy converts to heat at the roof surface which can transfer into the living space below or be released back to the night sky. The fraction of infrared heat energy that a roof releases is known as infrared or thermal Emittance. Any heat energy can also be transferred from the roof surface to the ambient air by convection with air movement. The changes in the reflectance and emittance properties due to weathering of the roof are very important in the overall cooling and heating energy consumption of a building over time.

COOL METAL ROOFING

Metal roofing offers design professionals a wide variety of colors, textures, profiles, strength levels and styles. A metal roof can also be a "cool roof" by many definitions. The family of metal roofing contains unpainted natural metal surfaces, prepainted metal surfaces, and granular-coated metal surfaces. Each type of metal roof has its inherent reasons for being selected by building designers or building owners, and each provides a range of radiative properties. Table 1 below displays typical properties of common roofing products.

Table 1. Roofing Material Radiative Properties

Material	**Total Solar Reflectance**	**Infrared Emittance**
Painted Metal	0.05 – 0 .70 *	0.85 +
Granular Coated Metal	0.05 – 0.65	0.90 +
Acrylic coated 55% Al-Zn	Avg. 0.68	0.08
Chem treated 55% Al-Zn	Avg. 0.78	0.06
Chem treated galvanized	Avg. 0.66	0.04
Asphalt Shingle	0.05 – 0.25	0.90 +
Single Ply Membrane	0.70 – 0.80	0.85 +
Built Up Roofing	0.05 – 0.80	0.90
Concrete / Clay Tile	0.20 – 0.70	0.90

Source: ORNL, LBNL database

* depending on color

A three-year study of metal roofing by ORNL provided information on the interaction between reflectance and emittance, durability, resistance to dirt and biological growth, related to this type of roofing material. (Miller and Kriner, 2001) The experiment involved a range of unpainted and painted metal roofing products in low slope and steep slope configurations exposed at the ORNL test facility in Tennessee. Samples from each type of roofing system were also exposed on weathering sites across North America. The data from this study were combined with similar data from a membrane roof study conducted by ORNL to create a whole-building model that predicts cooling and heating energy savings as a function of the characteristics of a chosen low slope roof. A similar model for steep slope roofing energy savings was also recently completed. (ORNL, 2003)

The most common paint system used for prepainted metal roofing in North America is based on polyvinylidene fluoride resin chemistry. This dense tough coating sheds dirt and retains its color for decades. In the ORNL metal roofing study, metal roofing products were found to resist the growth of biomass which can lead to mold or fungus. In fact, prepainted metal was found to retain almost 95% of its initial solar reflectance over three years of exposure. By comparison, some membrane roofing products and white coatings displayed a 40% and 25% drop in reflectance, respectively, over the same exposure period. (Miller, 2004).

In many cases, energy codes and regulations stipulate initial reflectance/emittance values for cool roofing, but sometimes aged values are also specified. The excellent durability of prepainted metal roofing is important since over time conventional roofs can become soiled by air pollutants, biological growth, and general degradation. These factors can have an impact on the aged reflectance values which affect the true heating/cooling energy costs for a building.

The Florida Solar Energy Center (FSEC), in cooperation with the Florida Power and Light Company, recently conducted a study of Habitat for Humanity homes in the Ft. Myers, FL areas with a variety of roof products on homes. FSEC found that metal roofing "... saves the most energy as a result of its high reflectance and superior ability to cool quickly at night." After studying the cooling energy of identical size homes, unoccupied, they concluded that a white painted metal roof could save the typical Florida homeowner 23% annually in their cooling energy costs, compared to a dark gray asphalt shingle roof. The other products included in the Florida study were dark gray shingles, white shingles, white flat tile, white S-shaped tile, and terra cotta S-shaped tile. (Parker, Sonne and Sherwin, 2002; Parker et. al., 1998)

INCENTIVES AND REBATES

There are many reasons for the increasing popularity of cool roofing, beside the obvious savings in cooling/heating costs. Federal and local jurisdictions in the United States and Canada are developing policies related to cool roofing. The requirements vary from mandatory code compliance, to energy credits for insulation or other building envelope components, to energy penalties if cool roofing is not used. Codes and standards are the primary policies at this point. Some pending legislation at the US Federal level may also highlight the benefits of cool roofing by creating tax credits for users of such roof products. A summary of some of the common cool roof policies in North America is shown in Appendix A. (Eley Associates, 2003)

Throughout North America rebate programs and energy credits are being offered to contractors and building owners to change their dark absorptive roofing materials to cool roof systems. In some regions, the utility industries are also offering significant rebate programs to building owners using cool metal roofs in order to reduce the peak energy demand in the cooling season. For example, the rolling blackouts that occurred in 2001 in California caused that state's utility industry to find a way to alleviate the peak demand being placed on the power grid system. Other states in the US have followed suit in this regard. Even at the local municipal jurisdiction levels there are cool roof programs, incentives and rebates being offered to building owners and planners.

URBAN HEAT ISLAND

Urban areas are prevalent with dark building materials, dark pavements and dark roofs that absorb solar radiation and become hot. The lower amount of vegetation in the urban areas, compared to the suburban surroundings, contributes to the warming phenomenon due to minimal shading and reduced evaporative cooling. These conditions result in urban areas air temperatures being 6-12° F higher than the surrounding suburbs and rural areas of major metropolitan cities. (Heat Island Group, 2003)

The higher urban air temperature has a significant impact on the environment and on the health of the population in major cities. As air temperature increases, the formation of smog increases from the reaction of NO_x emissions and VOCs. In addition, the warmer urban temperatures mean that buildings in these areas require more cooling energy, which translates into more fossil fuel power generation at the utility plant and more emissions into the air. According to EPA data, the average fossil-fueled utility plant in the United States emits 5.7 pounds of smog-forming NO_x for every MWh generated.

LBNL performed a computer simulation estimating the impact of reflectance and emittance on the heating and cooling energy consumption for eleven metropolitan cities in the US. The simulations were based on residential and commercial construction, with ceiling insulation values of R-11 and R-19, respectively. They found that in the US, $750 million could be saved annually by the use of light-colored reflective roofs in the cooling dominant climates.

Cool metal roofing is one way to help mitigate the urban heat island effect. Prepainted metal roofing products offer light colors that can reflect more of the solar radiation and lower the roof temperature, which in turn lowers the urban air temperatures. A recent technological improvement in the use of infrared reflective pigments allows for more solar radiation to be reflected even with darker colors of industrial paint systems. This advance is allowing for popular colors, other than white and lighter colors, to be considered cool roofing. (Barista, 2003)

SUSTAINABILITY

Metal roofing has environmental and functional benefits in addition to its energy efficiency. Cool metal roofing is very durable for longer service life. Metal roofing withstands harsh weather including high winds, hail, ice and snow loads. It withstands thermal cycling and wet/dry conditions that often destroy other types of materials. Commercial metal roofs with 30 years service have been documented. In addition, painted metal roofs are credibly warranted up to 30 years for color fade.

Metal roofs typically have a minimum recycled content of 25% and are 100% recyclable when they are removed as part of a building renovation or demolition. Other roofing materials are routinely removed, often classified as hazardous waste, and disposed of by the ton in landfills across the nation. According to the US National Association of Home Builders, traditional roofing products generate an estimated 1.36 billion pounds of waste asphalt or 3% of the entire municipal solid waste stream per year. Metal is an exceptional roofing product that can credibly claim both recycled content and recyclability.

Depending on the specific product chosen, the weight of metal roofing can be as little as 1/8 that of conventional roofing shingles, for example. The lower weight, but higher strength, of metal roofing produces less static and dynamic loading on the structure. This often allows for metal roofing to be installed over old roofing material without requiring tear-off and disposal of the old material.

COOL METAL ROOFING COALITION

In 2002 the Cool Metal Roofing Coalition was formed to promote the sustainable energy efficient properties of metal roofing. Charter members include the American Iron and Steel Institute, the Metal Building Manufacturers Association, the Metal Construction Association, the National Coil Coating Association and the North American Zinc-Aluminum Coaters Association. The mission of the Coalition is to educate the code-writing bodies, regulatory agencies, architects, and building owners about cool metal roofing. Affiliate members include the American Zinc Association and ORNL. Educational and technical information on cool metal roofing, as well as links to other related sources of information, can be found at www.coolmetalroofing.org.

SUMMARY

Metal roofing offers design professionals and building owners a wide range of shapes, textures, colors, attractive life cycle costs, and energy efficiency. It is a cool roof and qualifies for many incentive and rebate programs. The durability and longevity of metal roofing allows for the radiative properties to be sustained over time, contributing to lower cooling and heating energy costs for a building owner over the life of the roof. A Coalition of the metal roofing industry was created to promote the benefits of cool metal roofing. Metal continues to crown the building envelope with its energy efficiency and sustainability. Architects and design professionals are realizing the features and benefits of this type of roofing product.

Appendix A. Cool Roof Public Policies in North America

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

References

Barista, D. 2003, “Power of Reflection”, *Building Design and Construction*, Feb 2003

Eley Associates, April 2003, “*Assessment of Public Policies Affecting Cool Metal Roofs*”, prepared for the Cool Metal Roofing Coalition.

Heat Island Group Website, 2003, www.eetd.lbl.gov/HeatIsland/CoolRoofs

Miller W.A. and Kriner, S. Dec 2001, “The Thermal Performance of Painted and Unpainted Structural Standing Seam Metal Roofing Systems Exposed to One Year of Weathering” in Thermal Performance of the Exterior Envelopes of Buildings, VIII, proceedings of ASHRAE THERM VIII, Clearwater, FL.

Miller, W.A., Parker, D.S., Kriner, S.A., 2004, “Painted Metal Roofs Are Energy Efficient, Durable and Sustainable”, Performance of Exterior Envelopes of Whole Buildings, IX International Conference, Clearwater, FL.

ORNL Website, 2003, www.ornl.gov/btc

Parker, D.S., Sherwin, J.R., 1998, “Comparative summer attic thermal performance of six roof constructions” *ASHRAE Trans*., Vol. 104, pt.2, 1084-1092.

Parker, D.S., Sonne, J.K., Sherwin, J.R., Aug 2002, “Comparative Evaluation of the Impact of Roofing Systems on Residential Cooing Energy Demand in Florida”, in ACEEE Summer Study on Energy Efficiency in Buildings, proceedings of American Council for an Energy Efficient Economy, California.