1.25 AIA LU/HSW

Learning Objectives

After reading this article, you should be able to:

1. Identify and recognize the characteristics of high-performance green and sustainable buildings as defined by national standards such as LEED and others.
2. Investigate the design flexibility, inherent efficiencies, and general characteristics of metal buildings that contribute to them being sustainable by nature.
3. Assess the green and sustainable contributions of different aspects of metal building design and construction.
4. Evaluate different building types for their green and environmental impact aspects compared to metal buildings through case studies.

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AIA COURSE # K1812J

Sustainable Metal Buildings

Inherent efficiencies and whole building life-cycle assessments produce very positive results

Sponsored by Metal Building Manufacturers Association (MBMA) | *By Peter J. Arsenault, FAIA, NCARB, LEED AP*

A well-designed building is defined by certain attributes that include, among other things, the ability of the building to achieve a desired level of sustainability. At a minimum, this means achieving energy performance that complies with energy-conservation code requirements. It can also include other green and sustainable attributes related to human health, material life-cycle assessments (LCAs), site impacts, and indoor environmental quality. These categories are more specifically defined and addressed in various codes and voluntary standards across the United States and elsewhere. Achieving building designs that incorporate any or all of these attributes at targeted levels can be realized using many different construction methods and building systems. This course will look at one particular construction type that has been successfully used for green and sustainable design, namely metal building systems. While some professionals have erroneously thought that such systems would mean a compromise on energy efficiency and sustainability, independent research and a review of their attributes clearly indicate otherwise. In reality, working with a metal building manufacturer to design a complete steel structural system with a coordinated set of building enclosure components can meet or exceed high standards for sustainability in a very cost effective manner.

All images courtesy of MBMA

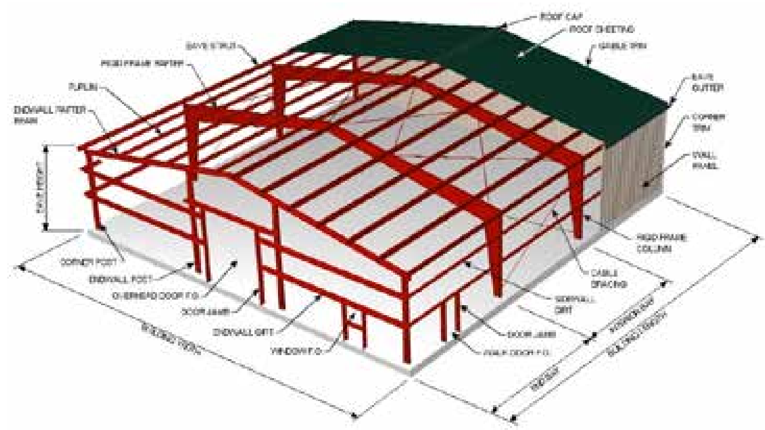
Today's metal buildings come in all shapes, sizes, and architectural styles, providing a sustainable solution for buildings of all types.

METAL BUILDING OVERVIEW

When talking about metal buildings, different people may envision different things. Historically, metal buildings date back over a century ago to 1917 with The Austin Company in Cleveland. They had 10 standard designs, which is where the term "preengineered" originated since the designs were created in advance and were sold as an unmodifiable package. Then, during the 1920s and 1930s, the oil boom in the west created the need for quick and simple-to-construct buildings to provide for storage and basic shelters. The young but burgeoning metal building industry was quick to respond.

The use of metal buildings increased during World War II when large metal buildings were used for aircraft hangars; but most people identify early metal buildings with the venerable Quonset hut. Between 150,000 and 170,000 of them were constructed and in use by the end of the war. They were highly effective because they could be constructed quickly by military personnel and serve multiple purposes. Once World War II ended, metal building manufacturers began producing low-cost, quickly installed factory buildings that satisfied a post-world-war economic boom by providing relatively inexpensive utilitarian buildings. These structures served an important purpose: to house the economic and industrial engine that fueled America's rise to prominence as a world superpower. This utilitarian role may still be foremost in the minds of some designers today, but metal building technology has progressed to allow for much more.

Metal building design and manufacturing has evolved to be a significant source for architecturally inviting and fully customizable structures. The industry has become a provider for site specific, fully engineered buildings such that no two metal buildings are exactly the same. As such, the industry has evolved from being based on standardized designs, to a source of custom design for every single building produced. In the 21st century, metal building systems employ advanced, computer-based engineering, and building information modeling (BIM) technology to create building solutions that align with the specific needs of each project. While the interiors and exteriors can look completely different, based on the design requirements, the basic component types of a metal building system remain constant: rigid steel frames, wall girts, roof purlins, metal roofing, wall cladding, and bracing. A metal building manufacturer can also provide additional building envelope components, including insulated panels, fenestration, roll-up doors, and other features. These common components provide for economy without hampering design flexibility and creativity in the end product.



The basic elements of a metal building system include primary and secondary structural members, metal roofing systems, and metal wall-cladding panels.

Based on all of these advances, it should be no surprise to learn that metal buildings currently comprise approximately 40–50 percent of the low-rise nonresidential building square footage designed and constructed each year in the United States. As such, they have become the building system of choice for a full range of commercial, institutional, and industrial buildings in a broad range of sizes and architectural styles. One important attribute behind such widespread adoption is their design flexibility. Metal buildings allow for long clearspans (in excess of 400 feet) and variable eave heights, so they are very functional for small, medium, and large-sized buildings. Wide-open interior spaces created by these attributes are increasingly popular and equally valuable for manufacturing facilities, warehouses, showrooms, large retail buildings, recreation facilities, and athletic practice facilities.

Speed of delivery and construction is another key advantage that has helped with the growth of metal buildings. Once the building is designed, it can be manufactured in as little as two weeks. The engineered parts and pieces of the complete metal building package are delivered as a single-source package to the job site and received by a qualified erector. Once the project is staged on the ground, the metal building shell typically goes up much faster than conventional construction.

The growth of metal buildings is also attributed to the strength of a trade association founded in 1956 as the Metal Building Manufacturers Association (MBMA). The MBMA has represented and directly helped the industry grow over the past 60 plus years. Its activities include education, research, advocacy, and other programs on behalf of the entire metal building industry. As one of its key programs, the MBMA partnered with the International Accreditation Service (IAS) to implement a comprehensive, robust quality-assurance program. Known as IAS AC472: Inspection Programs for Manufacturers of Metal Building Systems, it is the most comprehensive quality-assurance accreditation program of its kind and is designed specifically for manufacturers of metal building systems. It is based on detailed quality-control requirements that must be independently audited twice a year to maintain accreditation. By setting this high standard of excellence, the industry has been able to demonstrate its competence while gaining the trust of design professionals and building owners.

With a basic understanding of where the metal building industry is today, let's look now at the evolutionary state of green building design.

GENERAL GREEN BUILDING APPROACHES

Green design and construction is no longer a specialty building type but rather has blossomed into a mainstream expectation of most building owners whether for reduced energy costs, improved marketing image, higher returns on investment, or as part of an organizational philosophy. All of this has led to the development and growth of a number of green building rating systems and standards that identify key sustainability categories and then indicate various means to quantify their relevance and impact as applied to a specific building. Perhaps the best known and most often cited program is the LEED green building rating system developed by the U.S. Green Building Council (USGBC), although there are others as well. In addition, the engineering community represented by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) has long been involved in defining criteria for energy performance in buildings, such as the often cited and used ASHRAE 90.1: Energy Standard for Buildings except Low-Rise Residential Buildings. ASHRAE has also worked collaboratively with the USGBC and others to develop ASHRAE 189.1: Standard for the Design of High-Performance Green Buildings except Low-Rise Residential Buildings.

At the same time, the International Code Council (ICC) has developed a series of relevant model codes that have been widely adopted across the United States. The International Energy Conservation Code (IECC) regulates building design and construction with the intent of achieving energy conservation over the life of the building. In a collaborative move that recognizes there are multiple ways to achieve the same results, the IECC allows using the criteria in ASHRAE 90.1 as an equivalent means to demonstrate compliance with the IECC. Similarly, the International Green Construction Code (IgCC) was developed to go beyond just energy and address other categories of green and sustainable building design. In a welcome move and a reflection of the maturity of the industry, the most recent version of the IgCC is actually merged with ASHRAE 189.1 into a single standard, which can be adopted as a code by authorities having jurisdiction (AHJ).

Through this evolving development, all of these codes and standards address the same fundamental categories of green and sustainable design for buildings. These categories include the following, most of which are directly relevant to projects that use metal building systems:

Site-Related Impacts: Adding a building to an existing site will certainly impact things already there. The green and sustainable approach is to find ways that minimize harm to the site in terms of environmental aspects while maximizing benefit through methods that can actually improve environmental site conditions.

Water Conservation: Potable water is an increasingly valuable commodity in many locations due to population growth creating more demand or compromised sources of water that can reduce available supply. Buildings that reduce or eliminate the need for irrigation of plantings and reduce the volume of water needed for common activities related to drinking water, sanitation, and cleaning are clearly more sustainable than those that don't address this fundamental aspect of design and construction.

Optimize Energy Performance: Addressing energy performance takes on several forms. The most significant and cost-effective first step is to address the building envelope by designing for conservation of energy through a reduction in energy demand in the first place. This is achieved through proper levels of insulation, elimination of thermal bridging, and controlling air leakage in opaque wall, floor, and roof areas of building enclosures. It also includes attention to details at fenestration, openings, and penetrations in these opaque areas to address the continuity of building enclosure barriers. The next step is to select HVAC and electrical systems that are efficient to operate, meaning that they use less energy to produce the desired end results of heating, cooling, lighting, etc. This is done through good engineering design and proper specification of equipment and systems that have been tested to demonstrate high levels of efficiency. Finally, the use of on-site renewable energy systems such as solar photovoltaic (PV) systems is recognized as a means to meet energy needs in buildings in a manner that is non-polluting and currently very cost-effective.

Green building rating systems and standards address interior and exterior aspects of buildings in multiple common categories.

Materials and Resources: This category is focused on the sustainable use of building materials and respect for the natural resources where they originate. That means addressing the inherent efficiencies of material use, use of recycled and low-impact materials, reduction or elimination of waste, and resiliency and durability of materials are all important. In order to identify and quantify these aspects of materials, international standards have been developed to create an LCA of materials and products used in construction. In order to carry out a LCA, product category rules (PCR) are often developed by trade and industry associations to determine the overall relevant parameters. Manufacturers can then use the established procedures and rules to create environmental product declarations (EPDs) for their particular materials and products.

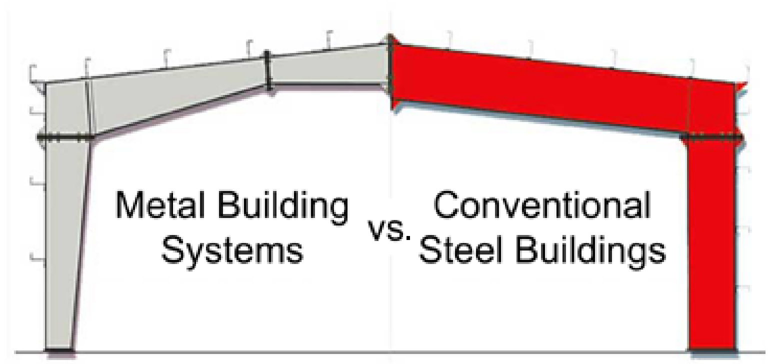
Indoor Environmental Quality: Most green building standards recognize that many people spend more time indoors than they do outside, which can have direct impacts on all aspects of human health. Therefore, they promote or require the use of materials that do not use or emit substances that can be harmful either immediately or over time. For general psychological and emotional well-being, they also promote design options for natural daylight, views to the exterior, acoustical control, and similar conditions.

Innovation in Design: Green building standards and codes are not intended to limit creativity and innovation; in fact, they tend to encourage it. Therefore, customized designs and building systems can often be used to demonstrate project specific attributes that contribute to sustainability.

Based on all of the foregoing, let's now discuss the ways these green building design approaches are applied to metal buildings. We'll do so by looking at some of the main construction aspects of a building: structure, enclosure, materials, and mechanical/electrical systems.

FOUNDATION AND STRUCTURAL SYSTEMS

The sustainability traits associated with the structural system of a building are directly related to the size, weight, and environmental impacts of the materials used for construction. In that regard, it is significant to note that metal building systems using optimized built-up steel frames and cold-formed structural members are structurally very efficient. That means they can use less steel for the same performance as building systems that use hot-rolled members (i.e., I-beams, columns, etc.). Since the metal building steel structure is custom designed to meet the needs for the project, the lighter-weight cold-formed steel members are simply engineered and shaped to put the strength where it is needed and eliminate any unnecessary dead-load weight. This applies to primary members such as columns and rafter beams as well as secondary members like purlins and girts that attach to the primary steel. Overall, that translates to an optimized, lighter-weight, custom-engineered steel structure. Further, since steel is commonly sold by weight, a lighter-weight structure also means project cost savings.



Metal buildings are structurally efficient. They can use 30 percent less steel and are lighter than conventional steel buildings.

A direct result of lighter steel structures is a corresponding impact on concrete foundations. Concrete is commonly regarded as one of the more energy intensive construction materials in use with a number of environmental impacts. Reducing the dead-load and steel-member sizes on concrete foundation systems can also mean reducing the size of the foundations—thus reducing the amount of concrete needed.

The steel used in metal buildings is sustainable overall. That's because a typical metal building is produced from at least 70 percent recycled steel, thus substantially reducing the need for virgin materials excavated from the earth. In addition, the processing of recycled steel for producing goods for a metal building requires significantly less energy.

There are some other less obvious but still significant sustainability aspects of the primary and secondary structural members of a metal building. First is the fact that all of the components are custom designed and efficiently fabricated in an off-site controlled environment. They are then delivered according to a pre-determined construction schedule. Portions of the metal building package can be sequenced to arrive as needed so that the staging area on-site can be minimized—with reduced site impacts. And since there is usually little if any field cutting required, there is very little or no on-site waste.

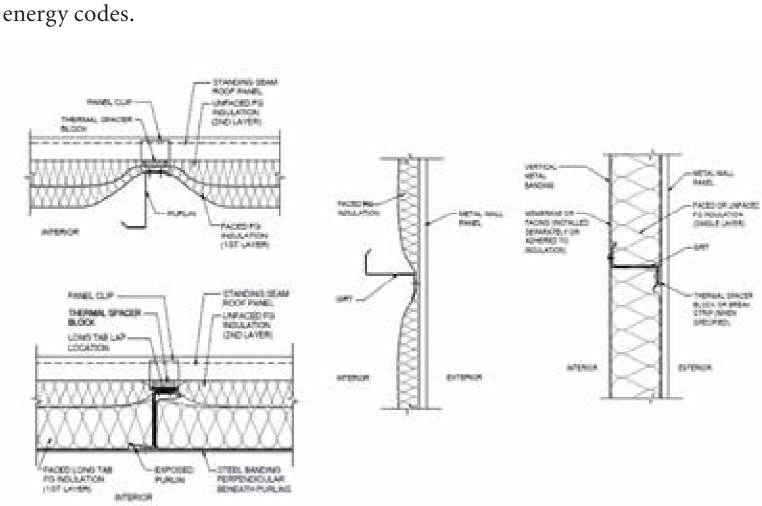
Related to sustainability is the emerging focus on designing and constructing buildings that are resilient, meaning they can not only survive but also bounce back quickly after a natural disaster such as wind, seismic, and flood events. Metal building structural systems can be fully evaluated for such events with the members, connections, and bracing designed specifically for any of the potential hazards of the project location. Since they are custom designed, specifications can include requirements that go beyond the building code to satisfy an owner's commitment to any performance or resiliency goal.

THE BUILDING ENVELOPE

Beyond the structure, most metal building manufacturers offer a complete building enclosure package of components. This commonly includes, at a minimum, a wide range of metal wall cladding and metal roofing in a variety of profiles, colors, and types. Since these are made of steel with factory-applied finishes that are durable and long lasting, they are inherently sustainable. Further, most of them have been engineered and tested as roofing and wall systems to meet stringent requirements for resistance to wind, hail, rain, fire, and other hazards, contributing to the overall resilience of the enclosure. Architectural preferences for wall finishes are what makes metal buildings so adaptable for any application. While the metal building manufacturer may not provide an architectural wall finish such as brick, concrete masonry, glass, etc., the metal building is readily designed to accommodate the required interface.

Insulation

Any discussion of a building enclosure needs to address energy performance, and metal buildings have made significant advances in this regard. Energy codes recognize metal building systems as a distinct construction type and provide minimum requirements for insulation in their exterior walls and roofs. That insulation can take different forms based on the specific details of construction. One of the most common methods has been to drape fiberglass batt insulation over the outside of metal purlins and then fasten the metal roofing or siding to the purlins through the insulation. The fiberglass insulation may have a liner facing the building interior (commonly referred to as liner system) that acts as a vapor retarder and general covering of the insulation that may be left as a finish surface or covered with any common finish such as gypsum board. Either way, draping the fiberglass is time efficient but compresses the insulation at each purlin, reducing its energy-conserving effectiveness. In response, thermal spacer blocks made of rigid insulating material can be placed along the metal purlins to reduce the thermal transmission along those lines. Energy codes require such thermal spacing blocks to carry a minimum R-value on the order of R-3 to R-5 where they are acceptable for use. The insulation itself may carry R-values of R-19 to R-30 or more in the sections where it is not compressed. Either way, hot-box testing of multiple metal building and wall assemblies can provide owners or design professionals the necessary information for demonstrating compliance with the adopted energy codes.



Shown are examples of different methods of using fiberglass insulation in wall and roof assemblies in manufactured metal buildings.

In many climate zones, there is a need for higher energy performance, and both the energy codes and metal building manufacturers have responded. Instead of using only a single layer of fiberglass insulation, it is now routine to use a double layer: one that is installed between the metal framing members and one that is continuous over the outside of those framing members. The metal roofing or siding is then held off from the purlins or girts with mounting clips spaced at intervals appropriate to structural needs. In lieu of fiberglass, foam plastic insulation may be used whether in the form of rigid boards applied to the outside of the structure or spray foam that fills all of the framing cavities completely. In either case, fully insulated metal buildings that meet or exceed code requirements are readily achievable with this field installed method.

Insulated metal panels (IMPs) use rigid, high-efficiency foam plastic insulation between an inner and outer metal skins to create a continuous building enclosure panel.

A factory-installed insulation method is also available in the form of insulated metal panels (IMPs). In this case, an inner and outer metal skin is filled with foam plastic insulation to create a rigid, durable, prefinished panel. The exterior surface is metal siding or metal roofing in a typical choice of profiles and colors. The interior surface is a simple prefinished metal skin. The edges are formed so panels overlap or interlock and are typically designed with thermal breaks so the inner and outer metal skins do not touch, thus avoiding thermal bridging between inside and outside. The edge details also allow for continuous sealing using gaskets, caulk, or sealants as appropriate. The panels are typically fastened to the structure using concealed clips and screws compatible with the IMP system. Thus a continuous, factory finished installation is achieved over the outside of the building structure with a durable interior skin facing inward. This provides a continuous enclosure system that can be specified to comparatively high insulation levels. The attributes of the foam insulation used can range from R-5 to R-7 per inch, allowing IMPs to readily meet and exceed energy code requirements with less wall or roof thickness than fiberglass systems.

Air Sealing

A significant source of energy loss occurs from air infiltration or exfiltration in buildings. Energy codes recognize this and now have mandatory provisions for addressing it for all types of construction, including metal buildings. The details of ensuring proper air sealing remain with the design and construction professionals involved in a project, but metal building manufacturers have acknowledged this need and facilitated good air sealing. Metal roofing and wall cladding qualify as an air barrier under the codes (i.e., sheet steel or aluminum is one of 16 listed air barrier materials), but the edges and penetrations need to be treated. This is accomplished in the usual manner by using gaskets, sealants, or caulking suitable to the panel type and installation.

Customizable Fenestration

All buildings need fenestration openings for access, light, and ventilation. Providing those openings in a manner that is sustainable is a function of controlling the things that pass through them. Hence, it is important for windows, doors, and skylights to admit visible light but restrict the amount of solar heat gain if air-conditioning is in use. Similarly, restricting heat loss and air infiltration through fenestration becomes paramount when the building is being heated. In that regard, the fenestration industry has made available a full range of product choices that have performance characteristics related to overall thermal U-factors, solar heat gain coefficient (SHGC), visible light transmission (VT), and air infiltration. Any of these commercial products can be specified and selected to be incorporated into metal buildings. In some cases, the metal building manufacturers may offer their own customizable products in the form of windows, skylights, and even translucent wall and roof panels that are readily incorporated into a building.

In finding the right balance of fenestration characteristics, a sustainability trait worth focusing on is the use of natural daylight. The benefits of energy conservation can be realized when daylight is harnessed to replace the need for electric lighting in a building. This is readily done in a metal building, particularly since many of them are low rise and can incorporate skylights between the structural members to illuminate the interior spaces. Many retailers with large sales floor areas have recognized this, and it is common to find skylights linked with automatic controls to dim or turn off electric lights in retail stores such as Walmart, Home Depot, Costco, supermarkets, and others. This same concept is readily applied to virtually any metal building.

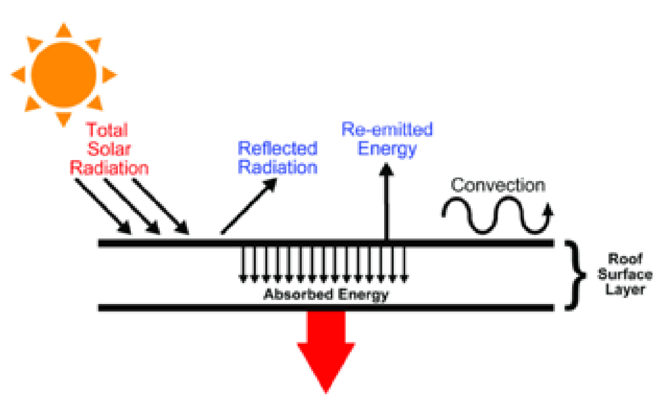
In addition to energy cost savings, providing daylight and views are part of the definition of most sustainable and green buildings. This is based on the documented health and well-being benefits on people that have been evidenced. It is common to locate windows and skylights throughout occupied spaces so that all or at least most of the people in those spaces can access a view to the exterior and benefit from some natural daylight. This is quite achievable in metal buildings just as with any other building construction system—it is wholly predicated on the design.

Daylight can be incorporated in metal buildings using windows, skylights, or translucent panels—some of which can be supplied as part of a manufactured metal building package.

Cool Roofs

In recent years, there has been a recognition that sunlight striking dark-colored surfaces such as roofs can contribute to creating higher air temperatures around buildings. In the interest of reducing the creation of "heat islands," lighter-colored roofs have become a common sustainability strategy. Green building rating systems use defined criteria and nationally recognized sources to quantify how effective any particular roof can be in reducing heat absorption to determine if they qualify as a "cool roof" or not. Research from the U.S. Department of Energy shows that one additional percentage of reflectivity in a roof coating, on average, will reduce roof temperature by 1 degree.

A common calculation used to define a cool roof is the solar reflectance index (SRI) as defined in ASTM E1980: Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces. SRI is a method to obtain an index for relative surface temperature with respect to a standard white (SRI = 100) and a standard black (SRI = 0) under standard solar ambient conditions and wind speed. In order to accurately determine the SRI of many materials, The Cool Roof Rating Council (CRRC) was established in 1998 and administers a Product Rating Program in which companies can label roof surface products with radiative property values. All radiative roofing tests and aged field tests are conducted by CRCC approved facilities.



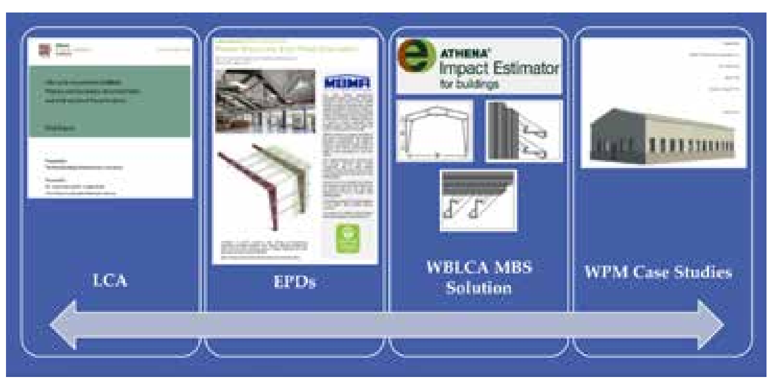
A cool metal roof is one that has been manufactured and coated to reflect noticeably more sunlight than it absorbs thus reducing the heat generated by the surface.

The MBMA has been an active member in the CRRC since its founding and has worked with the CRRC through the Cool Metal Roofing Coalition. Metal building manufacturers can supply roof systems in a wide range of profiles and thousands of colors. Rating each material would be onerous as well as prohibitively expensive. As a result, the CRRC adopted the Color Family Program, which is a predefined range of "L," "a," and "b" color values on the Hunter Lab Color Scale that establishes the color space for a CRRC predefined set of 17 colors.

Compared to all other cool roof products, metal roofing stands out in terms of long-term performance. Both painted and unpainted metal roofs exhibit sustainable reflectance and emittance values in even the harshest environments. One reason for their outstanding performance is their ability to "self-clean" with rainwater and their inherent resistance to mold and mildew growth. These factors, in addition to the ability to expand and contract with fluctuations in the roof temperature, make metal an excellent choice for cool roofing.

MATERIAL LIFE-CYCLE ASSESSMENTS

LCAs are recognized as the most effective means to holistically assess the impacts that materials and processes have on the environment and on people too. In that light, the MBMA has funded extensive research related to the environmental impacts of metal building systems. Through collaboration with the Athena Sustainable Materials Institute and UL Environment, MBMA developed an industrywide LCA report and three industrywide environmental product declarations (EPDs) for designers to use when specifying MBMA-Member products. The purpose of this effort was to conduct an LCA to benchmark the average environmental impacts of the structural and panel products used in metal building systems as manufactured by its member companies.



The MBMA has facilitated the creation of LCAs and EPDs for metal building systems that have been used as the basis for additional comparative studies and analyses.

The LCA study focused on both MBMA member company manufacturing processes (gate-to-gate) as well as four key product profiles (cradle-to-gate): primary structural frame, secondary structural components, metal wall cladding, and metal roofing. The respective gate-to-gate (G2G) process and cradle-to-gate (C2G) product environmental profiles are used by MBMA for environmental benchmarking purposes. This study did not consider the installation, use, or end-of-life phases of these products. Consequently, the C2G LCA results without end-of-life recycling as portrayed in this study are considered conservative.

The Executive Summary of the report states: "A contribution analysis [conducted as part of the project] revealed that the G2G processing generally accounted for 4 percent to 16 percent of the total primary energy use and 3 percent to 12 percent of the global warming potential (GWP) of the total C2G product system." These low numbers suggest that the metal building manufacturing process accounts for a small portion of the total embodied energy in the steel. This is reinforced as the report goes on to say: “Upstream steel production is the single and most significant input driving the environmental burden of all four products looked at.” Getting a bit more specific, it states: “Generally, the upstream production and delivery of steel inputs was more significant for wall and roof panels (due to the inclusion of high-performance coatings and paints) than the semifinished steel inputs used in the production of primary and secondary frame components. On a unit of output basis, wall and roof cladding embodies more energy and results in more emissions than either primary or secondary frame components.”

In the interest of identifying areas for improvement, the report points out “Electricity use, especially in the production of primary and secondary frame materials, was the main energy input used in MBMA plants and varied by as much as 20 percent across plants producing the same component. Curbing in-plant electricity use would yield the greatest improvement in plant operations.”

BUILDING MECHANICAL AND ELECTRICAL SYSTEMS

All modern buildings rely on using energy to run mechanical and electrical equipment for conditioning the spaces in them, lighting them, or other operating aspects. Using energy efficiently for these purposes is paramount in energy codes and green building programs. There are two things to keep in mind in this regard to metal buildings per the following.

HVAC and Electrical Systems

There is nothing about a metal building system that restricts or limits the available choices in energy-efficient and environmentally friendly HVAC systems. Rather, the selection and sizing of that equipment will be based on good engineering principles, the available energy sources to run the equipment (electric, natural gas, steam, etc.), and the preferences of the building owner/operators, which may be influenced by cost. More relevant is the design of an energy-conserving building envelope, which, if done properly, will lower the heating and cooling load of the building to begin with, thus reducing the size of the equipment. Smaller-sized equipment usually means less initial costs, less operating cost over time, and less replacement cost at the end of its service life. Hence, a properly designed metal building has all of the energy efficiency and cost savings potential of any other building for HVAC systems with no restrictions.

Similarly, there is nothing inherent about a metal building that restricts the design and layout of electrical items within a building. In fact, the use of natural light can enhance the options for electrical lighting and allow for more choices and more creativity in the way electrical lighting is laid out and used in the building.

Solar Systems

Solar photovoltaic (PV) electric and solar water-heating systems are more economical than ever before and offer a ready opportunity to generate on-site renewable energy. Hence, they are showing up on all types of buildings, commonly on the roof. Metal buildings that use standing-seam metal roofing are an ideal opportunity for installing such systems due to the simplified methods of mounting the PV array and the longevity of the standing-seam metal roofing system, both of which translate to further significant cost savings. The metal roof generally provides a service life in excess of 40 years, which means it can outlast the PV array, thus avoiding costly roof replacements during the life of most PV arrays.

From an installation and weatherability standpoint, PV systems can be mounted on a standing-seam metal roof by means of non-penetrating seam clamps which are not invasive to the roof. Therefore, depending upon wire management techniques and other details, it is not only possible but common practice to mount PV arrays on metal rooftops with no penetrations of the roofing. By correctly mounting to a metal roof in this fashion, weather integrity and roof warranties remain intact, which is not generally the case with other types of roofing systems. When the usable life of metal roofing and PV is expired, virtually all roof and PV materials are recyclable—thus having environmental advantages over competitive roof types. It is also worth noting that the solar panel mounting costs are significantly lower for standing-seam metal roofs because the standing seams provide a grid to mount directly upon. That means there is no extra framing or other materials so hardware costs, construction time, and labor can be less. Once installed, the space between the solar panels and the roofing provides a desirable air flow. This air flow helps to cool the panels and has been found to lead to higher efficiency of operation.

Mounting solar electric photovoltaic (PV) panels on a standing-seam metal roof is quicker and more economical than on other roofing systems.

CONCLUSION

Metal building systems have come a long way over the past century. With a proven track record of engineered, economical solutions, they have also proven their ability to provide great design flexibility. In particular, their efficient construction techniques, comparatively low environmental impact materials, and design opportunities for improved building envelopes, healthy spaces, and renewable energy use all contribute to high levels of sustainability. As such, metal building systems can be considered for any type of green and sustainable commercial, industrial, institutional low-rise building.

METAL BUILDING NAMED FIRST PLATINUM-CERTIFIED HANGAR

Project: Hangar 25, Bob Hope Airport
Location: Burbank, California

The Project: The world's first LEED Platinum-certified aircraft hangar resides at the Bob Hope Airport in Burbank, California. At the heart of Hangar 25 is a maintenance facility that can service planes as large as a Boeing 757-200. The $17-million building is situated on a 2.81-acre site at the airport and has 50,630 square feet of hangar space, plus approximately 12,000 square feet of office and meeting area.

The versatility of the building is manifested in the combination of the office and hangar space, allowing the nose of an aircraft to pierce the typical office-hangar line. This design allows for the first- and second-floor offices to be situated on both front corners of a building while utilizing a fully glazed translucent front entryway, showcasing views of an aircraft. There is also a steel bridge across the foyer that allows occupants to cross to either side of the offices and provides excellent views of the hangar operations.

Sustainable Construction: The hangar uses a metal building system including a metal roof and metal wall panels that incorporate a multitude of sustainable features. Metal building systems are popular choices for airport hangars because they are cost-effective and can offer clear spans to suit any size aircraft. Hangar 25 demonstrates that they are also sustainable. The hangar gained valuable LEED points for its recycled content with recycled steel used for the primary structural members being a large part of that. Steel is generally regarded as the most recycled and recyclable building material in the world. In the quest for efficiency, the structural members in this metal building system are custom engineered to handle the specific load needs for Hangar 25. This optimizes the steel used in the building and keeps costs down. In this case, that also meant designing a structure that could handle a 225 kW photovoltaic (PV) system on the roof. The PV panels are mounted to a standard R-panel roof on a rack system that attaches to the purlins. An added benefit of the PV system is the shading it provides to the roof. This helps to keep the cooling costs down and, along with the highly reflective white metal roof panels, reduces the heat island effect of the building. The roof itself is considered a cool roof, with a solar reflectance of 0.70, an infrared emittance of 0.85, and a solar reflective index (SRI) of 85.

Renewable Energy: The solar array has more than 1,500 PV panels, producing 110 percent of the power needed to operate the facility. It is expected to produce more than 400,000 kWh of energy per year. The electricity savings from the solar array are significant. The building has operating expenses that are approximately 2 cents per square foot compared to a traditional hangar that operates at about 20 cents per square foot. All of the equipment for the hangar, including rechargeable tractors, forklifts, and tugs, run off the electricity produced by the solar array. Further, when aircraft receive maintenance, the power to keep all the systems running comes from the solar array. Using the solar power is not only cost-effective, but it also does away with fumes and odors from the diesel and jet fuel that would ordinarily be required.

Ventilation: Six large metal fans hang from the steel frame of the building and provide a low-cost system for circulating air. The large-volume, slowmoving fans help to maintain high air quality and keep the hangar cool in the summer and warm in the winter. Additionally, when a plane comes in fresh from a flight they can blow away condensation quickly.

Natural Lighting: Daylighting is also a popular energy saving feature in new buildings, and the ease with which a metal building system can handle this is evident in Hangar 25. There are more than 100 translucent panels in the metal roof, keeping lighting costs down and creating a better work environment. More than 95 percent of the regularly used areas of the facility, including the office space, receive natural daylight.

Other Sustainable Features: The concrete floor of the hangar incorporates a unique, diamond-polished surface. In many maintenance hangars, the floors often have a coating with epoxy and other potentially harmful contaminants; they also need to be resurfaced every few years. The natural concrete floor of Hangar 25 was polished to a bright finish using a diamond-bladed polisher. The final product is a chemical-free concrete floor that is estimated to last at least 20 years, and those who work here won't have to worry about toxic compounds. Another benefit of the polished floor is the high reflectivity, which increases the impact of daylighting. Other sustainable features include low-flow plumbing fixtures, natural landscaping, and a special water mist fire-suppression system.

Results: Hangar 25 at the Bob Hope Airport is an excellent example of how metal building systems can incorporate the benefits of sustainable designs.

Based on a case Study by Jay D. Johnson, LEED AP, Director of Architectural Services for the Metal Building Manufacturers Association

WALTER P. MOORE COMPARATIVE CASE STUDIES OF BUILDING TYPES

Comparative Case Study Overview: The Metal Building Manufacturers Association (MBMA) engaged Walter P. Moore and Associates to conduct a whole-building life-cycle assessment (WBLCA) comparing the environmental impacts of a metal building system against other forms of construction based on the results of the Athena Institute Impact Estimator software. The purpose of the study was to compare the environmental impacts for the building envelope of 10 case study buildings that included metal building systems[1] and other forms of construction located in three different climate regions in the United States. As a result, 30 total building case studies were evaluated in this study.

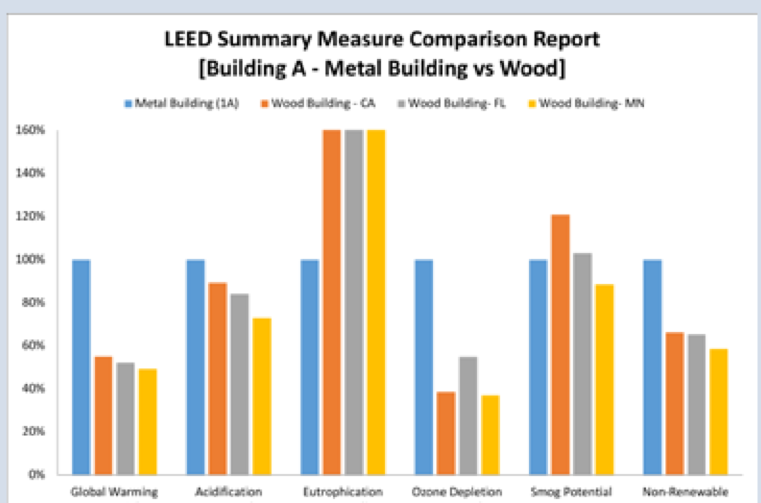
This study compared WBLCAs between metal buildings and alternate construction types for the three different building uses and footprints using Athena Impact Estimator software. WBLCA is not intended to give exact calculations of environmental metrics but instead gives a picture of how the buildings compare in various categories. This study focused on the following environmental metrics:

- Global warming potential
- Ozone depletion potential
- Acidification potential
- Smog potential
- Nonrenewable energy
- Eutrophication potential

The Comparisons: This case study comparison looks at three different but common building types, namely a small office building, a medium-sized storage building, and a large-sized industrial building. Each type is compared based on being constructed of one or more of five different structural building system types: 1) a metal building system, 2) a wood-framed building, 3) load-bearing masonry, 4) concrete tilt-up construction, and 5) wide-flange steel construction. Case study A compared a metal building with a wood-framed building for a small office, while case studies B and C compared a metal building with a load-bearing masonry, concrete tilt-up, and wide-flange steel buildings for a medium storage facility and a large industrial building. Each of the case studies are analyzed in three different climate locations, namely Florida, California, and Minnesota.

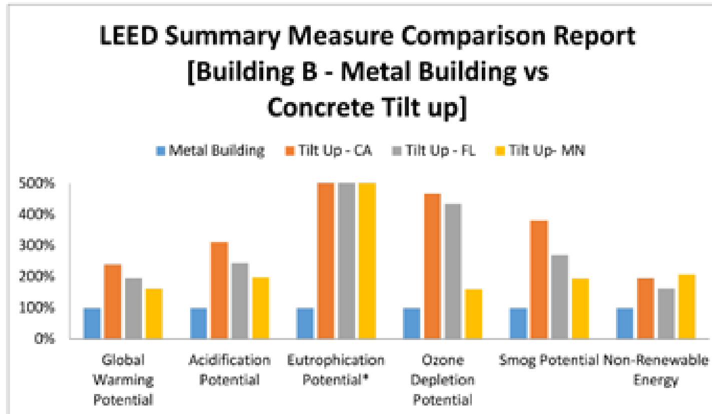
Case Study A: Small Office Building

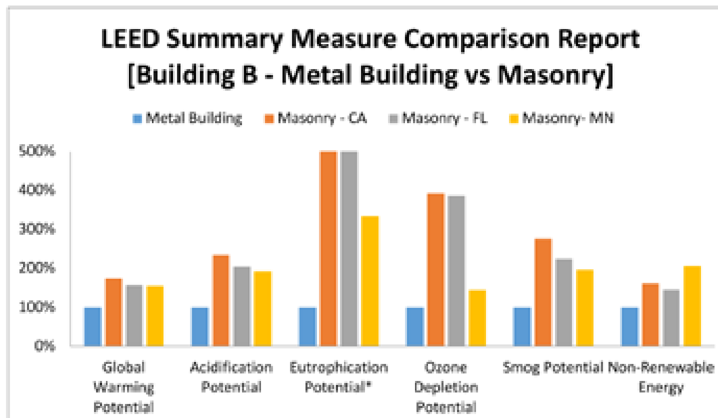
For the small office building case study, a metal building was compared to a wood-framed building. Overall, the wood frame building materials showed less embodied impact than the metal building in the categories of global warming, ozone depletion, acidification potential, and nonrenewable energy for all project locations. It showed more impact for eutrophication potential. The results for smog potential varied by project location and were within 10 percent and are considered within the error of the data reporting.

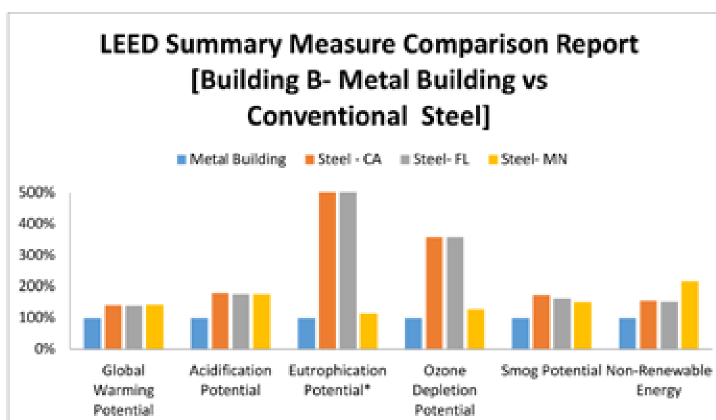


Case Study B: Medium-Sized Storage Building

The medium-sized storage case study building compared the metal building to a load-bearing masonry, concrete tilt-up, and conventional steel-framed building for each of the three locations. Overall, the metal building had less environmental impacts than all three other building systems in all six categories, with the largest difference between metal buildings and concrete tilt-up. The results are closest between the metal buildings and conventional steel buildings. The non-metal buildings case study buildings had the same structural roof members for California and Florida, and a higher roof tonnage for the Minnesota buildings due to snow load.

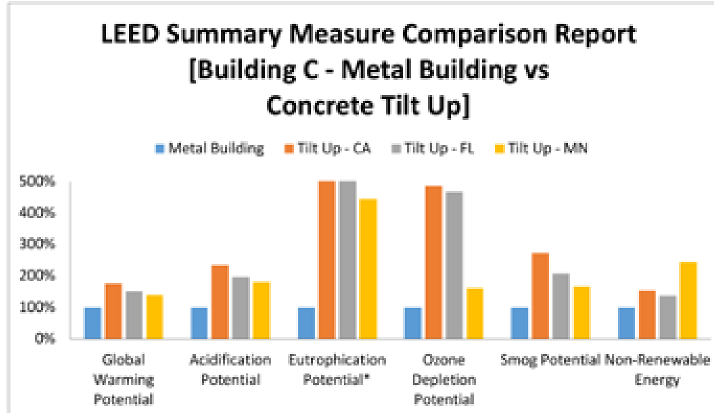


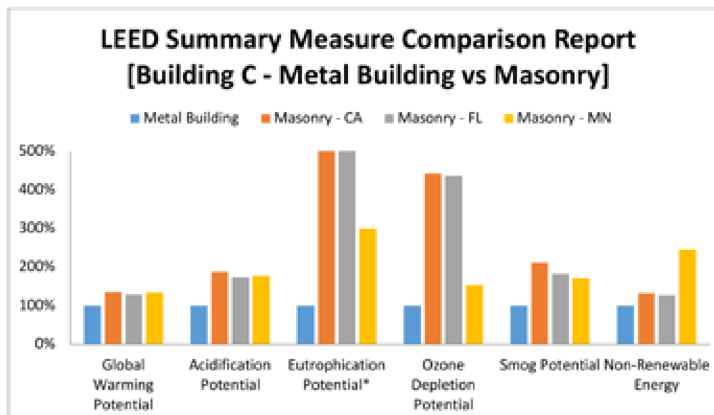


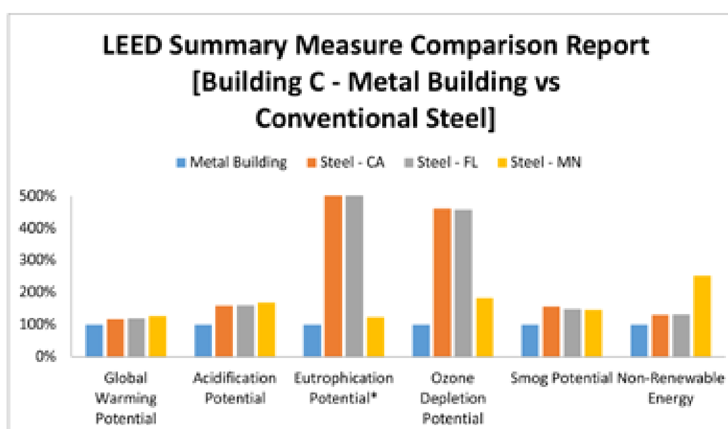


Case Study C: Large-Sized Industrial Building

The large-sized industrial building case study compared the metal building to a load-bearing masonry, concrete tilt-up, and conventional steel-framed building for each of the three locations. Similar to case study B, the metal building showed less impact than all three other building systems in all six categories, with concrete tilt-up scoring the worst among the nonmetal buildings. The environmental impact differences between the metal building and the other results were closer for case study C compared to case study B.







Case Study Conclusions

The Walter P. Moore study comparisons show that metal buildings perform quite favorably when evaluated against most forms of construction. The economical use of recycled materials when combined with the lesser need for foundation materials provide for a significant reduction in environmental impacts across all six measures for most building types and categories and in all building locations.

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The Metal Building Manufacturers Association (MBMA) serves to promote the metal building systems industry. Its membership represents more than $2.4 billion in annual sales and accounts for approximately 50 percent of the total nonresidential low-rise construction market in the United States. Follow MBMA on LinkedIn or Twitter @LearnAboutMBMA. **www.mbma.com**

END NOTES

[1] "Athena Impact Estimator Case Studies." Walter P. Moore and Associates for the Metal Building Manufacturers Association. August 2015. Web. 27 Nov. 2018. <mbma.com/media/WalterPMooreAthenaImpactorCaseStudies-MBMA_Aug2015.pdf>.

QUIZ

1. Based on historical advances, metal buildings currently comprise approximately what percentage of construction each year in the United States?
   - a. 10–20 percent of low-rise building square footage
   - b. 30–40 percent of nonresidential building square footage
   - c. 40–50 percent of all building square footage
   - **d. 40–50 percent of low-rise nonresidential building square footage**

2. The most recent version of the International Green Construction Code (IgCC) is actually merged into a single standard with:
   - a. ASHRAE 90.1.
   - **b. ASHRAE 189.1.**
   - c. The IECC.
   - d. LEED.

3. The most significant and cost-effective first step for energy conservation is to:
   - **a. address the building envelope by designing for conservation of energy through a reduction in energy demand in the first place.**
   - b. select energy-efficient HVAC and other equipment.
   - c. incorporate daylighting.
   - d. provide a solar electric system for the building.

4. A typical metal building is produced from at least _____ of recycled steel, thus substantially reducing the need for virgin materials excavated from the earth.
   a. 90 percent
   b. 70 percent
   c. 50 percent
   d. 30 percent

5. A factory-installed insulation method for metal buildings is available in the form of:
   a. a liner system.
   b. spray foam insulation .
   c. insulated metal panels (IMPs) with an inner and outer metal skin filled with foam plastic insulation to create a rigid, durable, prefinished panel.
   d. None of the above

6. Metal roofing and wall cladding qualify as an air barrier under the codes (i.e., sheet steel or aluminum is one of 16 listed air barrier materials), but the edges and penetrations need to be treated.
   a. True
   b. False

7. Research from the U.S. Department of Energy shows that one additional percentage of reflectivity in a roof coating, on average, will reduce roof temperature by:
   a. 5 degrees.
   b. 3 degrees.
   c. 1 degree.
   d. 0 degrees.

8. Life-cycle assessments (LCA) are recognized as the most effective means to holistically assess the impacts that materials and processes have on the environment and on people too.
   a. True
   b. False

9. Metal buildings that use standing-seam metal roofing are an ideal opportunity for installing photovoltaic (PV) systems due to:
   a. the simplified methods of mounting the PV array.
   b. the longevity of the standing-seam metal roofing system.
   c. the metal roof generally providing a service life in excess of 40 years, which means it can outlast the PV array.
   d. All of the above

10. The Walter P. Moore study comparisons show that metal buildings perform quite favorably when evaluated against most forms of construction.
   a. True
   b. False