INTRODUCTION

Metal roofs may not seem like the obvious choice when you are looking for a high-performance roof. However, they offer many benefits that other “green” roofs can’t compete with. Not only are they aesthetically appealing, they are also energy efficient, made from recyclable material and will likely be the last roof you will ever need to install. They are durable and can withstand the toughest of the elements while remaining resistant to cracking, shrinking, and many other problems traditional roofing materials struggle with. This article will look closer at the many benefits of selecting a metal roof with a solar reflective coating system for your next project.

WHAT IS A COOL ROOF?

A cool roof is one that reflects the heat emitted by the sun back into the atmosphere, keeping the temperature of the roof lower and thereby reducing the amount of heat transferred into the building below.

The coolness level of a roof is determined by several factors, including geographical location, climate, materials in the building envelope, facility design, and insulation used.

There are two key properties that are important for the temperature that a roof will reach in direct sunlight. They are solar reflectance (SR), the amount of solar energy that is immediately reflected from a surface, and thermal emittance (TE), the amount of heat energy a surface can re-emit in the form of infrared energy into the atmosphere.

A cool roof with a high solar reflectance and a high thermal emittance will have a lower surface temperature compared to that of a roof with a low solar reflectance and a low thermal emittance. A lower surface temperature translates into less heat gain in the structure below, resulting in a cooler building, which means less energy used and lower energy bills. Metal roofs use solar-reflective surfaces to maintain lower roof temperatures. In the summer sun, some standard roofs’ surface temperatures can reach up to 150°F. Under the same conditions, a metal roof with a solar reflective coating could remain 50°F cooler.
CONTINUING EDUCATION

BENEFITS OF COOL ROOFING

Cool roof requirements appear in national and local energy codes, green building initiatives and energy rebate programs because a cool roof reduces air conditioning use and lowers utility bills. It also mitigates the urban heat island effect while increasing occupant comfort and reducing the occurrence of health issues associated with poor air quality and smog. Cool roofing lowers maintenance costs and extends roof life. It also assists a building project in meeting or exceeding today's energy and building codes.

The remainder of this article will look at ecological and economical ways to finish metal roofing.

Metal roofs are already recognized as sustainable, durable building components and as such are used in a variety of applications. Cool metal roofs, finished with the proper coating system, not only benefit the environment globally and locally, but can also significantly reduce a building's carbon footprint, energy consumption and cooling/heating loads.

In addition to lowering energy costs, there are many benefits to having a cool metal roof.

**Sustainability:** Metal roofs last much longer than most non-metal roofing products. Conventional roofing products, including asphalt shingles, contribute an estimated 20 billion pounds of waste to U.S. landfills annually. Metal roofs can be installed over an existing roof to help minimize the cost and disposal of tearing off old roofing materials.

**Durability:** Metal roofs have the greatest ability to perform over a long period of time in a wide range of weather conditions, making them an ideal choice for residential, school, government, commercial, industrial and institutional buildings.

**Fire and wind resistance:** Metal roofs are extremely fire resistant and can be designed to withstand extreme weather conditions, such as heavy snow loads, hailstorms and even wildfires.

**Light weight:** Depending on the type of metal used, a metal roof can be 1/8 the weight of other roofing products, placing a lighter load on the structure and foundation and thereby extending the life of the entire building.

**Aesthetics:** Prior to installation, metal coils can be painted to color-match the roof to the design theme of a structure. Pre-painted metal roofing can achieve nearly unlimited design options. Colors can range from standard to metallic colors, special effects, textured coatings and even prints such as weathered copper or burnished slate. The metal panels can be shaped to look like shingles, clay tiles and other popular roofing types, and the metal can also be embossed or stamped for additional aesthetic purposes if desired.

**Retains solar reflectance:** Oak Ridge National Laboratory research shows that metal roofing retains solar reflectance better over time than any other roofing product. This is because it resists the growth of organic matter and sheds dirt more readily than other materials.

**URBAN HEAT ISLAND EFFECT**

The term “heat island” is used to describe built-up urban areas that are hotter than their surrounding rural areas. The urban heat island effect is common to cities in industrialized nations where outside air temperatures are five to 10 degrees Fahrenheit hotter than outlying areas. Due to the lack of vegetation and soil moisture in a metropolis, direct sunlight and heat is easily absorbed by dry, exposed man-made structures such as buildings and roads, thus increasing surface and ambient air temperatures in the built-up landscape. The elevated temperatures result in higher energy costs to cool a building.

In addition, urban heat islands:
- change regional weather patterns
- increase photochemical smog and pollution levels
- compromise our air quality

**MITIGATING THE HEAT ISLAND EFFECT**

Today’s headlines about increased energy costs and environmental concerns are changing how building owners, construction professionals and architects select building materials and how they design for energy performance. The roof can be one of the least energy-efficient components of the building envelope, and metal roofing is one of the most viable solutions to this problem. Technology and advances in coatings and finishes have qualified metal roofing as a recognized “cool roofing” product with the following key national green building initiatives:

- Cool Roof Rating Council (CRRC, www.coolroofs.org)
- U.S. Environmental Protection Agency’s (EPA) ENERGY STAR® Reflective Roof program (www.energystar.gov)
- California Energy Commission’s Building Energy Efficiency Standard, Title 24 (www.energy.ca.gov/title24)
- LEED® green building certification program, a point-based system developed by the U.S. Green Building Council (USGBC, www.usgbc.org)

WHY BUILD WITH STEEL?

When people think of a green roof, they sometimes assume that a vegetated roof is the best option. However, there are actually disadvantages to selecting a vegetated roof over a cool metal roof. There are increased costs associated with these types of roofs, and on average, vegetated roofs cost twice as much as conventional systems. When you select a vegetated roof, it requires constant

![LATE AFTERNOON TEMPERATURES](image)

This graph illustrates how the spread of homes and buildings has increased the holding of heat in the center of a metropolis, in this case Atlanta, GA. As seen, the urban heat island is significantly warmer than its surrounding rural areas.

- raise the temperature of our waterways
- impact our health and that of our environment
maintenance. While conventional roofing materials may require routine maintenance, a vegetated roof requires landscaping, weeding and many unwanted wildlife or insects to look out for. Not only does this maintenance create a headache, the risk of a leak in the membrane or interior could cause substantial damage to the building.

When looking at metal roofs, both steel and aluminum are used in the manufacture of a cool metal roof, although steel is more commonly used. So, why build with steel? In weight, pound for pound, steel is a very economical metal roofing and siding material. The life-cycle costs of steel roofing make it an attractive investment. Steel roofing make it an attractive investment. Steel is an aluminum-zinc alloy — a mixture of aluminum, 55 percent, and zinc, 45 percent. It is the most recycled material in the world, and 64 percent of all new steel in the U.S. is manufactured from recycled steel.

**LEVELS OF SUBSTRATE PROTECTION**

A Galvalume® coating for metal roofing is an aluminum-zinc alloy — a mixture of aluminum, 55 percent, and zinc, 45 percent. It is produced in either A250 or A255 coating weights, where AZ stands for aluminum/zinc and the 50 or 55 means there is 0.5 or 0.55 of an ounce of coating per square foot of the total area, on both sides. Different substrates will vary in weight and composition. Selecting the appropriate substrate and coating system will depend on the building type, location and project requirements.

A galvanized (G) coating for metal roofing is produced in either G60 or G90 coating weights. The numbers indicate how many ounces of zinc are applied to every 100 square feet of surface. “Red Rust” and “Salt Spray” tests measure corrosion resistance. These test are conducted with a salt spray to force corrosion so elapsed time can be measured. The higher the level of zinc, the better the panel performs.

**PURPOSE OF METALLIC COATINGS**

Corrosion can affect the structural integrity and durability of metals and alloys. Overall metal loss may be insignificant, but localized corrosion can lead to pitting, cracking and eventual fracture, causing leakages or more serious failure of building components.

There are two general types of corrosion protection.

- Sacrificial corrosion protection happens when the protective coating reacts in the corrosive media, meaning that the coating, rather than the steel, is attacked.

Eventually, the sacrificial coating will be completely corroded away, leaving the bare steel to rust. Galvanized, Galvalume and Galfan® (5% aluminum-zinc alloy) are excellent sacrificial coatings.

- Barrier corrosion protection happens when the protective coating repels the corrosive media. There is very little attack by the corrosive media on the barrier-type coating. Galvalume and aluminum-coated sheets are excellent barrier coatings.

Galvalume is listed in both the sacrificial and barrier categories, and as such is proving to be a high-performance product for standing seam roofing. The zinc provides protection on exposed edges and places where the coating may become scratched, and the aluminum provides an excellent barrier against corrosive media.

**COATING AND PAINT SYSTEMS**

This next section will focus on coating and paint systems. First, it is important to understand what paint really is. There are four main components of paint. Paints are film formers, which is generally how the paint’s coating is described. Pigment creates color and opacity. Solvents are diluents that enable us to control application properly. Finally, additives can be used to improve performance characteristics of the paint.

A typical gallon of liquid paint will be comprised of solvent, pigment, resin and additives. Paint is a dispersion of pigment into a resin/binder. A paint manufacturer must suspend the particles as best as possible for an applicator to have a homogeneous product to apply to a surface. A paint mixture is reduced to a liquid or paste form before it is used to protect or color a surface. The paint finish provides the aesthetic qualities that consumers, building owners and designers want to see on their roofs.

Paints used on metal roofs are manufactured using a specific paint technology. In the coil coating process, the roofing material is uncoiled and painted in a flat sheet form. The paint is flexible enough that the metal can be re-coiled, formed or stamped into the final roof form. Coil coatings will be discussed further in the presentation.

Resins

Resins are composed of polymers, extremely large molecules that are assembled from a combination of many small molecules. The primary function of resin is to act as the “glue” in a paint formulation by binding all of the components together. In terms of paint, “resin,” “binder” and “vehicle” are interchangeable terms.

The resin is the primary source for a coating’s durability and physical properties. It increases the physical strength and chemical resistance of the film coating, and allows for the curing process — a chemical reaction — to occur while paint is drying. Common resins used in the manufacture of paint coatings for metal roofing include polyester, silicone polyester (SMP) and fluoropolymer.

Resins differ in their ability to withstand UV degradation, and this criterion should be considered when selecting a roof coating for a specific location and application. UV degradation results in chalking of the coating film, essentially a failure of the coating system. Contact your coating supplier for suggested coating system.

**Pigments**

Pigments are added to paint to provide color and can be blended to create a desired color to suit the aesthetics of an application. Pigments also provide opacity to UV light by either absorbing or reflecting light, which often ensures a longer life for the coating. Since most resin systems are typically UV transparent, the pigment must provide UV blocking protection for the primer layer. Pigment can also increase hardness and surface roughness, which lowers the coating’s gloss level.

The performance properties of the final film are affected by the pigments used in the coating mix. Organic pigments have a very bright appearance, but typically degrade more quickly than inorganic pigments. Inorganic pigments, which generally are made from ceramic or mixed-metal oxide, have a high resistance to fade. Metalescent pigments are composed of tiny metal flakes of aluminum, natural mica or synthetic mica-like material. They can produce coatings that shine and sparkle as a result of the shape and size of the metal flakes. Some
coatings with metalescent pigments also change color depending on the viewing angle and light conditions.

**Solvents**

Solvents are chosen for their compatibility with the paint system and their evaporation rate. Solvents are mainly used as a thinner, or diluent, to help maintain and control the viscosity of the paint so that it can be applied. However, solvents serve other uses in the coating as well, such as to dissolve and disperse solid resins and to help film coalescence. Solvents are the volatile ingredients in paint. During the bake process of a metal roof coating, the solvents are released and incinerated, leaving the pigment and resins on the substrate.

**Additives**

Additives are formulated into coatings to enhance the performance of paint. Additives are used to control foam, flow and leveling. They can also provide aesthetic details such as texture or a low-gloss appearance. Viscosity modifiers are used to improve settling and catalysts are used to accelerate a chemical reaction, but are not consumed.

**SOLAR REFLECTANCE (SR) AND THERMAL EMITTANCE (TE)**

Both solar reflectance and thermal emittance are factored on a scale from zero to one, with one being the most reflective or emissive.

It is important to remember that the greater the amount of solar energy reflected from the roof surface, the less energy the building will need to cool down. This concept is especially important in the South with warmer climates. Also, the greater the emissivity, the greater the ability of a surface to cool itself through radiative heat loss; the faster a surface can cool down, the less energy the building needs to be cool.

Ultraviolet, visual and infrared spectra are components of natural sunlight. A compilation of these three components is measured to determine the reflectance value of a surface (i.e. infrared radiation 42 percent, visible light 52 percent and ultraviolet 6 percent).

As solar radiation strikes the outer surface of a roof, a portion of that energy leaves as reflected radiation. The amount of reflected energy is measured as a ratio and depends on the reflectivity of the roof’s surface. For example, if 90 percent of the solar radiation is reflected away, the reflectivity of that roof’s surface is 0.90.

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**QUIZ**

1. True or False: A cool roof with a high solar reflectance and a high thermal emittance will have a lower surface temperature compared to that of a roof with a low solar reflectance and a low emittance.

2. In addition to lowering energy costs, which of the following is a benefit of a cool metal roof?
   a. Sustainability
   b. Durability
   c. Fire and wind resistance
   d. All of the above

3. Which of the following is not true of an urban heat island?
   a. Increases photochemical smog and pollution levels
   b. Compromises our air quality
   c. Decreases the temperature of our waterways
   d. Changes regional weather patterns

4. Which of the following is a component of paint?
   a. Resin
   b. Pigment
   c. Solvent
   d. All of the above

5. Which of the following is the primary source for a coating’s durability and physical properties?
   a. Resin
   b. Pigment
   c. Solvent
   d. Additive

6. True or False: The greater the amount of solar energy reflected from the roof surface, the less energy the building will need to cool down.

7. In which category do cool roofs contribute toward earning points needed for LEED certification?
   a. Energy and Atmosphere
   b. Innovation
   c. Indoor Environmental Quality
   d. Sustainable Sites

8. True or False: When looking at the paint system, the pretreatment aids provide added corrosion protection and a solid base for the top coat.

9. Coil coatings for metal roofing:
   a. Reflect more of the sun’s rays, reducing energy needed to cool a building
   b. Emit heat more rapidly, allowing a building to cool faster
   c. Retain solar reflectance and admittance properties over time
   d. All of the above

10. True or False: Natural exterior exposure is one of the best ways to see how a coating system will stand up to the test of time.

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**SPONSOR INFORMATION**

For over 200 years, Valspar has been a leader in the art and science of coatings that excel in both beauty and function. Our expansive range of superior quality coatings comes to life through a full palette of colors and textures to meet the most demanding environmental conditions and designs.

This article continues on http://go.hw.net/AR1015Course4. Go online to read the rest of the article and complete the corresponding quiz for credit.
The remaining solar energy is absorbed by the roof; however, some of it can be re-emitted. The amount of re-emitted energy is measured as a ratio and depends on the emissivity of the roof’s surface. For example, if 70 percent of the energy is re-emitted, the emissivity of that roof’s surface is 0.70.

The re-emitted energy is really ultra-high wavelength light rather than heat, so it does not contribute to the heat island effect. Energy that is not reflected away or re-emitted can heat a roof’s surface whereby the flow of ambient air causes convection heating, potentially contributing to higher urban temperatures (heat island effect).

In certain metal roofing profiles, a built-in “dead” or vented airspace can enhance energy savings by reducing conductive heat transfer, but the balance of the total solar radiation becomes absorbed energy and enters the building as part of the net heat flux into the roof.

DEFINING A COOL ROOF: ENERGY STAR®

ENERGY STAR qualifying criteria for a cool roof is as follows:

- Low-slope (less than 2:12 pitch, 2 inches of rise over 12 inches of run) — must have an initial SR of 0.65 and an SR of 0.50 after three years of service life (low-slope SR is only met by a white coating)
- Steep-slope (2:12 pitch or greater) — must have an initial SR of 0.25 and an SR of 0.15 after three years of service life

Improvements to SR values can be made even though roof coatings may already comply with the 0.25 steep-slope level. This is achieved with cool pigment technology, the use of infrared pigments (examples of which can be seen below). The values shown here illustrate how different colors may have different SR values. Consult individual manufacturers for detailed data about specific color palettes.

IMPACT ON TEMPERATURE AND ENERGY CONSUMPTION

When looking at the impact on temperature and energy consumption, it is important to follow this rule of thumb. For every 1 percent, or 0.01, increase in roof reflectance, the surface temperature decreases 0.5 degrees to one degree Fahrenheit. Also, for every 10 percent, or 0.10, increase in roof reflectance, cooling and heating energy costs drop $0.02 per square foot in warm climates.

U.S. GREEN BUILDING COUNCIL AND LEED

The U.S. Green Building Council, USGBC, is a 501(c) (3) nonprofit organization composed of leaders from every sector of the building industry working to promote buildings and communities that are environmentally responsible, profitable and healthy places to live and work.

USGBC developed the LEED (Leadership in Energy and Environmental Design) green building certification program, the nationally accepted benchmark for the design, construction and operation of high-performance green buildings. For detailed information about the council, their principles and programs, please visit www.usgbc.org.

The LEED green building certification program is a point-based system where points are awarded for actions taken during design, construction and use phases to reduce the impact a project and its construction will have on the environment and natural resources. The program has nine main categories:

- Integrative Process
- Location and Transportation
- Materials and Resources
- Water Efficiency
- Energy & Atmosphere
- Sustainable Sites
- Indoor Environmental Quality
- Innovation
- Regional Priority Credits

LEED credit requirements cover the performance of materials in aggregate, not the performance of individual products or brands. Therefore, products that meet the LEED performance criteria can only contribute toward earning points needed for LEED certification; they cannot earn points individually toward LEED certification.

LEED SUSTAINABLE SITES CREDITS

Consult individual manufacturers for specific information about LEED programs and relevant credits, but a cool metal roof that has a coating system with solar reflectance and emittance properties may help a building project satisfy the requirements of earning LEED credits in the following categories:

- EA Credit 1: Optimize Energy Performance
- SS Credit 7.2: Heat Island Effect — Roof
- MR Credit 1: Building Reuse
- MR Credit 4: Recycled Content

When looking at the heat island effect within LEED, it is important to understand the requirements to achieve this point. Option 1 is to use roofing materials that have a SRI equal to or greater than 82 for a low-slope roof that is less than 2:12 pitch. For a steep-slope roof, that is greater than 2:12 pitch, the SRI must be equal to or greater than 39.

PAINT MANUFACTURING PROCESS

The paint manufacturing process is largely a matter of dispersing pigments adequately in resins and solvents. Dry pigments are combined and added to a container that contains pre-measured amounts of a specified resin and solvent. A high-speed disperser (mixer or blender) in which propellers revolve provides the dispersing action required to mix the ingredients. The mixture is then pumped over to a second machine, called a media mill. The media contained in the mill may be glass beads, zirconium, steel shot or sand. The hard particles help break up the clumps of pigment into the small-sized particles required to produce a homogenous paint solution. Finally, the balance of resin and solvent is added to the dispersion to complete the batch of paint.

THE PAINT SYSTEM

When looking at the paint system, the pretreatment aids the primer in adhering to the metallic coating. The primer provides added corrosion protection and a solid base for the top coat, and the top coat provides an appealing color. The paint system provides basic protection from the exterior conditions that are prevalent. Special formulations are used for added protection of the substrate in highly aggressive areas such as coastal and industrial regions. Clear coats also allow for the
The bare metal coil is cleaned and pretreated. Proper cleaning and chemical pretreatments are important steps in the continuous coil coating process and will vary depending on the metal being used. An incorrect pretreatment can result in the delamination and failure of a coating. However, an efficient cleaning and correct pretreatment will improve paint adhesion, improve corrosion resistance and make the surface more homogeneous.

The pre-paint, coil coat industry continues to meet and exceed strict industry environmental standards regarding the production and application of paint. The coating industry is constantly testing and evaluating how weather elements interact with paint. For example, we know that exposure to UV light usually starts to break down the coating’s molecules, but a combination of the sun, heat and moisture can accelerate the damage more than any one factor alone. Tests and evaluations are performed to appropriate industry association standards by technical experts. Technology is key to the weather testing of coatings, the formulation of new materials or the improvement of old formulas. It allows for resin development and pigment studies. A coating manufacturer continually develops new products to expand and improve current product lines that prevent field failure, improve quality and durability, meet customer expectations and comply with government and environmental regulations.

Coil coated products are made of recycled content and are recyclable at the end of their service life.

The line roller coating process is very efficient and very little paint is wasted.

The factory application process of solvent based coatings allows the coaters to capture and destroy any volatile organic compounds (VOCs) before they escape into the atmosphere (the heat of combustion of the solvents, which are consumed in the process, is used to heat the metal, and any effluent is incinerated).

Coil coatings for metal roofing reflect more of the sun’s rays, reducing the amount of energy needed to cool a building. They also emit heat more rapidly than other traditional roofing products, allowing the building to cool faster. They are able to retain their solar reflectance and admittance properties over time. Coil coatings are available in a wide array of solar reflective colors including green, red, white and black, and have the same long-life performance as the original formulations.

Factors such as exposure to the sun, UV light, moisture and humidity, high temperatures and temperature fluctuations can lead to color changes, chalking, blistering and corrosion to a protective metal roof coating. Knowing the enemy and understanding how it can affect a painted metal product helps a manufacturer develop and deliver products that meet a project’s specific performance requirements.

**TESTING**

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Weather exposure is a key component in a coating's performance. Natural exterior exposure is one of the best ways to see how a coating system will stand up to the test of time. A testing facility in Ft. Myers, Florida exposes panels at a 45-degree angle facing south for maximum stress on the coating performance. This location provides weather conditions such as salt spray, UV exposure, humidity and climate, making it ideal for natural testing.

Numerous coated and bare metal panels, in some cases in excess of 100,000, can be monitored simultaneously. Be sure to consult individual manufacturers for more information about their test methods and facilities.

To perform physical tests on a cured film, the film must be cast on a coated metal panel, or draw-down. A draw-down panel is a lab-applied panel of aluminum or steel on which a wet coating film has been applied using a wire wound metal rod, which applies a uniform wet film thickness of the coating. The draw-down is then baked at the time and temperature required to assure the proper cure. The draw-down is used to evaluate various properties of the cured film.

Various color instrumentation is utilized to measure the color of a batch versus the standard. The color is always measured versus the standard and as looked at by the human eye. Color is measured in three dimensions. The "L" scale measures light to dark or white to black, the "a" scale measures red to green and the "b" scale measures yellow to blue. This is the convention used in the industry so that all are using common jargon.

Many warranties cite $\Delta E$ (Delta E) which refers to the distance that a color has changed from when it was cured to where it is on exterior aging. It is calculated as follows: $\Delta E = \sqrt{L^2 + a^2 + b^2}$.

A DJH machine is used to measure the dry film thickness (DFT) of coating films by microscopic observation of a precision-cut, shallow-angle crater bored into the coating film. This crater reveals cross-sectional layers appearing as rings, whose width is proportional to the depth of the coating layer(s) and allows for direct calculation of dry film thickness.

Flexibility is critical, as the metal will be post-manufactured into shapes after the film is applied. The "T" bend refers to the number of thicknesses of metal between the two outside in the bend. A special tape is applied to the bend to determine if adhesion is lost. Again, there is a range of performance specified. All American Society for Testing and Materials (ASTM) tests have a range which the coating must comply with before being passed along to the next stage.

Resistance to erosion is important in exterior exposure. The sand abrasion test determines the toughness of the film. Sand, the abrasive, is put in the hopper and allowed to fall from a specified height through a guide tube onto the coated panel below. The sand continues to fall until a hole in the film is created, revealing the substrate below. The volume of sand that falls is measured in liters. The amount of abrasive per unit film thickness is reported as the abrasion resistance of the coating on the panel.

The chemical spot test determines a film's resistance to high acidic or corrosive conditions. A concentrated acid or base is dropped onto the film and covered with a watch glass. After a prescribed period of time, the panel is wiped off and examined. Fluoropolymers are fairly inert and do not change when subjected to such conditions.

CHALKING AND FADING

Chalking is caused by degradation of the resin system at the surface of the finish, due predominantly to exposure to UV rays. As the resin system breaks down, resin particles take on a white appearance, and embedded pigment particles lose their adhesion to the film.

Another common issue is fading, which occurs when substances in the environment attack the pigment in the paint, causing it to change in color.

SUMMARY

In addition to lowering energy costs, there are many benefits to having a cool metal roof including long service life, sustainability, durability, fire and wind resistance, light weight, aesthetics and retention of solar reflectance properties. When comparing metal roofs with other roofing materials, cool metal roofs are clearly the smart, long-lasting choice in roofing materials.