BUILDING ENVELOPE TECHNOLOGY SYMPOSIUM

METAL ROOFING: A PLATFORM FOR RENEWABLE ENERGY SYSTEMS

SCOTT KRINER

METAL CONSTRUCTION ASSOCIATION

4700 Lake Ave., Glenview, IL 60025
Phone: 847-375-4718 • Fax: 847-375-6488 • E-mail: skriner1@verizon.net

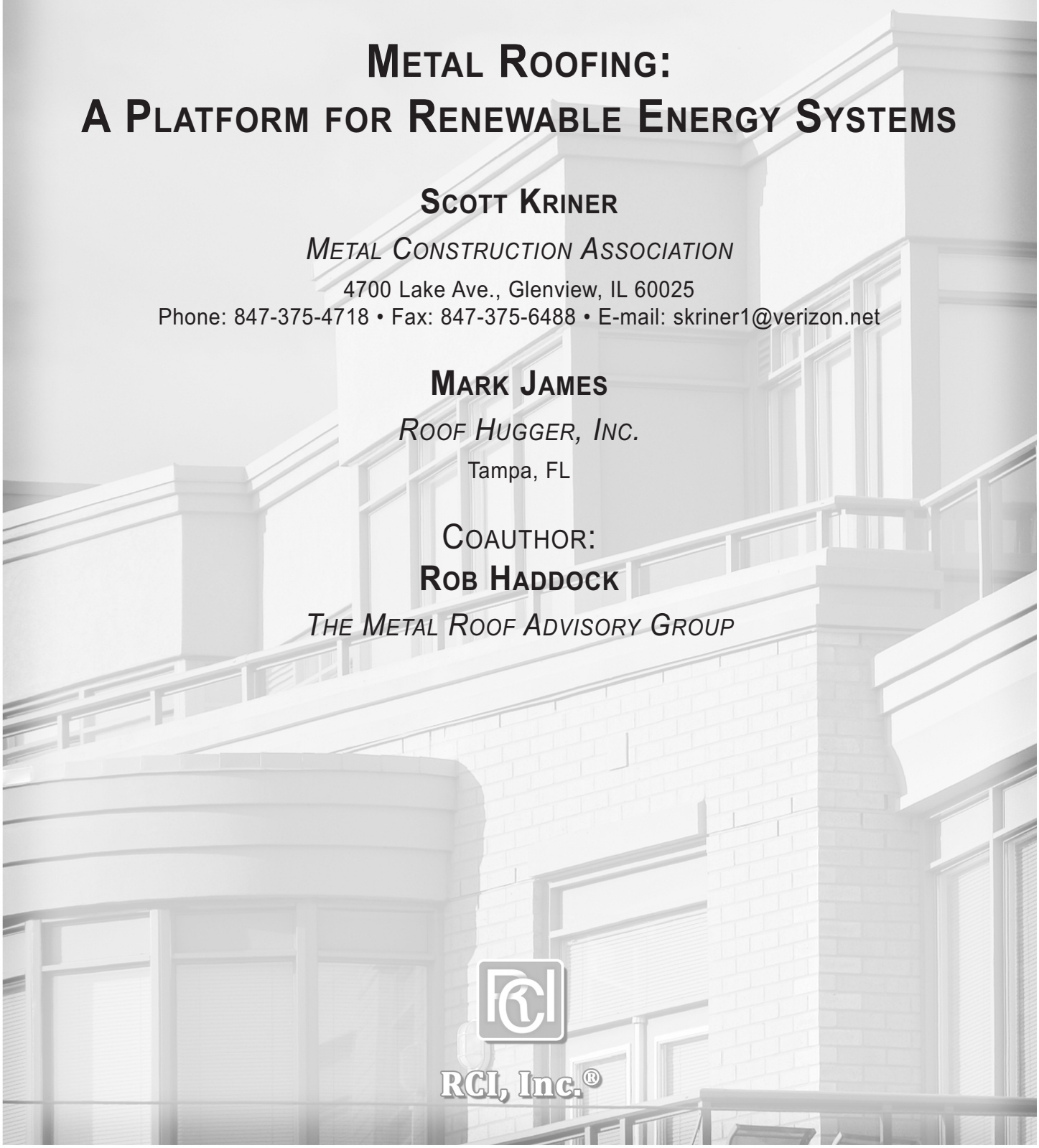
MARK JAMES

ROOF HUGGER, INC.

Tampa, FL

COAUTHOR:
ROB HADDOCK

THE METAL ROOF ADVISORY GROUP



RCI, Inc.®

ABSTRACT

The Department of Energy states that more energy is lost through existing building envelopes than is generated by their heating systems. Solar heat gain and internal loads from equipment and occupants can easily add 50% to the annual heating capacity. Solar heat gain and air infiltration through roofs contribute as much as 24-30% to cooling loads.

This paper introduces metal roofing as the platform to address deficiencies in existing roofs as well as new construction. It will describe how to integrate proven energy savings technologies into a "sandwiched" plenum between the old and new roofs. Various types of radiant air barriers and above-sheathing ventilation (ASV) for natural convective cooling ventilation will be explained. Other new-generation, energy-saving technologies, such as phase change materials (PCM) for extreme thermal resistance, renewable solar thermal heating and cooling (water), and solar heat recovery (air) for space and process heating, as well as roof-mounted photovoltaic systems, will be illustrated. All of these materials can be installed separately or collectively to create a fully integrated encapsulated thermal-composite roof assembly over an existing roof that is aesthetically and architecturally pleasing.

The paper will also introduce previous and current research being conducted at Oak Ridge National Laboratories (ORNL) that relates the benefits to building owners and design professionals. This research substantiates the systems' performance insofar as energy consumption and potential savings through third-party independent case studies. The presentation will conclude with an overview of the various incentives that are applicable to these reroofing technologies, including funding, grants, and federal tax credits/deductions afforded to building owners through the American Recovery and Reinvestment Act (ARRA).

SPEAKERS

Scott Kriner — Metal Construction Association

Scott Kriner, MCA's technical director, is the president and founder of Green Metal Consulting Inc. A LEED® AP, he began his career in the metal construction industry in 1981 with Bethlehem Steel. His company is a member of the U.S. Green Building Council, California Association of Building Energy Consultants, and the Residential Energy Services Network (RESNET). Kriner has served as an officer/director of the National Coil Coating Association, Cool Roof Ratings Council, Metal Roofing Alliance, Metal Construction Association, Zinc and Aluminum Coaters Association, NamZAC, and he was founding chairman of the Cool Metal Roofing Coalition. He is a U.S. patent holder and has published over 25 technical papers in the last 29 years.

Mark James — Roof Hugger, Inc.

Mark James has been an active contributor to the growth of the retrofit concept in the metal construction marketplace since 1986. He has been instrumental in the successful preparation and completion of over 20 million sq ft of retrofit projects. His over 35-year construction industry experience includes the design, sales, fabrication, and construction of conventional and preengineered buildings and architectural metal roof systems. He is a recognized and accomplished technical seminar speaker/presenter for building owners, contractors, and design professionals seeking knowledge to properly retrofit existing buildings. He is now vice president of sales and marketing for Roof Hugger, Inc., of Tampa, Florida.

METAL ROOFING: A PLATFORM FOR RENEWABLE ENERGY SYSTEMS

ABSTRACT

Buildings are responsible for 39% of all energy consumption, 72% of all electricity consumption, and 55% of natural gas use in the United States.[1] The Department of Energy states that more energy is lost through existing building envelopes than is generated by building heating systems. Approximately 15% of residential[2] and commercial building heating loads are from the direct loss of heat through the roof,[3] up to 24-30% when combined with air infiltration.[4] For cooling, the heat transfer from residential building exteriors to the interior accounts for 15% of cooling loads.[5] Furthermore, the Heat Island Group of the Lawrence Berkeley National Laboratory has stated that cooling costs attributed to solar heat gains on roofs can reach $175 million annually.[6]

One of the most significant opportunities to increase energy efficiency lies within the commercial roof sector where over 50 billion sq ft of flat roof surface is currently available for retrofit.[7] An annual energy savings would exceed $2 billon if the insulation levels in these commercial roofs were upgraded from their current condition to the levels required by the Commercial Building Tax Deduction provisions in the *American Recovery and Reinvestment Act of 2009*, which references a building that meets ASHRAE 90.1-2001.

In addition to addressing both energy efficiency and renewable energy, the roofing market provides a significant multiplier effect for achieving national energy goals. For every new roof installed on a new building, approximately three additional roofs are installed on existing buildings to replace older, less efficient roof systems.[8] As a result, the footprint of the reroofing industry greatly exceeds the footprint of new construction starts by a factor of four, accounting for more than 16 billion sq ft of commercial and residential reroof installations annually.

Metal roofing is an excellent platform to address deficiencies in roofs on existing buildings and in new construction. Retrofitting an existing roof with a metal roof allows for the integration of energy savings technologies into a "sandwiched" plenum between the old and new roofs. These technologies include various types of radiant air barriers and above-sheathing ventilation (ASV) for natural convective cooling ventilation. Other new-generation, energy-saving products and technologies can be integrated into the metal retrofitted roof, such as phase-change materials (PCM) for extreme thermal resistance, and renewable solar thermal heating and cooling (water) and solar heat recovery (air) for space and process heating. Owing to its established durability, metal is the ideal platform for roof-mounted photovoltaic systems. All of these energy-saving materials can be installed separately or collectively to create a fully integrated, encapsulated, thermal-composite roof assembly over an existing roof that is aesthetically pleasing and functional.

EXECUTIVE SUMMARY

The term "retrofit" has many connotations when used in the current green construction market for building energy improvements. Retrofitting is often focused on changes to lighting systems, HVAC equipment, and fenestration systems. While there are a multitude of building envelope retrofit methods and concepts employed to achieve energy savings, many do not provide significant savings in either the short term or long term. However, retrofit reroofing with metal provides substantial and continual energy savings with long-term service life. In addition to improving the thermal performance of a roof system, this type of metal roof application also provides an opportunity to employ rooftop renewable energy technologies.

The Department of Energy (DOE) estimates that 25% of our nation's buildings have poorly insulated and maintained roofs,[9] making them immediate candidates for high-performance retrofit metal reroof applications. Furthermore, the DOE's Building Technologies Program (BTP) identified residential and commercial buildings as the largest energy-consuming sectors, accounting for about 40% of the total U.S. annual energy use.[10]

METAL ROOFING RETROFIT APPLICATIONS

Metal-over-metal retrofit roofing systems have been installed on over 50 million sq ft of buildings since 1992, including 1.85 million on military and federal facilities nationwide. The most common metal roofing retrofit applications involve the installation of metal roofs over existing low-slope conventional roofs or over existing steep-slope roofs. Both of these can improve a building's appearance and reduce maintenance. The metal retrofit system can introduce greater slope to a building that previously had a low-sloped roof.

A licensed design professional from the state in which the structure is located should fully engineer the metal roofing retrofit system for the structural analysis, design of the new structural framing system, wind uplift, and snow loads. From the design phase through completion of installation, several steps must be taken to ensure the integrity of the system and the project. The existing roof needs to be thoroughly inspected for degradation such as water deterioration or rust. The roof structure must also be analyzed to ensure that it can support the added weight of 2 to 5 pounds per sq ft in addition to any resultant increase in snow loads due to roof geometry and /or increase in insulation levels for the retrofit system. The actual weight depends on the complexity and gauge of the steel support framing system required to meet specified building codes.

A full engineering analysis is required to determine the appropriate framing and anchorage system, and it is imperative that the new retrofit system be properly anchored to the existing roof's structural system. Improper attachment can result in the new system's being torn from the building in severe wind uplift. It has been documented in wind uplift tests that proper attachment is the main factor in maintaining system integrity. Since the installation involves through fastening of the steel framing into the existing roof structural support system, a temporary waterproofing plan is required to protect the areas where the existing roof is penetrated. These areas are

eventually enclosed and protected by the full retrofit system.

In the engineering phase, the designers can evaluate other opportunities to improve energy efficiency of the new retrofit metal roof system. An air space is created between the existing roof and the new metal roof, in which a more balanced ventilation system is possible and additional insulation can be added. In addition, the installation of a new metal roof allows for integration of a number of rooftop renewable solar energy technologies.

EXISTING LOW SLOPE ROOF APPLICATIONS

The two common types of retrofit applications on existing flat-roofed structures are low-slope and steep-slope metal roofs. During installation of either of these types of retrofit systems, the building interior is not exposed to outside elements or contamination from construction.

Low-slope installations are usually utilitarian and economically driven. Typically, a low-slope metal roof retrofit system does not add curb appeal but is designed to improve discharge of rainwater. In contrast, steep-slope metal roof retrofits improve the aesthetics of the building. They use a variety of framing methods that can turn a low-slope roof into a new roof sloped with a pitch up to 8:12.

Metal roof retrofit systems can solve problems that may result from existing low-slope roof geometry, such as poor drainage, snow drifting, or the addition of a new building adjacent to the existing structure.

BENEFITS OF METAL ROOF RETROFITS

Metal roof retrofit systems provide design professionals and building owners with solutions for improving energy performance and for correcting problematic roofs. In a retrofit application, an air space is created between the existing roof and the new metal roof. The air space provides an opportunity to place additional insulation and/or enhance natural ventilation. Both help to reduce the heat gain and heat loss from the roof, thereby reducing energy demand and substantially reducing dependence on fossil fuel.

Retrofit metal reroofing creates benefits for building owners in many ways. According to a Ducker Worldwide study,[11] a metal roof can reduce the maintenance of a flat roof by as much as 40-50% compared to other conventional low-slope roofing materials. This helps to lower the overall life-cycle cost of the roofing system, in addition to the energy saving benefits mentioned previously.

A retrofit system uses many components, including light-gauge steel framing members, fasteners, insulation, metal roof materials, and renewable solar energy technologies. The growing interest in retrofitting existing buildings creates an increase in the job market in areas of components manufacturing, design, and construction. The metal roof retrofit systems are engineered to comply with all governing national and local building codes.

THE SOLUTION IS RIGHT OVER OUR HEADS

Designers and building owners often overlook an obvious solution when needing to improve an existing building's energy efficiency. A metal roof retrofit system is a well established technology that is available throughout the United States. The system is economical and long-lasting and provides building owners with immediate and continuing returns on their investment. This technology has been used for several decades by all types of governmental bodies and commercial building owners. When retrofitting a building for energy efficiency, metal roofing should be considered as the platform upon which to achieve greater energy savings and sustainability. Retrofit reroofing systems are installed on existing buildings with both low-slope and steep-slope roofs, as shown in *Figures 1* through *4*.

ENERGY SAVINGS AND ENVIRONMENTAL BENEFITS

Retrofit metal reroofing has several environmental benefits. In most cases, the light-gauge steel framing system can be installed over the existing roof and secured into the structural system of the roof. This typically eliminates the need to tear off the original roof, eliminating the solid waste stream to a landfill and improving the cost of landfill management. The International Building Code provides for a standing seam metal roof to be installed over an existing roof without tear-off since the metal roof is attached directly to the structural support system of the building.[12]

According to the Construction Materials Recycling Association, 11 million tons of asphalt shingles are dumped into U.S. landfills annually.[13] With a metal roof retrofit system, much of this tear-off material can remain in place. The metal roofing material provides more than double the service life of

Figure 1 – New steep-slope metal roof over existing low-slope roof.

Figure 2 – New metal roof over existing steep-slope metal roof.

Figure 3 – Existing low-slope roof before retrofit.

Figure 4 – New metal steep-slope roof after retrofit.

asphalt-based products, reducing the frequency of roof replacement and materials being taken to the landfill.

Metal roof retrofit systems provide many options that can include the addition of insulation to upgrade the building to current energy code standards, convective ventilation for cooling the roof assembly, and using Energy Star®-labeled "cool" metal roofing that reflects and emits a high percentage of solar energy. In addition, integrated renewable solar water heating, solar space heating, and solar electricity can easily be employed in the reroof assembly. Each of these systems is well known in the retrofit construction marketplace, with years of history that prove their sustainable value by their ability to pay for themselves. Metal roofing is a good platform for these technologies due to the long-lasting, high-performance roof material that is currently assessed with a 41.6-year service life.[14] That durability allows for the roof platform to outlast the solar technology being integrated into the roof.

The use of metal roofing in retrofitting applications allows a building owner to use a material that is high in recycled content and fully recyclable at the end of its useful life. According to the Steel Recycling Center, steel's recycled content is at least 28%.[15] The recycled content of steel manufactured using the electric arc furnace is as high as 45%.[16] In the case of aluminum, the recycled content is even higher. For both steel and aluminum roofs, the material can be completely recycled through existing waste segregation and reclamation systems in the nation. For a USGBC Leadership in Energy and Environment Design (LEED®) Existing Building-registered building project, the use of material with high recycled content and complete recyclability can qualify for points in the Material and Resource category.

The scrap that is generated during installation can be segregated into a 100% recyclable stream, which can qualify for LEED® points in waste management credit.

HIGH-PERFORMANCE, INTEGRATED RETROFIT REROOFING SYSTEMS

The accompanying illustrations explain the basic fundamentals of integrated, energy-efficient, and renewable-energy roof systems depicting a retrofit application over an existing steep-sloped metal roof. When the metal roofing requires replacement, it is generally caused by the local environment or in cases where the roof has reached its full service life. Metal roofs of yesteryear employed less advanced coatings and design practices than are used and practiced today. According to the Metal Building Manufacturer Association (MBMA), some 18

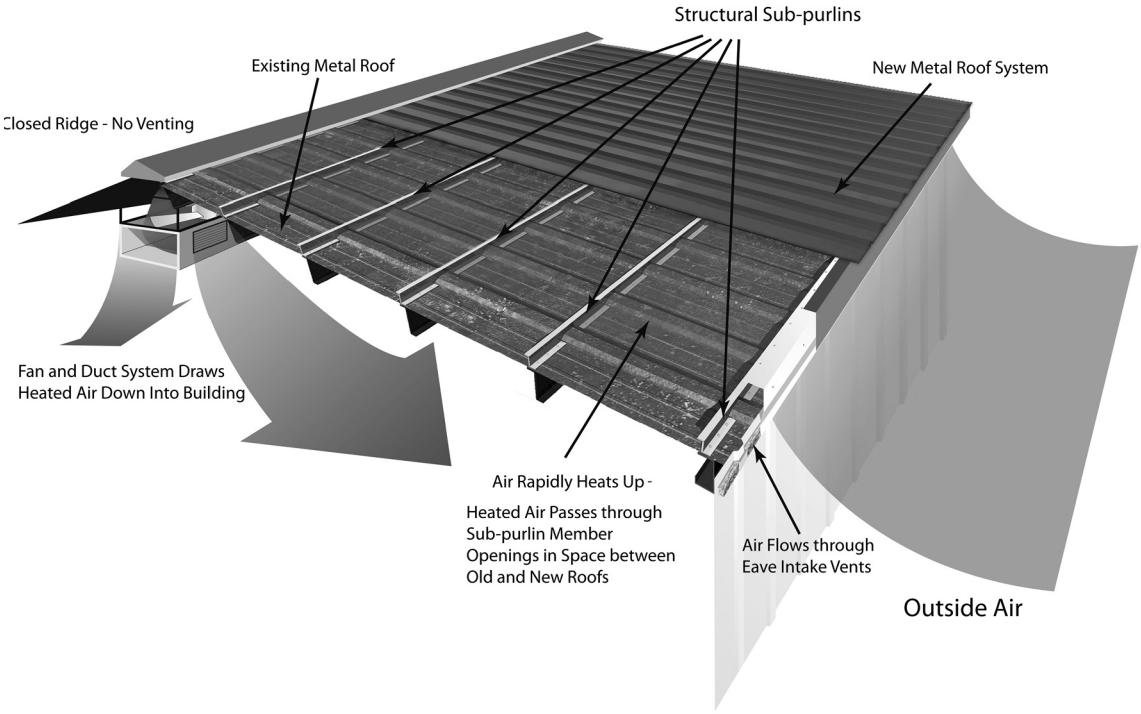


Diagram 1

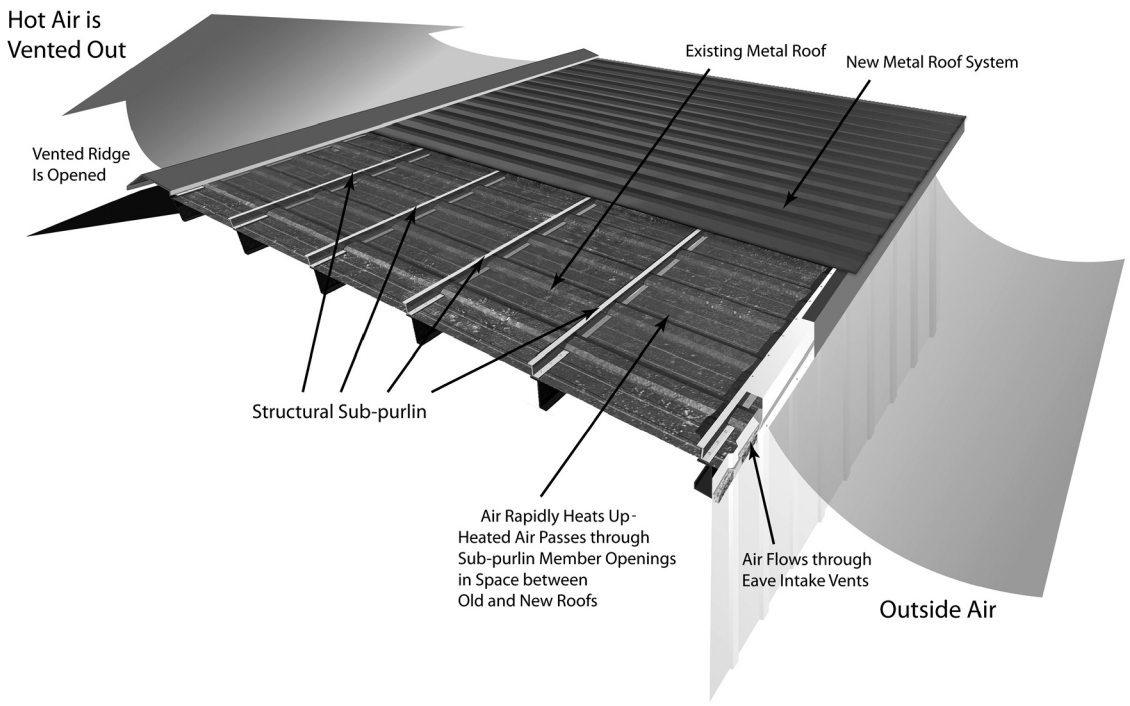


Diagram 2

billion sq ft of preengineered metal buildings were erected between 1970 and 1990, resulting in roofs that are from 20 to 40 years of age.[17] Many of them are prime candidates for retrofit applications that use high-performance integrated systems, such as above-sheathing ventilation, solar heat recovery, and solar water and space heating.

Above-Sheathing Ventilation

The air space created between the existing roof and the new metal retrofit roof can allow for natural convective cooling to take place in warm climates. This phenomenon is referred to as above-sheathing ventilation (ASV). The air flow in this plenum, as shown in *Diagram 1*, can dissipate heat through the ridge vent and has been proven to reduce the heat transmission through the new cool metal and existing roof assemblies by as much as 45%.[18] This air space can also act as an insulator to reduce heat loss from the roof assembly in colder climates.

Solar Heat Recovery

Similar to ASV, a solar heat recovery system captures the ventilated air above the old roof assembly, but rather than allowing it to flow out the ridge vent, it redirects it to the building's existing ductwork and/or other convective construction materials that retain heat, as shown in *Diagram 2*. Solar thermal heating technologies can be applied for space heating to lower energy consumption in the winter months. In summer months, the air is vented out through damperable roof ventilators located at the high point of the roof, or it is used to assist in heating water.

Solar Water and Space Heating

Solar water heating technologies can be integrated directly into a metal roof application as shown in *Diagram 3*. The surface of the metal roof is heated by solar energy, and the heat is transferred to a fluid for heat exchange in domestic water heating, radiant space heating, and process heating and cooling systems. This renewable source of heating can significantly lower energy demand in the building. These systems are highly efficient and can provide returns on investment in as few as five years. These technologies can be integrated with ASV and solar thermal heat recovery in the same retrofit roof assembly.

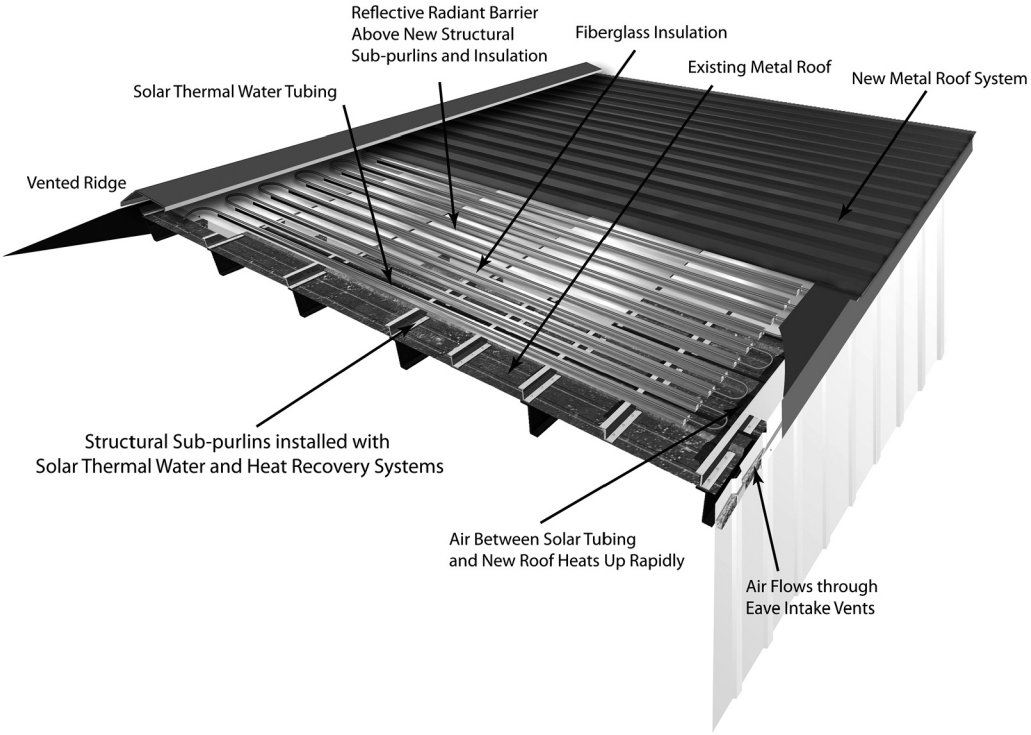


Diagram 3

Photovoltaic Solar Electricity

With a durable retrofit metal roof acting as the platform for retrofit reroofing, the addition of renewable photovoltaic solar electricity installed atop the new metal roof is very feasible. The two common photovoltaic systems include thin-film laminated photovoltaic and mono- or polycrystalline modules, as shown in *Figures 5* and *6*. The thin-film laminated PV is adhered to the flat pan region of metal panels, between the standing seams. The crystalline PV modules are mounted to the new metal roof's standing ribs/seams. In both cases, no penetrations of the roof are made in the installation process. When installed with an ASV system, the efficiency of these PV systems is improved because of the cooling of the roof assembly.

Rainwater Harvesting

Rainwater harvesting systems reduce the consumption of fresh water and can help major urban areas with stormwater drainage problems and related costs. These types of integrated rooftop systems meet the requirements of almost any structure for delivering nonpotable water and have a 95% collection efficiency.[19] They meet building requirements for stormwater drainage and surface water runoff. There are numerous nonpotable uses such as landscape irrigation, equipment /vehicle washing, exterior building maintenance, fire protection, and toilet flushing. Water efficiency is another area in the LEED® program where a metal roof can qualify for points if it is integrated with rainwater harvesting systems.

ECONOMIC IMPACT

Roofs in North America offer tremendous opportunity to achieve long-term energy independence while reducing environmental impact and sustaining a strong economy. Metal roofing, whether for new construction or retrofit reroofing, is an excellent "platform" for the deployment of high performance insulation systems, renewable solar photovoltaic PV and thermal systems, and other integrated roof assemblies as explained in this paper. According to U.S. Census data, the existing rooftops of the United States alone offer over 200 billon sq ft of potential surface area for the installation of these high performance technologies. Assuming only 25%

Figure 5 – Thin-film adhered photovoltaics.

Figure 6 – Mono- or polycrystalline.

of this area is suitable for unobstructed and continuous operation, the photovoltaic PV systems alone could generate over 50,000 megawatts, or the equivalent of ten Grand Coulee Dams.[20]

Furthermore and possibly more realistic, the DOE states that the average commercial building size is approximately 15,000 sq ft and the average residence is 2,300 sq ft. Applying those figures and the relative market share of the metal roofing at 10%[21] in each of these two building segments, we can project that 37,000 commercial buildings and 730,000 homes could potentially see their cooling/heating energy loads reduced by at least 45%, thereby saving 10-12 Gigawatts of energy (kWh PV-T) annually.

A recent McGraw-Hill report projected the retrofitting of existing buildings to grow between 20-30% by the end of 2014, and in the process, create as many as 50,000 jobs.[22] It is estimated that 7,500 of these new jobs will be in the metal construction industry, which experienced a net loss of 30,000 jobs during the recent economic slowdown.

SUMMARY

Over the past 25 years, thousands of buildings have been retrofitted with metal roofing on schools, federal/military installations, and state and municipal facilities, as well as commercial buildings. Each of them is currently enjoying the benefits and cost savings of this reroofing concept. If the other previously mentioned energy-saving retrofit techniques would be employed with a retrofit metal reroof application, the result would be a building that has come closer to achieving net-zero energy status.

ENDNOTES

1. United States Green Building Council (USGBC).
2. J. Huang and J. Hanford, et al., *Residential Heating and Cooling Loads Component Analysis*, Lawrence Berkeley National Laboratory Building Technologies Department: LBNL-44636, 1999.
3. J. Huang and E. Franconi et al., *Commercial Heating and Cooling Loads Component Analysis*, Lawrence Berkeley National Laboratory Building Technologies Department: LBNL-37208, 1999.
4. Department of Energy, Oak Ridge National Laboratory research conducted from 2002-2010.
5. Ibid.2.
6. S. Konopacki, H. Akbari, et al., *Cooling Energy Savings Potential of Light-Colored Roofs for Residential and Commercial Buildings in 11 U.S. Metropolitan Areas*, Lawrence Berkeley National Laboratory: LBNL-39433, 1997.
7. Center for Environmental Innovation in Roofing (2009), *Economic Growth, Energy Independence & America's Rooftops.*
8. National Roofing Contractors Association, *2006-07 NRCA Annual Market Survey*, 2008.
9. Energy Information Administration Report (2006).
10. Ibid.4.
11. Ducker Worldwide Metal Roofing Report, 2006-2007.
12. International Building Code (IBC) Section 1510.3.
13. Construction Materials Recycling Association, *Environmental Issues Associated With Asphalt Shingle Recycling Report*, 2007.
14. Ibid.11.
15. Steel Recycling Institute, *Steel Takes LEED with Recycling Content*, 2009.
16. Ibid.15.
17. Kwon Kim, *MBMA Statistics Report on Metal Building Shipments 1970 Through 1990*, 2008.
18. W. Miller *et al.*, (2007), *Natural Convection Heat Transfer in Roofs With Above-Sheathing Ventilation*, 2007.
19. Englert, Inc., *Rainwater Harvesting Data Sheets*, 2009.
20. Ibid.7.
21. Ibid.8.
22. McGraw-Hill Smart Market Report, *Green Retrofit and Renovation Market Opportunities*, 2009.