Modular Building and the USGBC's LEED™ Version 3.0 2009 Building Rating System

Prepared for

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This report was prepared at the request of the Modular Building Institute (MBI). It is intended to provide the membership of MBI and other interested stakeholders with an overview of how the Modular Building Institute's current practices and products can benefit from an awareness of the US Green Building Council's Leadership in Energy and Environmental Design (LEED™) Building Rating System. Information in this document represents the author's best attempt to align the modular building industry with the Prerequisite and Credit requirements imbedded in LEED. The interpretations herein are those of the author and do not represent any official posture of the US Green Building Council beyond those contained in the Reference Guide to LEED for New Construction and Major Renovations, Version 3.0, 2009.

It is recognized that modular building components and finished modular building units can be a part of any LEED design and construction effort. This report is limited to LEED for New Construction and Major Renovations, applied to commercial construction, and LEED for Schools. The literature shows there is a growing awareness of the environmental benefits of modular construction in the residential sector. LEED for Homes has emerged from its pilot phase and is currently in use. Most of the comments and observations of this report can be applied to LEED for Homes.

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Modular Building and the USGBC's LEED™ Building Rating System

Introduction

The emergence of green building as the combination of environmental stewardship and economic opportunity has served to drive several related construction industries toward market opportunities provided by the green building movement. Conversely, existing industries with products and practices that resonate with the tenets of sustainable design and development and green building have naturally benefited from the increased awareness and market opportunities inherent in this paradigm shift. The US Green Building Council with its Leadership in Energy and Environmental Design (LEED™) building rating system has assumed a leadership position in the US and abroad and is serving as the preeminent organization identified with and instrumental in green building market transformation. This posture is underscored by the international adaptation of LEED as the most popular and best-known third party verified green building rating system currently in use. Federal, State and local building construction requirements and development practices now commonly reference or require LEED certification. Its influence continues to grow. At the USGBC Greenbuild Conference in Boston in November 2009, it was declared that the USGBC is the fastest growing not for profit organization in history. In response to market opportunities and the desire to respond to stakeholder desires to make LEED more specific to building applications, LEED has evolved from a single LEED for New Construction and Major Renovations to the following family of LEED products:

- LEED for New Construction and Major Renovations
- LEED for Commercial Interiors
- LEED for Existing Buildings
- LEED for Core and Shell
- LEED for Schools
- LEED for Homes
- LEED for Neighborhood Development
- Market Sector Rating Systems
  - Multi Buildings and Campuses
  - Retail
  - Healthcare
  - Laboratories

The purpose of this paper is to align the interests and goals of the Modular Building Industry with LEED Version 3, 2009, or LEED V3. The newest version of LEED reflects the US Green Building Council's desire to accomplish the following:

1. Normalize the scoring of the various rating systems to a 100 point system.
2. Give greater emphasis to those credits that stress energy conservation, renewable energy systems and the US Green Building Council's drive toward carbon neutral buildings.
3. Introduce a new Credit Category that rewards LEED project teams for successfully achieving credits dealing with regional priorities. In Version 3 (V3) these are referred to as Regional Priority credits or "RPs".

In LEED Version 3.0, 2009 the allocation of points between credits is based on the potential environmental impacts and human benefits of each credit with respect to a set of impact categories. These impacts are defined as the environmental or human impacts of design, construction, operation and maintenance of buildings. These include such things as greenhouse gas emissions, the production of toxins, fossil fuel use and water and air pollution. The US Green Building Council used parameters from the US Environmental protection Agency's TRACI environmental impact categories as the basis for weighting individual credits. TRACI was developed to assist in the evaluation of life cycle assessment, industrial ecology, process design and pollution prevention. LEED 2009 also takes into account weightings developed by the National Institute of Standards and Technology. These standards were used to compare one credit to another and assign a relative value to each.

LEED for New Construction and Major Renovations Version 3.0, 2009 is based on Credit Categories with the same titles. As mentioned the *Regional Priority* category has been added. The Credits and attendant points in LEED 2009 are now:

- *Sustainable Sites (SS)*
  (1) Prerequisite and (26) possible points
- *Water Efficiency (WE)*
  (1) Prerequisite and (10) possible points

- *Energy and Atmosphere (EA)*
  (3) Prerequisites and (35) possible points
- *Materials and Resources (MR)*
  (1) Prerequisite and (14) possible points
- *Indoor Environmental Quality (EQ)*
  (3) Prerequisites and (15) possible points
- *Innovation & Design (ID)*
  (0) Prerequisites and (6) possible points
- *Regional Priority*
  (4) possible points

This results in an arithmetic tally of 110 possible points. However the nature of LEED in practice holds that achieving all 110 points is not possible; they are available but subject to the influence of project *context*, design and construction *choices* and design and construction *process* variables. Project context is simply a matter of where the project is located. A project pursuing Sustainable Sites Credit 1 – Site Selection is awarded a LEED point if the site selected does not violate any of the site selection criteria. An example of design and construction choices is achieving the requirements for Materials and Resources Credit 4.1 – Low Emitting Materials, Adhesives and Sealants by not exceeding the allowable volatile organic compound (VOC) limits. Design and construction processes are such activities as those necessary to attain Materials and Resources Credit 3.2 – Construction IEQ Management Plan Before Construction. The many benefits of modular building do not enable the finish project to escape the influence of site selection. However, the economies associated with manufacturing in a closed environment with stringent material use and quality control capabilities makes modular building an ideal choice for manufacturing energy, material and resource efficient structures.

In LEED 2009 the threshold levels for LEED certification are:

Certified	40 – 49 Points
Silver	50 - 59 Points
Gold	60 – 79 Points
Platinum	80 or more Points

The goal of most stakeholders using LEED as a building rating tool is to achieve the highest LEED certification rating possible. Certification

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is the process by which a project team fulfills the prerequisites and earns sufficient credit points to reach one of four certification levels: Certified, Silver, Gold or Platinum. This process is explained in complete detail in the Reference Guides issued for each of the LEED rating systems as well as on line at www.usgbc.org.

In the LEED certification system *prerequisites* are activities or processes that must be done but for which no points are awarded. Credits are pursued as a matter of choice for which points are awarded if the requirements of the credits are achieved. In LEED for New Construction and Major Renovations Version 2009 there are nine Prerequisites, one hundred Base Points, six Innovation in Design Points and four Regional Priority Points.

In LEED 2009 there are nine prerequisites and seventy-nine possible points. The other LEED building rating systems vary but most carry a similar category / credit / point structure. The reader is referred to www.usgbc.org for a more complete description of each.

A LEED Accredited Professional is anyone who passes any of the current exams administered by the Green Building Certification Institute (GBCI), an organization allied with the USGBC to provide professional development and LEED accreditation testing. After March 31, 2009, individuals wishing to take the LEED AP exam will have to register for the LEED Version 3 exam. The GBCI will offer an entrance level exam designed for individuals who are allied with the green building movement and the application of LEED but who may not need or desire to be tested for a high degree of technical proficiency. A LEED AP Plus exam will be available for individuals who anticipate participating in the LEED certification process in a more involved and technical capacity. For the purpose of clarity buildings undergo a *certification* process. Individuals who pass a LEED accreditation exam become LEED *Accredited* at the level of the exam they take and are entitled to use the credential LEED Accredited Professional Associate or LEED Accredited Professional, LEED AP. The US Green Building Council and the LEED building rating system continue to evolve. Because of this the reader is encouraged to visit www.usgbc.org and www.gbci.org regularly to obtain the latest information on the LEED family of rating systems and the attendant LEED exam.

For the purpose of this study modular building is considered to be one of the following:

- Prefabricated building components, parts, pieces and sub assemblies assembled under controlled conditions and shipped to become part of a larger, primary building project. They may represent a small portion or a significant contribution of the completed project but they are not considered to represent the finished habitable project in and of themselves.
- Whole building units prefabricated under controlled conditions and delivered to the construction site. These units are commonly identified as those that are manufactured and assembled off site then shipped in whole or in part to the construction site to complete a finished unit. Usually they are erected on a foundation that is constructed ahead of delivery then assembled in large sections or as largely completed units less final systems connections to civil infra structure and site utilities.

Modular building applied to prefabricated components can be used in any building type LEED is used to certify. It is important to note that if prefabricated modular components are used in the context of a larger building they must meet the LEED criteria that apply to them but also are subject to the LEED rating system as it relates to the finished building type under consideration. The individual components or subassemblies do not, in themselves, receive LEED certification. In the case of modular building units the completed unit may be the subject of the LEED rating application and certification effort and may ultimately be the finished project that receives LEED certification.

Modular Building and the LEED Building Rating System

In order to better understand what affects a modular building's potential for LEED certification and the way LEED certification scores are compiled it is necessary to consider the following observations and conditions that inform the LEED certification process

LEED prerequisites and credit opportunities fall into three broad areas of concern:

- Context and Community Connectivity. These issues are largely a function of where the project is located. They are not specific to modular building practice, processes or products. A project using modular building techniques is subject to the opportunities or limitations inherent in good site selection the same as any other project.

- Architectural, Engineering and Construction Choices. These are the decisions that comprise how a project is designed and constructed. Material selection, construction techniques, building systems selection, installation and controls and most other decisions that pertain to building envelope, mechanical, electrical and plumbing systems and space conditioning are in this category. Modular building offers significant opportunities for environmental stewardship, economic opportunity, LEED certification and market penetration in this area. Material handling, optimal construction conditions and environmental control during construction all can contribute to attaining LEED credits and attendant points. **Much of this report is focused on this area.**

- Construction Administration and Processes. These include such activities as commissioning, construction waste management, maintaining superior interior air quality during construction and before occupancy and measurement and verification. Like *Context and Community Connectivity*, *Construction Administration and Processes* are not specific to modular construction. Instead they are prerequisites and credit opportunities that are common to all construction and the project as a whole. However, commissioning can be done under optimal factory conditions, construction waste management and material recycling can occur under tight factory control and construction documentation can be very efficient. All of this can make LEED credit compliance and documentation very efficient.

The LEED tables and attendant narrative that follow at the end of this document are provided to illustrate how modular building practices and products align with the goals of high performance green building and the USGBC's LEED building rating system. Each is presented as a reflection of current industry practice. **The "Y M N" columns are provided to help the reader self evaluate projects. The letters stand for "Yes", "Maybe" and "No", referring to the likelihood of each of the credits in the project under consideration.** *They are provided only as a guide to assist the reader in understanding the application of LEED and how it can be used to evaluate different products and projects.*

LEED Evaluation Matrix - Modular Building Institute							
	Credit	Description	Y	M	N	Submittal Requirement	Modular Building Issues

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Sustainable Sites and Modular Building

The Sustainable Sites Category in LEED 2009 has one *Prerequisite* and twenty six possible points. The additional weight given to credits and points in this category are in *SS Credits 2 through 4.4*, none of which have a direct bearing on modular building.

SS Credit 7.2: Heat Island Effect – Roof is the only Credit in this category that is a matter of design and construction of a modular unit. The *Prerequisites* and all other credits in this category are a function of context and community connectivity. In order to achieve SS credit 7.2 modular construction must meet the requirements for solar reflective index or SRI in the roofing material(s) used over 75% of the roof area. These are SRI of 29 for roof areas of more than 2 in 12 and SRI of 78 for roof areas in excess of 2 in 12.

Modular construction may also have unique attributes regarding *SS Credit 6.1 – Site Development - Protect and Restore Habitat*. Option One in this credit applies to construction done on green fields or sites not previously disturbed or developed. It rewards construction techniques that limit site disturbance and keep disturbed areas to within the areas immediately adjacent to the building footprint. The intent of the credit is to stay within forty feet of the building perimeter, within ten feet of sidewalks and utility trenches serving connection of ten inches in Diameter or less, within 15 feet of trenches with larger utility connections and within twenty five feet of areas intended to remain permeable.

Because modular components and complete modular building units are fabricated off site and delivered by a variety of over the road transport it is possible to achieve tighter site control and less disturbed area in the project perimeter. Industry representatives need to coordinate delivery of modular components with contractors to insure the site tolerances for SS Credit 6.1 can be maintained.

SS Credit 9 – Site Master Plan and *SS Credit 10 – Joint use of Facilities* are specific to LEED for schools and are not reliant on either conventional or modular construction for credit compliance.

Even though the majority of the credits in the Sustainable Sites category are not a function of construction techniques it is important for stakeholders in the modular building industry to understand the overall intent and requirements of each credit. Proper siting or placement of modular units can contribute to improved daylighting, natural ventilation, better storm water management, more efficient site lighting and a host of other sustainable design and development improvements that contribute to a more energy, material and resource efficient project.

MBI 2009 Awards of Distinction: Green Building Winners

Waldorf School, Charlottesville, VA

Jim Russell Racing Drivers School, Sonoma, CA

How are modular structures *more* beneficial?

Modular construction techniques have been shown to be inherently advantageous in 7 major areas:

1 **Less Materials Waste** – Pre-fabrication makes it possible to optimize construction materials purchases and usage while minimizing on-site waste and offering a higher quality product to the buyer. Bulk materials are delivered to the manufacturing facility where they are stored in a protected environment safe from theft and exposure to the environmental conditions of a job site.

2 **Less Material Exposure to Inclement Weather** – Many of the indoor air quality issues identified in new construction result from high moisture levels in the framing materials. Because the modular structure is substantially completed in a factory-controlled setting using dry materials, the potential for high levels of moisture being trapped in the new construction is eliminated.

3 **Less Site Disturbance** – The modular structure is constructed off-site simultaneous to foundation and other site work, thereby reducing the time and impact on the surrounding site environment, as well as reducing the number of vehicles and equipment needed at the site.

4 **Safer Construction** – Modular construction is a safer alternative. Conventional construction workers regularly work in less than ideal conditions dealing with temperature extremes, rain, wind, or any combination of natural conditions. This, by its very nature, is a much more challenging environment to work safely in. Additionally, the potential for injury including falls, the most common work site risk, is much higher. In a factory controlled setting, each worker is typically assigned to a work station supplied with all the appropriate equipment needed to provide the safest work environment possible. Off-site construction also eliminates the hazards associated with materials, equipment and an incomplete construction processes typical of construction sites that can attract curious and unwelcome "visitors" (i.e. students on a school expansion project).

5 **Flexibility** – When the needs change, modular buildings can be disassembled and the modules relocated or refurbished for their next use reducing the demand for raw materials and minimizing the amount of energy expended to create a building to meet the new need. In essence, the entire building can be recycled in some cases.

6 **Adaptability** – Modular buildings are frequently designed to quickly add or remove one or more "modules" minimizing disruptions to adjacent buildings and surroundings.

7 **Built to Code With Shorter Build Times** – The bottom line is that with modular construction you can get a facility built to the same local codes with construction quality as good as or better than a comparable site built building in much less time. Additionally, the abbreviated construction schedule allows you to get a return on your investment sooner while minimizing the exposure to the risks commonly associated with protracted construction schedules.

source: Modular Building Institute

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Water Efficiency and Modular Building

LEED rewards project stakeholders for appreciating where our water comes from, how we use and recycle it while we have it on site and where it goes once we are finished using it. The primary emphasis is on reducing dependence on municipally supplied potable water for irrigation, the transportation of waste using potable water and overall water conservation. Through integrated design we can see relationships between the Sustainable Sites Category in LEED and the water conservation goals and intents of the Water Efficiency category. Rainwater harvesting can reduce the reliance on conventional civil infrastructure while contributing to the need for irrigation, if there is one. Or, the reductions on potable water demand due to more water efficient bathroom or restroom fixtures can lessen the need for transporting waste while integrating well with an on site grey water separation and treatment facility.

In LEED Version 3, 2009, the Water Efficiency Category carries a Prerequisite and ten possible points. *WE Prerequisite1Water Use Reduction – 20%* is based on the previous *WE Credit One - 20%* Reduction based on the Energy Policy Act of 1992. In the new version project teams must achieve a minimum 20% reduction in water use below that allowed in the Energy Policy Act of 1992 in order to meet *WE Prerequisite 1 Water Use Reduction – 20%.* In addition, LEED 2009 awards two points to each credit in the Water Efficiency category, doubling that available in LEED Version 2.2, 2007.

As with the LEED Sustainable Sites Category, the LEED Water Efficiency credits are not specific to modular building. *WE Credits 1.1 and 1.2* associated with reducing potable water demand for irrigation are a matter of resource efficient landscaping and site water management in any project. All construction whether conventional or modular can include the principles, practices and products associated with water conservation and site water management. Rain water harvesting systems can be integrated into modular building designs. Ecologically sensitive landscaping, intelligent plant selection, integrated pest management and sensitivity to the microclimates buildings create when sited are universal principles and practices that apply to all construction.

WE Credit 2 – Innovative Waste Water Technology rewards project stakeholders for utilizing fixtures that out perform the allowable water quantities listed in the Energy Conservation Act of 1992. This is done by conducting an inventory of those fixtures associated with flushing or transporting waste. The fixtures are inventoried and bench marked against those in the Act. Then, substitutions are made to enact a water conservation strategy that reduces the overall need for potable water associated with transporting waste. Points are rewarded for achieving a 50% reduction or more in potable water required to transport waste below that allowed by the flow rates listed in the Energy Conservation Act of 1992. This can be achieved through a combination of water efficient fixtures and / or the utilization of rain water or treated grey water for flushing. Estimates of water saved from a single waterless urinal range from 20,000 to 60,000 gallons per year depending on the location and frequency of use.

WE Credit 3.1 and WE 3.2 – Water Use Reduction recognize the potential for conserving water in any way possible with the exclusion of potable water used for irrigation which is accounted for in WE Credits 1.1 and 1.2. Modular building manufacturers and suppliers have embraced many of the strategies commonly used to reduce water consumption. Water conservation and the ability to implement these strategies in modular construction is well known and largely a matter of choice. Current products are durable, reliable attractive and reasonably priced.

WE Credit 3.3 – Process Use Water Reduction is specific to LEED for Schools. It is intended to reward any effort to aggregate a number of water conservation opportunities commonly found in schools. If these uses are housed in modular building units then they are in play just as they would be for any other building type.

Water conservation and the LEED Water Efficiency credits are gaining in priority and application as the awareness of the importance of water and, in some cases, growing shortages emerge.

Water conservation is one of the hallmarks of high performance green buildings and one area where modular building can enjoy the same benefits as conventional construction. Several modular construction manufacturers currently list water conservation and LEED Water Efficiency credit compliance as part of their marketing effort. At the same time modular building advocates need to be aware of the integrated design implications for whole building and total site water management to insure the completed design meshes site water harvesting opportunities with current water conservation and water management strategies. The modular building industry can benefit by studying the art and science of stormwater management to better participate in LEED discussions centering on how a building should be sited, how retention ponds, rain gardens and other site amenities contribute to LEED credits with open space requirements. Modular construction that anticipates inclusion in projects with rain water harvesting is best if it has anticipated the detailing, structural loads and system interfaces that are part of the building and site engineering necessary to be part of the overall systems integration.

Contest Aims to Green Senior Living

Modular Building Institute Extends Annual Award Contest for a Real-World Application

In 2008 MBI's Awards of Distinction contest proposed a real-world scenario aimed at delivering a sustainable design to deserving community populations.

Students from eligible schools of design, architecture and engineering submitted their plans for a community center of a senior population called The Meadows, located in Crozet, Va. The Meadows provides low-income housing to people ages 62 and older.

The winning entry, pictured here, was submitted by Ball State architecture student Tyler Stanley. Stanley's 4,900-sf design capitalizes on some of the greenest aspects of modular construction: use of recycled materials and reduced waste from off-site construction.

MBI's student design competition offered a challenge to architecture students for a real-world scenario. The winning entry (pictured here) came from Tyler Stanley of Ball State University. The senior community center's green features include: Low to no emitting materials; no VOC paint and carpets; double-pane, low E windows; sound absorbing gypsum for reduce noise pollution; LED lighting and low-energy appliances; and, a vegetative roof.

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Energy and Atmosphere and Modular Building

Current literature supports the fact that energy conservation and the attendant reduction in building operating costs are two of the major drivers in the high performance green building movement. LEED recognizes the history of the energy conservation movement as the energy crises of the 1970s and the tools that have been developed to model energy use reduction via building envelope and building energy systems optimization since that time. LEED also recognizes the ongoing connection between the production of primary power via fossil fuels and the consequences for air pollution, global warming and ozone protection. Increasing energy costs and growing concern about energy availability and security are sure to keep the interest in energy conservation and renewable or alternative energy sources in the forefront of the high performance green building movement.

All of the Energy and Atmosphere *Prerequisite and Credit* opportunities can be applied directly to modular construction projects. While this is true of conventional construction modular building has a number of potential advantages if the industry chooses to pursue them. Modular construction that uses structural insulated panels or SIPS can produce relatively high R-values and low infiltration rates if fabricated and constructed with good quality control. Steel and aluminum stud frame construction can also produce energy efficient units if care is taken to insure proper installation techniques and air sealing. High performance windows contribute to the pursuit of high performance building envelopes in each case as do proper air sealing procedures and quality entrance systems. Several modular building manufactures tout superior energy conservation and reduced operating costs as a function of quality control in factory environments as opposed to conventional construction where both labor and materials can be subject to the influence of weather.

The following discourse summarizes the relationship of modular building and the LEED Energy and Atmosphere *Prerequisites* and *Credits*.

EA Prerequisite 1 – Fundamental Commissioning of the Building Energy Systems

Commissioning is the art and science of using diagnostic tools, experience and building forensic knowledge to guarantee to the greatest extent possible that a building will perform and be operated and maintained as it was intended. LEED requires fundamental commissioning of the HVAC and controls, lighting and controls, domestic hot water systems and renewable energy systems if they are included. Commissioning differs from traditional testing and balancing or the start up primary space conditioning equipment by manufacturer suppliers or subcontractors in that commissioning must insure that all systems are working collectively as intended. In the case of modular building commissioning is assumed to be applied to a finished project.

If a modular building is fully assembled prior to delivery and the systems that must be commissioned are installed and operational most fundamental commissioning activities can take place in the factory. However, the modular building is subject to additional commissioning activities if connecting to the civil infrastructure, site mounted renewable energy systems, site water supply pressure testing, etc. These activities can only happen in the field and are required for a complete commissioning report.

It should be noted that beyond the traditional commissioning activities themselves LEED requires the following:

1. Designate an individual as the commissioning agent to lead, review and oversee the completion of the commissioning process activities.
   a. The commissioning authority shall have documented commissioning authority experience in at least two projects of similar scale, scope and complexity.
   b. The individual serving as the Commissioning authority shall be independent of the project's design and construction management, though they may be employees of the firms providing those services. The commissioning authority may be a qualified employee or consultant of the Owner.
   c. The commissioning agent shall report the results, findings and recommendations directly to the owner.
   d. For projects smaller than 50,000 square feet, the commissioning agent may include qualified persons on the design or construction teams who have the required experience.
2. The Owner shall document the Owner's Project Requirements (OPR). The design team shall develop the Basis of Design (BOD). The

commissioning authority shall review these documents for clarity and completeness. The Owner and design team shall be responsible for updates to their respective documents.
3. Develop and incorporate commissioning requirements into the construction documents.
4. Develop and implement a commissioning plan.
5. Verify the installation and performance of the systems to be commissioned.
6. Complete a summary commissioning report.

Lastly it may be possible that the completed modular unit which has been commissioned largely in the factory is still a subassembly in a larger completed project. In this case all of the modular building commissioning activities will be part of a more comprehensive commissioning plan and will have to be coordinated accordingly. One of the most important roles a commissioning authority has when a project involves modular buildings is to act as the liaison between the modular building manufacturing plant and the construction site. The commissioning plan should address how commissioning activities that vary in scope and location will be coordinated and reported.

EA Prerequisite 2 – Minimum Energy Performance

In LEED 2009, all LEED projects are subject to exceeding the minimum energy performance criteria set forth in Sections 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 of ASHRAE / IESNA 90.1 – 2007 without amendments as well as the prescriptive requirements of Sections 5.5, 6.5, 7.5 and 9.5 without amendments by 10% for new construction and 5% for major renovations. The reader is referred to ASHRAE / IESNA 90.1 2007 for a complete description of the requirements. Generally the building categories are:
Section 5 – Building envelope
Section 6 – Heating, Ventilating and Air Conditioning (including parking garage ventilation, freeze protection, exhaust air recovery and condenser heat recovery)
Section 7 – Service water heating
Section 8 – Power (including all building power distribution systems)
Section 9 – Lighting (including exit signs, building exterior. Grounds and parking garages)
Section 10 – Other Equipment (including all permanently wired electric motors)

It is quite common for municipalities to base their building code requirements on ASHRAE standards and references. In this case the modular buildings in question are assumed to be permanently installed on foundations not meant to facilitate removal or frequent relocation.

EA Prerequisite 3 – Fundamental Refrigerant Management

This prerequisite prohibits the use of CFC – based refrigerants in new building HVAC&R systems. These refrigerants are not permitted in new construction in the US but may be present in central plants that modular buildings are serviced by. If this is the case the project using the modular building serviced by the central plant must obtain an inspection of the central plant as well as a commitment to phase out the equipment using CFCs in the central plant over time. Each is weighed on its merits.

EA Credit 1 – Optimum Energy Performance

This credit is based on meeting all the requirements of EA Prerequisite 2 Minimum Energy Performance which mandates exceeding ASHRAE 90.1 2007 minimum energy performance requirements by 10% for new construction. In Version 3, 2009, LEED provides an opportunity to obtain up to twenty one points for new construction by computer modeling the proposed design against a base case building using Appendix G of ASHRAE / IESNA 90.1 – 2007. Once the base case is created and an annual operating budget is established the design team is tasked with creating a design case building that reduces the annual operating budget by at least 12% below that required for the base case building before points can be scored. Projects whose yearly operating budget for energy is 12% below the Base Building modeling as established by Appendix G of ASHRAE 90.1 2007 can score the minimum two points. Projects with yearly energy operating budgets forty eight percent or more below the Base Building estimate are eligible for nineteen points.

It is important to note that the modular building in question must be modeled in the context of the site and the final design. This exercise cannot be done remotely or theoretically in the factory. This is because energy performance and the criteria that LEED requires to be considered are

dependent in whole or in part on final building orientation, passive solar and natural ventilation contributions, site lighting, occupancy and microclimate conditions that effect yearly energy use.

In large projects energy modeling using DOE.2e or other sophisticated modeling software is used. In smaller projects more prescriptive measures can be used based on several ASHRAE publications such as the *Advanced Buildings Core Performance Guide*. The LEED Reference Guide contains an extensive discussion of what evaluation procedures are most appropriate and what is acceptable as building envelope, building systems, site and occupancy variables.

EA Credit 2 – On-Site Renewable Energy Systems

Once the yearly operating budget of the design case building has been determined using the procedures contained in EA Credit 1 the project team can address meeting the annual energy demands of the project with renewable energy sources and building systems. LEED considers the following systems eligible for consideration in this credit:

- Photovoltaic systems
- Solar thermal Systems
- Bio-fuel based electrical systems
- Geothermal heating systems *(Geothermal heat pumps are excluded but their benefits are considered in EA Credit 1 – Optimum Energy Performance)*
- Geothermal electrical systems
- Low impact hydro electric power systems
- Wave and tidal systems

For *EA Credit 2* these systems are generally considered to be located on site and dedicated to the subject project. Systems such as photovoltaics and solar domestic water heating systems can have their internal components installed in the modular building factory but final assembly of the collectors or PV arrays is typically done in the field. This is certainly true of any array that is site mounted or part of a larger central array dedicated to more than one modular building.

Renewable energy systems can be applied to any building construction type and are being found increasing frequently in modular building projects. Integrated design is driving design trends that install relatively small-scale PV panels as window shading devices. Other eligible systems such as low impact hydro dams, while contributing to the credit, are clearly a matter of site selection and proximity. The contribution of these systems to the reduction of the annual energy costs are reflected in the energy modeling or prescriptive approaches to energy cost calculations found in *EA Credit 1*. *EA Credit 2 Renewable Energy* points are rewarded for displacing conventional fuels and the attendant reduction in yearly energy costs on a graduated scale. The percentage listed in the title of the credits refers to the reduction in dollars below the yearly energy cost in dollars for the base building modeled in Appendix G or through some other prescriptive method. They are:

1% Renewable Energy	1 Point
5% Renewable Energy	3 Points
9% Renewable Energy	5 Points
13% Renewable Energy	7 Points

EA Credit 3 – Enhanced Commissioning

LEED 2009 awards two points for *EA Credit 3*. Enhanced commissioning is related to the basic commissioning required for all LEED projects in *EA Perquisite 1*. In addition to the basic requirements inherent in *EA Prerequisite I* the commissioning authority must also:

1. Conduct a minimum of one commissioning design review of the Owners Program Requirements (OPR), the Basis of Design (BOD), and design documents prior to the mid-documents production phase. A back check of the remarks and responses to the design reviews must be included in subsequent phases.
2. The Commissioning authority shall also review contractor submittals concurrent with the A/E reviews. Findings must go directly to the owner.
3. Develop a systems manual that provides future operating staff the information needed to understand and properly operate the commissioned systems.
4. Verify the requirements for staff training and operating personnel have been completed.
5. Participate in a review of the building operation within 10 months of substantial completion.

As in the *EA Prerequisite 1 – Fundamental Building Systems Commissioning* enhanced commis-

sioning activities and responsibilities may be split between the manufacturing plant and the construction site. The commissioning plan must reflect how commissioning activities will be coordinated. And, systems that are assembled or sub-assembled at the factory which become part of the permanent installation must be commissioned as part of the finished installation.

EA Credit 4 – Enhanced Refrigerant Management

LEED 2009 awards two points for *EA Credit 4*. LEED rewards project teams that make responsible choices regarding the selection, installation and maintenance of refrigerants. This credit opportunity is not specific to modular building but is a function of space conditioning equipment and the refrigerant choices that accompany them. The point for this credit is obtained by not using refrigerants or by selecting one that has the qualities and attributes of being efficient while minimizing the potential for ozone depletion and global warming should the refrigerant wear out prematurely, require difficult or dangerous maintenance or escape to the atmosphere. R410A or Puron is preferable to R12 or R22. A LEED point is rewarded for selecting a refrigerant that balances these criteria and still meets equipment performance and warranty requirements.

EA Credit 5 – Measurement and Verification

LEED 2009 awards three points for *EA Credit 5*. Measurement and Verification is a process by which the operation and associated energy performance of a completed project is monitored for at least one year using the processes and practices set forth in the International Performance and Measurement & Verification Protocol (IPMVP) Volume III. The IPMVP allows the use of two protocols, Option B and D respectively depending on the complexity of the project and the number of systems that use energy.

While this credit is not specific to modular building project teams need to understand the requirement of the credit as it related to the installed controls, sensors, data acquisition systems and other performance indicators the IPMVP protocols involve. Obtaining this point may require coordination between the modular building supplier and the HVAC and / or the mechanical, electrical and plumbing engineers. The intention is to acquire sufficient building systems data to verify the building is performing as anticipated. In this regard this credit is often evaluated as a compliment to the commissioning activities that are taking place in the same time period, especially if Enhanced Commissioning activities are taking place.

The work associated with obtaining this credit can be relatively simple if the structures are modest in scale and the systems are limited and straight forward. Many modular building applications be they classrooms or small office are in this category. Modular buildings of this type are often single zone structures with dedicated space conditioning systems and simple controls.

EA Credit 6 – Green Power

LEED 2009 awards two points for *EA Credit 6*. Green Power refers to electrical energy generated off site using criteria established by the Center for Resource Solutions (CRS) Green-e products certification requirements. Projects are rewarded one LEED point for contracting for at least 35% of the project's electrical requirements for two years. A second point is available if the contract doubles to 70% for the same two year period.

This credit is not specific to modular buildings sans for the indirect implication that very energy efficient modular buildings can reduce the actual kW required per year, hence lowering the percentage of Green Power that is contracted for.

The literature supports the fact that modular buildings can be very energy and resource efficient. Competitions now showcase the various ways in which modular building suppliers are incorporating energy and water conserving equipment and features in completed projects. Stakeholders representing modular buildings in LEED applications need to have an appreciation for which activities are joined in the manufacturing facility and which are a function of outside collaborations and team member participation. It must also be noted that unless the modular unit represents the entire finished project, modular sub assemblies and modular units that comprise a portion of a larger whole project are evaluated against the energy performance of the project as a whole.

MODULAR BUILDING INSTITUTE

Materials and Resources and Modular Building

Modular building by nature is material and resource efficient. One of the great economies of modular building is the ability to assemble repetitive units in controlled conditions. Another is to minimize material waste associated with conventional construction due to weather intrusion and construction site theft. Modular components and subassemblies that exhibit controlled tolerances can be coordinated into larger projects. Whole modular units —largely finished prior to arriving at the construction site—can significantly limit construction waste generated at the site and contribute directly to construction site waste management.

LEED rewards projects for recognizing where materials come from, how they are used on site, whether or not they are salvaged during renovations, and how the residual waste stream is managed. Special recognition is given to using existing buildings, materials with recycled content and those that are mined, harvested, extracted and assembled within 500 miles of the construction site. Finally LEED rewards projects that use products grown using good stewardship practice, and are lightly processed or have low embodied energy.

In order to accurately evaluate the role of materials and resources in modular building and LEED projects the following must be understood:

- There are no LEED certified products
- A product can not give a LEED project points
- A product can contribute toward or comply with LEED credit requirements

In LEED products fall into two categories: *Contribution Credits* and *Compliance Credits*.

Contribution Credits require a calculation to determine what percentage of the project's materials meet the requirement set forth by the LEED rating system that the project team is applying for certification. *Compliance Credits* require all related materials to meet a certain requirement set forth by the standard. All products related to the credit must all pass the standard. These credits are pass or fail.

In order to facilitate the LEED application the modular component or modular unit manufacture must be intimately familiar with the nature, source and manufacturing processes associated with the materials assembled in the modular building entity in question. This will be discussed further in the *Credit* interpretations below. The reader is invited to study the LEED Reference Guide for the LEED rating system being used for a more complete discourse on the subjects of materials and resources.

The *Prerequisite* and LEED *Credit* opportunities in the Materials and Resources section are:

MR Prerequisite 1 – Storage and Collection of Recyclables

This prerequisite is common to all LEED projects and not specific to modular building. The project team must illustrate how glass, aluminum, paper, corrugated cardboard, and plastic are collected, stored and then removed from the project site whether or not a municipal waste collection program is in place. This is typically the responsibility of the design team.

- *MR Credit 1.1 – Building Reuse, Maintain 75% of Existing Walls Floors and Roof*
- *MR Credit 1.2 – Building Reuse, Maintain 95% of Existing Walls Floors and Roof*
- *MR Credit 1.3 – Building Reuse, Maintain 50% of Interior Non Structural Elements*

These credits only apply to LEED projects that involve existing buildings. In LEED 2009 *MR Credit 1.1* is awarded two points. It is possible that the existing building in question is a modular building. It is also possible that the project involves adding modular buildings or new construction that contains modular components to an existing building. In each case an inventory of the building(s) is conducted to calculate the percentage of each involved. These credits stay in play unless the new construction being added to the existing building (if any) exceeds the size of the existing building by two hundred percent, at which point these credits drop out and the existing building materials segue into *MR Credits 2.1 and 2.2, Construction Waste Management.*

- *MR Credit 2.1 – Construction Waste Management, Divert 50% from Disposal*
- *MR Credit 2.2 - Construction Waste Management, Divert 75% from Disposal*

One of the significant economies associated with modular construction is the ability to manage construction waste. LEED rewards construction waste management at the construction site by being able to account for the materials, by weight or by volume, that are diverted from landfills. This includes all non-hazardous materials excluding cut and fill and organic material removed from the site. One direct benefit of reducing the overall waste stream is the simplification of construction waste management at the site and the attendant reduction in dumpster costs and hauling fees.

In the case of modular building overall construction waste generated at the site can be reduced significantly. Moreover there may be *Innovation Points* available to LEED project teams that can illustrate similar waste management practices are in play at the modular building manufacturing facilities. In order to apply for an *Innovation Point* the LEED team must be able to do a similar "upstream" evaluation to determine the amount of construction waste material generated in the fabrication of modular buildings at the plant and the amount also diverted from landfills.

In order to calculate *MR Credits 3.1 through 5.2* LEED requires project teams to calculate the cost of building materials in Divisions Two through Ten less labor and transportation costs. This number then forms the denominator in the calculations used to determine compliance with the *Credit* requirements in each. Achieving these credits requires a working knowledge of the source of the materials, their composition and the point of purchase. Modular building representatives should familiar themselves with the full range of credit requirements detailed in the LEED Reference Guides. Only materials that are permanently installed qualify for inclusion in *MR Credits 3 through 7*.

- *MR Credit 3.1 – Material Reuse*, 5%
- *MR Credit 3.1 – Material Reuse*, 10%

LEED rewards incorporating used building materials in new construction and major renovation. To date this practice is very limited in the manufacture of new modular building components or modular units. However, it is quite possible that modular building practices could be used in LEED projects where other aspects of the overall construction could feature these materials. The percentages listed refer to the percentage of Divisions Two through Ten material costs of that are represented by reused materials.

- *MR Credit 4.1 – Recycled Content, 10% (post consumer + ½ pre consumer)*
- *MR Credit 4.2 – Recycled Content, 20% (post consumer + ½ pre consumer)*

Modern modular building construction uses a full range of materials with high recycled content. These materials are recognized for there relatively high strength to weight ratios, moisture resistance and cost effectiveness. LEED recognizes the contribution of material manufactures that use both post consumer and pre consumer recycled content. Post consumer recycled content is that which is manufactured from such items as plastic bottles and cans which, once used, find their way back into the manufacturing process. Pre consumer recycled content is that which transfers from one industry to another without interfacing with consumers. Fly ash in concrete or wheat straw substrate are two examples. In order to participate in obtaining these credits the modular building manufacturer must be able to identify and quantify the nature and percentage by weight of recycled content in the materials used in modular construction. These include but are certainly not limited to materials commonly found in the modular construction industry: oriented strand board (OSB) and insulation plastics found in structural insulated panels (SIPs) agriculturally based substrates, linoleum, aluminum, metal and glass window assemblies, medium and light gauge steel framing, carpet systems, floor tile, acoustic ceiling tile, cabinetry, interior drywall partitions, surface treatments and fabrics, doors, metal roofing, etc. Each must be evaluated for recycled content and cost relative to the overall cost of the modular component or unit less labor and transportation. Because transportation costs associated with transporting

modular building units is documented separately from the product this information simply needs to be recorded an provided to the appropriate LEED submission contact person.

- *MR Credit 5.1 – Regional Materials, 10% Extracted, Processed and Manufactured Regionally*
- *MR Credit 5.2 – Regional Materials, 20% Extracted, Processed and Manufactured Regionally*

These *Credits* recognize the economic and environmental benefits of building with materials that are found in proximity to the construction site. The percentages listed refer to the portion of the total material cost less labor and transportation of materials in Divisions Two through Ten. In order to qualify for these points the point of purchase of the modular building component or modular building unit must be within a 500 miles radius of the project site. The modular building manufacturer must then be able to identify what building products used in the construction of the component or modular building unit were extracted, processed, manufactured and purchased within that same 500 mile radius. For homogenous materials this can be a relatively easy assessment. For materials that are complex or which derive a portion of their materials outside the 500 mile radius this can be an involved calculation. The 1000 mile diameter that results from the 500 mile radius is a significantly large area and many LEED projects get one or both of the points associated with these *Credits*. Most modular building units are shipped from within a 500 mile radius of the construction site so it behooves the project team to attempt these Credits. It should be noted that the 10% and 20% of the value of the materials on the project are calculated against the total cost of materials including site development.

MR Credit 6 – Rapidly Renewable Materials

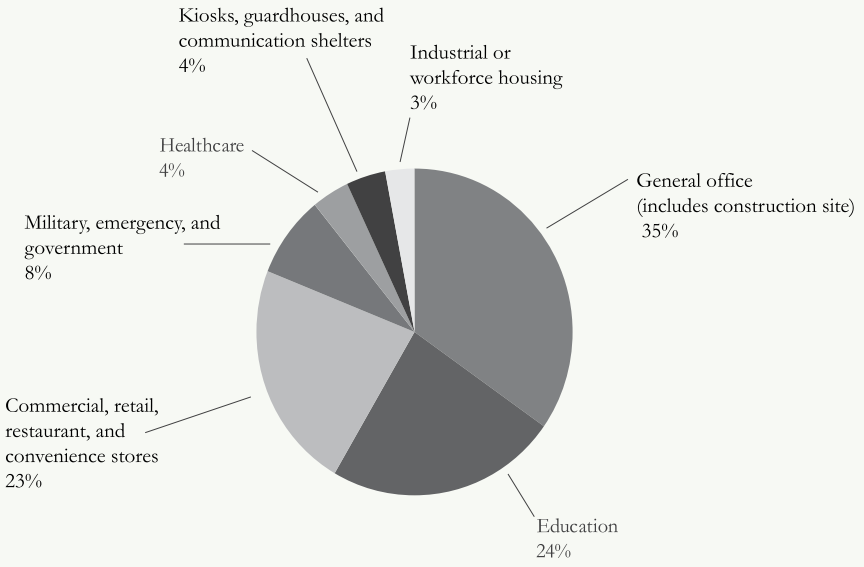
Rapidly renewable materials and products are those which are derived from raw materials that come to market in a ten year cycle or less. These are typically such materials as bamboo, Agrifiber, linoleum, cork, wool and cotton. LEED awards a point to LEED project teams that can show that at least 2.5% of the cost of the materials in Division Two through Ten in the entire project is represented by materials that have these attributes. In order to qualify for this Credit and the point available the modular building supplier must be able to identify and quantify which materials comply. These are then evaluated against the total project cost of materials in those divisions and a determination is made.

MR Credit 7 – Certified Wood

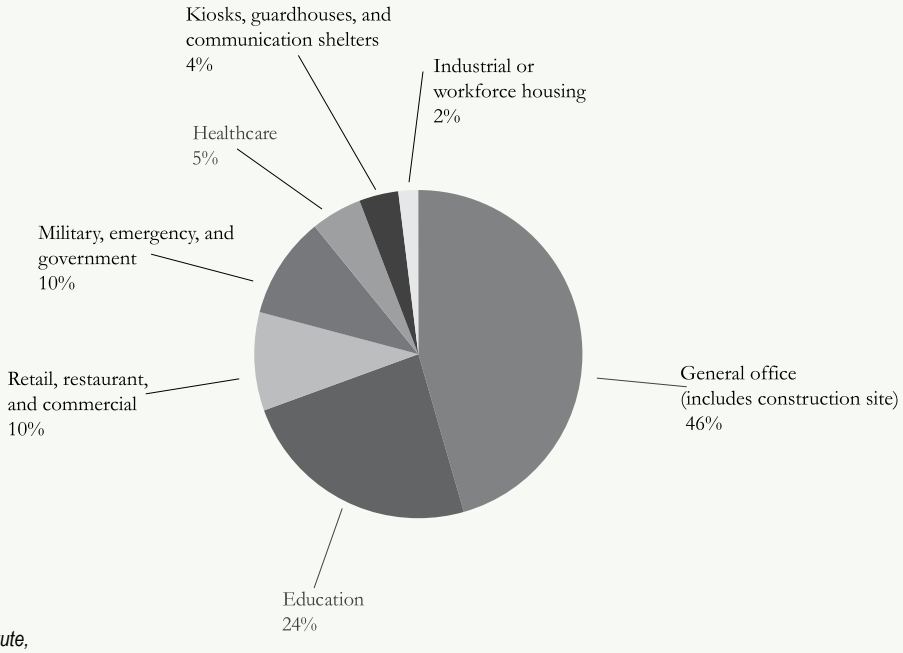
Certified wood is that which comes from sources certified by the Forest Stewardship Council's Principles and Criteria. These include but are not limited to structural framing, sub-flooring, wood doors and finishes. In order to qualify for this Credit and the point available 50% of the value of the wood based products in the completed project that are permanently affixed must come from FSC certified sources. The modular building supplier should be able to identify and quantify what those products are and have proof of the chain of custody that accompanies FSC certification. If the FSC certified source is within 5oo miles of the construction site credit can be taken for *MR Credit 5.1-Regional Materials*.

Markets Currently Served by Commercial Modular Construction

Dealers: Major Markets Served



Manufacturers: Major Markets Served



source: Modular Building Institute, 2007 Commercial Modular Construction Report

MODULAR BUILDING INSTITUTE

Indoor Environmental Quality and Modular Building

Next to overall energy efficiency, effective daylighting and natural ventilation, superior indoor environmental quality is one of the most desirable and important attributes of high performance green buildings. Improved health and optimum building occupant performance as a function of interior environments that are allergy free and non toxic are now appreciated as one of the most important returns on the investment in high performance green buildings. Studies linking occupant health and satisfaction to natural light and clean interior air have been in the medical literature for decades. More recent studies range from those focusing on single issues such as absenteeism and lost asthma days to the importance of good acoustics to broader concerns of human ecology, ergonomics and the ongoing impact of spending as much as 90% of our time indoors.

The design and construction market's response to our growing awareness of the impact of the built environment on our general well being and the financial benefits associated with environments optimized for health and productivity has been very positive. It has precipitated a major shift in industry response and product availability within the green building movement. Where it may have been difficult ten years ago to find non proprietary products that were allergy free and non toxic today they are commonplace and price competitive. Some are enhanced by the fact that they are manufactured with recycled materials and often found within 500 miles of the project site. Improvements in HVAC system efficiency, dehumidifying capability and the use of energy system modeling to right size space conditioning systems and controls has all contributed to more cost effective ways of maintaining acceptable psychrometrics and comfort conditions. We have arrived at the point where product suppliers aware of the health consequences of how materials impact interior air quality have joined forces with an enlightened design and engineering community who have the diagnostic tools necessary to optimize both natural and mechanical space conditioning systems. LEED has provided the forum through which the principles and practices of integrated design can be used to combine the best of both in the most cost effective ways possible.

We have arrived at this juncture in time with the full capability for industry-change toward provision of both environmentally conscious buildings and eco-friendly building materials. The modular building industry has control over both the materials and quality control features that provide superior building atmospheres. LEED is used to explore the relationship of energy efficiency, the influence of daylight and natural ventilation, the use of allergy free, non toxic materials and the psychology of space with respect of acoustics and views to provide highly desirable spaces using a variety of assembly techniques, including modular building. This is evidenced by the creative and inspirational responses produced by modular building manufactures who have participated in green building challenges. They are proof positive the modular building industry can continue to pioneer and respond to the evolution of the green building movement. The following is a discussion of modular building as it relates to the LEED Indoor Environmental Quality category.

EQ Prerequisite 1: Minimum IAQ Performance

This prerequisite is based on ASHRAE 62.1-2007, Ventilation for Acceptable Indoor Air Quality with separate consideration of paragraph 5.1 for buildings that are naturally ventilated. ASHRAE 62 is commonly used as the foundation of many codes but LEED requires adhering to local code requirements if they are more stringent. Generally ASHRAE 62 determines the amount of ventilation air required as well as standards for the quality of ventilation air and how it is best distributed. The Prerequisite apples to all building types classified as permanently installed buildings regardless of the fabrication or construction deliver method.

EQ Prerequisite 2: Environmental Tobacco Smoke (ETS) Control

The *Prerequisite* to eliminate or strictly control environmental tobacco smoke is applicable to all building types. The LEED reference guide gives specific requirements for the design, construction, commissioning and control of smoking areas inside LEED certified buildings if they are to be included. Requirements vary between com-

mercial and multi-family residential buildings. They are not specific to modular buildings.

EQ Prerequisite 3: Minimal Acoustical Performance (LEED for Schools only)

LEED for Schools contains this prerequisite which is intended to provide minimum acoustic performance in core learning spaces in academic buildings. Attaining the credit is based on designing classrooms and other learning spaces to meet the Reverberation Time (RT) requirements of ANSI standard S12.60-2002, Acoustical Performance Criteria, Design Requirements and Guidelines for Schools. Also, classrooms and other core learning spaces must meet Sound Transmission Class (STC) requirements except for windows which must meet an STC rating of at least 35.

In addition a background noise level of 45 dBA must be met using the methodologies described in annexes B through D of ANSI Standard S12.60-2002. Or, classrooms and other core learning spaces must achieve an RC (N) Mark II level of 37 with HVAC equipment and installations as defined in the 2003 HVAC Applications ASHRAE Handbook, Chapter 47.

Modular building units can be optimized to meet these criteria as they are seldom fabricated of heavy masonry construction or massive materials that reflect sound. SIP construction, metal studs with multiple layers of drywall mounted on resilient clips, acoustic ceiling tiles and other acoustic design techniques can all be applied. The strategy for meeting this *Prerequisite* and the associated *EQ Credit 9: Enhanced Acoustical Performance* can be formed around materials and construction techniques commonly used in the modular building industry. The overall approach must be considered against the site context, whether or not the finished project is multi-story and ambient noise conditions.

EQ Credit 1: Outdoor Air Delivery Monitoring

This Credit is intended to insure occupant comfort by monitoring the amount of air mechanically delivered to spaces with a density of 25 people per 1000 square feet or less, keeping it within 10% of designed air flow rates. 15% must be maintained in spaces that are not defined as high density.

Spaces that are naturally ventilated must have CO2 sensors in each space located between three and six feet above the floor.

Modular building manufactures must confirm these rates are achievable and install the proper sensors and associated limit indicators to inform building operators and occupants when design conditions are not being met. If space conditioning is accomplished with a combination of forced air and other equipment the LEED team must explain how ventilation air will be controlled and how the sensors will work in concert with other controls.

EQ Credit 2: Increased Ventilation

LEED rewards project teams for providing a minimum of thirty percent additional ventilation air to the regularly occupied areas of the building. The benefit is additional fresh air and increased assurance that any residual pollutants will be removed with additional ventilation and, hopefully, effective filtration. This credit can be applied to modular construction the application of which must be modeled in *EA Credit 1: Optimum Energy Performance*.

EQ Credit 3.1 Construction IAQ Management Plan During Construction

Obtaining this *Credit* requires understanding the *Credit* intent with respect to modular building manufacturing environments and conditions. The criteria for maintaining acceptable IAQ during construction are based on the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) IAQ Guidelines for Occupied Buildings Under Construction, 1995, Chapter 3. When applied to conventional construction projects the intent is to insure that work in place is protected, the project site is generally clean and free of excessive water, materials are effectively stored and kept dry and ductwork is kept clean, especially if the HVAC system is used during construction.

In modular building manufacturing plants the conditions are often ambient, reducing the need

for supplemental space conditioning during construction. The assembly areas are not subject to excessive moisture or extremes in temperature and are generally controlled to provide acceptable working conditions. If modular units are assembled in whole or in part outside these controlled conditions do not exist and the modular building units are subject to the same criteria for this *Credit* as conventional construction. And, it is assumed that factory finished units are shipped and installed in ways that also maintain the intent of the credit which assumes the precautions are observed until the project is completed. In order to meet the intent of this credit the conditions expected by meeting the SMACNA standard should be evidenced in the completed project. The narrative provided in the LEED template for this credit should explain how this is accomplished.

EQ Credit 3.2 Construction IAQ Management Plan Before Occupancy

LEED rewards project teams that build with allergy free non toxic material and building practices as defined in *EQ Credits 4.1 through 4.6* described below. As an extra precaution EQ *Credit 3.2 Construction IAQ Management Plan Before Occupancy* is available to insure that any residual indoor air pollutants are removed. This is done by either flushing out the completed building or measuring the same using IAQ testing procedures focused on the following:

- Formaldehyde (HCHO) not to exceed 50 parts per billion
- Particulates not to exceed 50 microns per cubic meter
- Total Volatile Organic Compounds (TVOC) not to exceed 500 micrograms per cubic meter
- Carbon Monoxide (CO) at 9 parts per billion and no greater than 2 parts per million above outdoor levels
- 4-phenylcyclohexane (4-PCH) not to exceed 6.5 micrograms per cubic meter

In order to insure superior air quality in any completed structure it is important to build with allergy free non toxic materials and maintain the same with ecologically acceptable cleaning products. Modular building is no exception. Once healthy building products and practices are implemented the LEED team can subscribe to one of two techniques to obtain the point for this credit.

The first is to flush out the building with a minimum of 14,000 cubic feet of outside air per square foot of building. The air must be introduced maintaining at least 60ºF and 60% relative humidity. Alternative approaches to this technique are allowable if the building is occupied. The flush out is complete when the total amount of air necessary to satisfy the credit requirement has been routed through the building.

The second alternative is to perform IAQ sampling and testing using testing protocols consistent with the US Environmental Protection Agency's Compendium of Methods for the Determination of Air Pollutants in Indoor Air. In this approach testing is conducted to specifically detect the presence and concentrations of the pollutants listed above. This approach is much more scientific and useful than simply flushing air through the structure although both are acceptable.

In order to meet the intent of the credit either method should be conducted on site in what is the completed LEED project. Air sampling and measurement done inside the modular building manufacturing facility can be adversely impacted by the manufacturing environment. Also, modular units can pick up pollutants during transportation that could impact the testing and which should be removed or ventilated out before the intent of the credit can be met. LEED only rewards acceptable IAQ levels in the completed structure so the testing must be completed on site.

EQ Credit 4: Low Emitting Materials

The modular building industry is scrutinized more than site-build construction for its ability to provide usable habitats with acceptable indoor air quality, despite the fact that this feature has also been proven to be very possible in modular environments. The combination of growing awareness of the consequences of poor indoor air quality coupled with LEED and the growing high performance green building movement has made compliance with this collection of credits

very desirable. The reader is invited to revisit **Materials and Resources and Modular Building** to refresh the association with the criteria in that LEED category.

In LEED 2009 the following four Low Emitting Materials Credits are contained in this Credit grouping in LEED for New Construction and Major Renovations:

- *EQ Credit 4.1: Low Emitting Materials – Adhesives and Sealants*
- *EQ Credit 4.2: Low Emitting Materials – Paints and Coatings*
- *EQ Credit 4.3: Low Emitting Materials – Flooring Systems*
- *EQ Credit 4.4: Low Emitting Materials – Composite Wood and Agrifiber Products*

In LEED 2009 *EQ Credit 4.3* was changed from Carpet Systems to *Flooring Systems*. This change acknowledges a wider selection of flooring materials and enables LEED 2009 for New Construction to align itself with LEED for Schools.

In LEED for Schools these Credits are also available:

- *EQ Credit 4: Option 3 – Flooring Systems*
- *EQ Credit 4: Option 5 – Furniture and Furnishings*
- *EQ Credit 4: Option 6 – Ceiling and Wall Systems*

Each of the above material categories are governed by organizations that set maximum allowable limits for volatile organic compounds in the products eligible for credit consideration. They are listed in the respective reference guides along with the submission requirements and allowable alternative compliance paths for calculating VOC budgets if a product does not comply. In essence LEED project teams are challenged to use only benign products with low or zero VOC content. These materials are now readily available and largely cost neutral, especially if purchased in bulk. The modular building industry has two unique situations that impact achieving LEED points for these credits.

The first is by assembling modular building components and units in controlled environments it is possible to critically meter and effectively apply only the amount of material necessary. Material off gassing and airborne overspray can be controlled. Controlled temperatures and humidity provide for optimum product storage, application and curing conditions. This is not true if modular building products and units are manufactured and / or assembled in whole or in part outdoors.

The second is technically these credits only consider materials applied on site. As in all credit categories only the finished LEED project is considered. If none of the materials evaluated in *EQ Credits 4.1 - 4.4: Low Emitting Materials* are applied on site then the *Credits* and associated points are not available. Conversely, if even small amounts of the subject materials are applied in the field, perhaps in touching up or final installation, then the entire application of the material in question must be evaluated.

It is very common for LEED projects to score well in this category. Modular building should not be an exception.

EQ Credit 5: Indoor Chemical and Pollutant Source Control

This Credit recognizes the importance of keeping finished buildings clean and uncontaminated during their service life. To obtain this credit and the associated point the following features and products must be in place:

- Walk off grates or removable mats in the main entrances
- Code based solutions to properly venting hazardous gases out of the building
- The inclusion of Minimum Efficiency Reporting Value (MERV) 13 filters in the permanent HVAC system(s)

These features are not specific to modular buildings but can be incorporated. The most serious challenge may be using the high efficiency MERV 13 filters in unit ventilators or through the wall and roof top mounted packaged HVAC equipment commonly found in modular units. The HVAC industry has responded with a growing number of MERV 13 filters than can be installed in packaged space conditioning and ventilation

equipment. The modular building manufacturer and / or supplier needs to know these choices are available.

Exhausting hazardous gases and other code related ventilation requirements are usually in response to special ventilation needs; laboratory or kitchen exhaust hoods, paint booths or other project specific conditions. If no special ventilation needs or conditions exist the credit can still be achieved.

EQ Credit 6.1: Controllability of Systems - Lighting

This credit requires individual lighting controls for 90% (minimum) of the building occupants and lighting system controls for all shared multi-occupant spaces. It is applicable to any building. Modular building manufacturers simply need to be aware of the lighting system design requirements and be sure they are incorporated into the finished project.

EQ Credit 6.2: Controllability of Systems – Thermal Comfort

Thermal comfort system control, for the purpose of this credit, is defined as the provision of control over at least one aspect of thermal comfort – air temperature, radiant temperature, air speed and humidity. The influence of these variables and acceptable strategies for controlling each are set forth in ASHRAE 55-2004. To obtain this credit at least 50% of building occupants must have access to comfort controls and be able to control at least one of the variables. All shared occupancy spaces must have accessible controls. This consideration also extends to operable windows if the parameters set forth in ASHRAE 62.1 – 2007, paragraph 5.1 are met.

EQ Credit 7.1: Thermal Comfort Design

The point for this credit is attained if the LEED project team can illustrate the building envelope and space conditioning systems can meet the comfort standards set forth in ASHRAE 55-2004. The comfort parameters – temperature, humidity, radiant comfort and air velocity - are the same as those in *EQ Credit 6.2*. This is largely a matter of envelope and building systems integration with controls and occupancy profiles. It is not specific to modular building.

EQ Credit 7.2: Thermal Comfort Verification

Project teams can obtain this credit and point by agreeing to conduct an anonymous survey six to eighteen months after occupancy to determine whether the comfort goals of the project have been met. It is typically conducted by the Owner or the Owner's agent. It is not specific to modular building.

EQ Credit 8.1: Daylight and Views – Daylight 75% of the Spaces

Effective daylighting is one of the signature characteristics of high performance green buildings. LEED rewards effective daylighting through its inclusion in the calculations for *EA Credit 1: Optimum Energy Performance*. This credit acknowledges the importance of daylight in reducing the dependence on electric lighting and its positive influence on the psychology of space.

LEED permits three different calculation methodologies to determine whether a minimum daylighting contribution has been made to a sufficient number of spaces. In essence project teams must balance the relationship of properly selected and placed glazing, and provide effective shading and glare control to meet minimum daylighting requirements.

Effective daylighting is a matter of good design and is not specific to any building type. The growing awareness of the importance of daylighting in school environments has put added emphasis on achieving this credit and point in modular units used as primary learning environments. Daylight also has a natural sanitizing capability that contributes to limiting mold growth.

EQ Credit 8.2: Daylight and Views – Views for 90% of the Spaces

LEED recognizes the importance of connecting building occupants with exterior environment. This point is obtained by providing views to the exterior from 90% or more of the regularly oc-

cupied spaces. This is a matter of room configuration, or shape, and the strategic placement of vision glazing assumed to be between 2'-6" and 7'-6" above the floor. This credit is a matter of design and not specific to modular construction. In integrated design glazing dedicated to passive solar gain or daylighting strategies are effectively combined with the desire to provide views. Modular buildings can attain this credit and point.

EQ Credit 9: Enhanced Acoustical Performance (LEED for Schools only)

EQ Credit 9 builds on the foundation of *EQ Prerequisite 3 – Minimum Acoustical Performance* and rewards a point to LEED project teams that can achieve a higher level of acoustic performance in primary learning spaces. Essentially teams must follow the design goals and criteria set forth in ANSI Standard S12.60 – 2002 to achieve more stringent acoustic performance goals than those associated with the *Prerequisite*.

Modular building manufactures and suppliers should assess what can be done to current modular building practice(s) to meet this credit requirement. It must be noted that windows with a minimum STC rating of 35 may be required in the modular unit if the overall unit is to qualify. If STC 35 windows are not included the units may be required to incorporate acoustic ceiling tile or other sound attenuating material. In addition the project team may be required to assess the ambient noise conditions of the project. In markets based on the construction and sale of repetitive units the investment made in an acoustic consultant can be recouped over time.

EQ Credit 10: Mold Prevention (LEED for Schools only)

Modular buildings used for classrooms and other similar purposes will continue to be the subject of reviews regarding IAQ issues in general and mold in particular. While the potential to have mold present is not specific to modular buildings, it is important to focus on building structures that are resistant to supporting micro flora despite a combination of interiors with high organic content, limited window area, external HVAC equipment and intermittent occupancy.

Several modular building providers have won competitions for their buildings that demonstrate superior indoor air quality is possible with informed design and construction choices and quality construction.

LEED rewards finished building projects that address Mold prevention by doing the following:

1. Earning EQ Credits 3.1: Construction IAQ Management Plan – During Construction, EQ 7.1: Thermal Comfort – Design, and EQ Credit 7.2: Thermal Comfort – Verification
2. Provide HVAC Systems and controls designed to limit space relative humidity to 60%
3. Develop and implement on an ongoing basis an ISAQ management program for buildings based on the EPA's "Building Air Quality: A guide for Building Owners and Facility Managers", EPA Reference Number 402.F-91-102, December, 1991.

Collectively these efforts represent a foundation that addresses the fact that mold is ambient, the propagation of mold is due to several interrelated factors, and the mediation of mold is dependent on proper maintenance and ongoing due diligence. The modular building industry must interface with LEED design teams and commissioning authorities to insure the preventive measures including in the factory are maintained through the final construction phases and into the occupancy of the building.

MODULAR BUILDING INSTITUTE

Innovation and Design Process and LEED

Perhaps the best feature of the LEED building rating system is the invitation to be innovative. It underscores that fact that all buildings, including modular buildings, are simply what we make them. If design is the first indication of intent then the finished building is simply the manifestation of that intent.

In LEED 2009 The Innovation & Design Process includes five credit opportunities to score points in what are called *ID Credit 1.1 through 1.5*. These credits can be achieved by accomplishing exemplary performance in the pursuit of any credit that is eligible for that approach. In LEED Version 3 2009 those three ways are:

1. Exemplary performance. This means the project team has gone beyond the last increment of the credit's graduated requirements by the next full increment. They include such credits as WE Credit 3.2 Water use Reduction where the LEED team would accomplish a savings of 50% reduction in water use in LEED NC including LEED for Schools. Or, in Materials and Resources Credit 2.3 Construction Waste Management, the team diverts more than 95% of the construction waste stream from a landfill.
2. Repeat a previously awarded Innovation in Design Credit. The USGBC publishes a catalog of ID Credits that teams have submitted for consideration. These are listed categorically and indicated as accepted or denied. If the LEED team that is using modular building components can repeat the credit listed it will receive one ID point. For instance, the ID Catalog contains a listing for a point rewarded for sensitive site planning that exhibits minimum site disturbance. Minimum site disturbance is something modular building can achieve. If the same gesture can be repeated and sufficiently documented the modular building LEED team can claim the same point.
3. Be truly innovative. In this case the LEED team needs to document the intent, requirements and the means by which the idea was achieved. Original ID credits are most successful if they quantify the results the project is trying to achieve. The ability to quantify savings and / or the environmental benefits to the project is central to achieving the LEED point. Modular building capitalizes on the ability to move product in controlled manufacturing conditions, tight inventory control and project schedules. It is inherently waste conscious and can have minimum site impact if delivered carefully and strategically with respect to site constraints. Modular units purchased within 500 miles of the construction site offer other LEED ID point opportunities, as does the installation of low VOC materials off site.

The LEED team using modular building components or modular units is encouraged to explore ways to achieve Innovation and Design process points both in the manufacturing facility and in the field. LEED project teams are invited to explore any and all innovation opportunities that resonate with LEED's premise of environmental stewardship.

Lastly, LEED projects that involve LEED Accredited Professionals, LEED APs, are also eligible for a point in this category. The GBCI has implemented a two-tiered LEED 2009 exam structure. Those who pass with the LEED AP Plus accreditation will be able to claim ID Credit 2 LEED AP. Those holding a LEED AP Associate status will not be eligible for the ID Credit 2 LEED AP ID Point.

A green building success story. As seen in *Building Design+Construction* magazine:

Proven green features

- Highly reflective roof membrane
- Increased R-value of building envelope (insulated doors, widows and a vapor barrier)
- Recycled materials, including exterior siding, floor and acoustical ceiling
- Dual glazed, Low E glass windows
- Daylight harvesting with sun tunnels
- Paperless drywall and no-VOC paint
- High-efficiency light fixtures (T-5s)
- Energy-efficient heat pump with reduced noise
- Placement for least impact on surface water movement

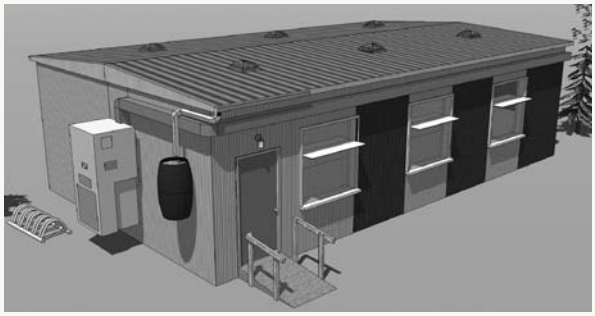
Head of the green class

Charlottesville, Va. Waldorf School (Waldorf) has spent the last 25 years educating students on the importance of taking care of the environment, with a core mission of *Setting the Green Standard.* When Waldorf needed extra space fast for the 2008 school year, it believed that a green modular classroom fit its vision. Enter the Modular Building Institute (MBI), also located in Charlottesville, Va. MBI's Educational Foundation recently launched a student green building contest as a part of its annual Awards of Distinction contest. The previous year's competition focused on a high-performance, relocatable classroom. William O'Brien of Concordia University designed the winning entry (pictured lower right).

Initially unaware of MBI's student design competition and its Charlottesville neighbor, Jim Zuffoletti, Chair for Waldorf Board of Directors, reached out to Tom Hardiman, MBI executive director, for assistance. At the outset, Zuffoletti was simply researching what green modular solutions might be available. Hardiman shared with him O'Brien's winning entry and took the additional step of posing a challenge to MBI membership. He asked for someone to step forward and build a green classroom for Waldorf—and it had to mimic O'Brien's award-winning design.

M Space Holdings (M Space) of New York, N.Y. jumped at the challenge. They started planning a green modular classroom with Zuffoletti that met time, budget and sustainable requirements of the school. In a little over one month, M Space delivered a slightly modified, but highly sustainable design inspired by O'Brien's winning entry.

Other MBI members, including Bard Manufacturing, Tell Manufacturing and Hunter Modular Construction, donated green products to enhance the learning environment of the school. "We were thrilled to help such a visionary school right in our own backyard, and proud of our members who rose to the occasion," said Hardiman. As for Zuffoletti, "We couldn't be more pleased. We started our conversations with MBI seeking nothing more than information on what was available. Instead, we got a green portable classroom." What better opportunity than this for a young architecture student to show how portable classrooms can be sustainable in real-world applications. "I entered MBI's contest and won, and now my design has jump-started this whole process," said William O'Brien. "I'm just happy that the Waldorf School stepped up to have this classroom built, and it is exciting to think that I am helping to change the way the world builds." **MBI**



MBI's student design competition had focused on a high performance relocatable classroom in 2007. William O'Brien, of Concordia University, designed the winning entry shown here. This student design inspired the classroom built for Charlottesville's Waldorf School this past year.

New Category: Regional Priority

The Regional Priority Credits category is new to LEED 2009. The category was introduced in response to the USGBC members who felt LEED should evolve toward something that could address local issues. It was developed largely through volunteer effort centered in local USGBC Chapters. In each case members were asked to propose credits that reflect regional concerns. The Regional Bonus Credit Category contains four possible *Regional Specific Environmental Priority credits*. A database of Regional Priority credits is available on the USGBC website www.usgbc.org. Each is indexed to the project location via zip code. For instance, if the location in which the modular building project has listed Energy and Atmosphere Credit One – Optimum Energy Performance as a Regional Priority Credit the team is eligible for a point via that Regional Priority credit opportunity if the team scores well in the EA point. If the team exceeds the Regional Priority credit threshold for Water Efficiency Credit 3.2 the team is eligible for an additional point.

Recycling: Before and After

Commercial modular construction providers lead the way on renovation and reuse of buildings

The modular building "before" was renovated into a model center for a senior citizen's assisted living facility. The renovated building stands alone at the gate of an assisted living community where it serves as an exact replica of what the living quarters of the facility will look like when built. The building has a cut sandstone and stucco exterior wall finish with a standing seam roofing material.

Before

After

Conclusions

In conclusion, the evolution of LEED is a reflection of the changing market forces, ongoing innovation and opportunities that present themselves in the design, construction, and operation and maintenance of high performance green buildings. The modular building industry should note the increased sophistication embedded in the evaluation of the credits and their associated point scores in LEED 2009. There is every opportunity for the modular building industry to identify with and achieve the value added in energy, material and resource efficient qualities and attributes of high performance buildings in LEED 2009 that have been assigned higher point scores. At the same time the modular building industry still offers the best strategies for construction waste management, material efficiencies and superior air quality which, although they were not revised in LEED 2009, still enable LEED project teams to have the best overall projects possible.

There are several sources that indicate that interest in sustainable design and development and the green building movement is continuing to grow. McGraw Hill publishes their Green Building Market Survey each year. It chronicles steady growth in the green building movement as well as a growing awareness of the benefits of green buildings in many market sectors. Publications as different as the *Wall Street Journal* and the *American Wind Energy Journal* site market influences and construction trends that point to the emergence of green technologies and new jobs. This Obama administration's stimulus package earmarks funding for green schools and alternative energy development. The indicators that green development will lead the recovery in the real estate industry are everywhere.

In order for the Modular Building Industry to capitalize on these trends a number of issues must be addressed. Among these are:

1. The ability to embrace change and recognize how the qualities and attributes in modular building can be used to gain market share.
2. The need to overcome the negative impressions many design professionals have regarding the limits to creativity and adaptability of modular building techniques by positively promoting the unique qualities and attributes of modular building, especially as they relate to green building.
3. Continue current practices and activities such as conferences and design competitions in a way that positively promotes the modular building industry. The ability to speak with a unified voice to the AIA, ASHRAE, BOMA, the US Green Building Council, the Collaborative for High Performance Schools, and the Association of School Board Officials is critical to promoting the interests of the Modular Building Industry.

It is in the best interest of the members of the Modular Building Industry and the environment at large that we work together to promote energy, material and resource efficient buildings that are optimized for the health and productivity of building occupants and users.

Sustainable Sites and Modular Building

LEED Evaluation Matrix - Modular Building Institute							
SUSTAINABLE SITES	**Credit**	**Description**	**Y**	**M**	**N**	**Submittal Requirement**	**Modular Building Issues**
	Attaining the Sustainable Sites Credits is largely a matter of project context. They are not specific to the physical qualities or attributes of modular building with the exception on SS Credit 7.2 : Heat Island Effect - Roof						
	Prereq. 1	Construction Activity Pollution Prevention	Required			Erosion and sediment control drawing and narrative. Confirm compliance path.	This is a general requirement for most building projects. Modular units need to be placed within the guidelines of good site management practice.
	SS CR 1	Site Selection				Evidence that all six limiting factors have been observed.	Credit requirements are not specific to building type.
	SS CR 2	Development Density and Community Connectivity				Evidence that the project and surrounding projects meet or exceed 60,000 sq. ft. / acre or the community criteria enterprises are present within 1/2 mile.	Credit requirements are not specific to building type.
	SS CR 3	Brownfield Redevelopment				Projects can only obtain this point via SS Prerequisite 2 by remediating the site.	Credit requirements are not specific to building type.
	SS CR 4.1	Alt. Transportation Public Transportation Access				Evidence of the mass transit elements and / or the district demographics regarding the percentage of the school population that is within walking distance.	Credit requirements are not specific to building type.
	SS CR 4.2	Alt. Transportation Bicycle Storage and Changing Rooms				Calculate FTE and transient (student and visitor) populations. Drawings showing bike racks and showers. Need two or more safe bike paths to the edge of the site.	Credit requirements are not specific to building type.
	SS CR 4.3	Alt. Transportation Low Emitting and Fuel Efficient Veh.				Option One: Convert vehicles serving the school to 20% alternative fuels. Option Two: Provide preferred parking for 5% of the total vehicle parking of the site and at least one designated drop off area for low emitting and fuel efficient vehicles.	Credit requirements are not specific to building type.

Sustainable Sites and Modular Building (cont)

LEED Evaluation Matrix - Modular Building Institute							
	Credit	Description	Y	M	N	Submittal Requirement	Modular Building Issues
SUSTAINABLE SITES	SS CR 4.4	Alt. Transportation Parking Capacity				Calculate total parking for site, as per Option One. Renovations may qualify under Option Two: No new Parking.	Credit requirements are not specific to building type.
	SS CR 5.1	Site Development: Protect or Restore Habitat				On greenfield sites limit disturbed area of construction to LEED requirements. On previously developed or graded sites protect a minimum of 50% of the site area excluding the building footprint with native or adaptive vegetation.	Credit requirements are not specific to building type.
	SS CR 5.2	Site Development: Max. Open Space				Project site and building footprint area, landscape dwg & open space calcs.	Credit requirements are not specific to building type.
	SS CR 6.1	Stormwater Design Quantity Control				Narrative and stormwater design calculations for site and roof areas, as per option 1. Coordinate with LA.	Credit requirements are not specific to building type.
	SS CR 6.2	Stormwater Design Quality Control				Narrative and stormwater design calculations. This needs to be coordinated with C&R and EWC.	Credit requirements are not specific to building type.
	SS CR 7.1	Heat Island Effect Non-Roof				Site dwgs with material locations, shading and SRIs and narrative of compliance strategy.	Credit requirements are not specific to building type.
	SS CR 7.2	Heat Island Effect Roof				Roof dwgs with material locations and SRIs and narrative of compliance strategy.	Modular construction must comply with the SRI requirements for roofing materials; SRI of 78 for roof pitches less than 2/12 and SRI of 29 for roof pitches greater than 2/12.
	SS CR 8	Light Pollution Reduction				Lighting layouts, photometrics, LPD tables, site zone classification, SLCs and narrative. Exterior - LZ2 Interior - Option 2.	Lighting levels need to be reduced to those stated in the LEED NC or LEED for Schools reference guide which are a percentage of IESNA recommendations. Also, curfew controls with manual override must be included to meet light trespass requirements for aft.
	SS CR 9	Site Master Plan LEED for Schools				A Master Plan must be authored that achieves 4 out of the 7 following credits: SS CR 1, SS CR 5.1, SS CR 5.2, SS CR 6.1, SS CR 6.2, SS CR 7.1, SS CR 8.	Modular buildings can be included in Master Plan. Master plan may also include removal or relocation of modular units.
		SS Section Totals					

Water Efficiency and Modular Building

LEED Evaluation Matrix - Modular Building Institute							
	Credit	**Description**	**Y**	**M**	**N**	**Submittal Requirement**	**Modular Building Issues**
WATER EFFICIENCY	Prereq. 1	Water Use Reduction	Required			20% reduction	Changed from WEc3.1 to WEp1.
	WE CR 1.1	Water Efficient Landscaping Reduce by 50%				Baseline Total Water Applied and design case TWA; total non-potable water supplied for irrigation; and supporting narrative.	Credit requirements are not specific to building type and are largely a function of site design.
	WE CR 1.2	Water Efficient Landscaping: No Potable Water Use				Baseline Total Water Applied and design case TWA, total non-potable water supplied for irrigation and supporting narrative.	Credit requirements are not specific to building type and are largely a function of site design.
	WE CR 2	Innovative Wastewater Tech.				Plumbing fixture drwgs., occupancy, baseline and design case sewage water use.	Modular building can incorporate the full range of water conserving fixtures and technologies associated with transporting waste using potable water and can benefit equally from rain water harvesting, grey water distributed by host municipalities, etc.
	WE CR 3.1	Water Use Reduction: 20%				Calculate occupancy, baseline and design case water use, nonpotable water use and narrative.	Credit requirements are not specific to building type and are largely a function of site design.
	WE CR 3.2	Water Use Reduction: 30%				Calculate occupancy, baseline and design case water use, nonpotable water use and narrative.	Modular building can incorporate the full range of water conserving fixtures and technologies associated with water conservation and can benefit equally from rain water harvesting.
	WE CR 3.3	Water Use Reduction: 40%				Calculate occupancy, baseline and design case water use, nonpotable water use and narrative.	
	WE CR 4	Process Water Use Reduction				Evidence that no cooling equipment uses through put of potable water, no garbage disposals are used, and at least four other water uses are addressed.	This credit applies to the building functions associated with the water functions they host. It is not specific to building type.
WE Section Totals							

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Energy and Atmosphere and Modular Building

LEED Evaluation Matrix - Modular Building Institute							
	Credit	Description	Y	M	N	Submittal Requirement	Modular Building Issues
ENERGY & ATMOSPHERE	Prereq. 1	Fundamental Commissioning	Required			Cx Qualifications, (6) required Cx tasks per Reference Guide and narrative.	Required of each project.
	Prereq. 2	Minimum Energy Performance	Required			Confirm compliance with ASHRAE 90.1 2004 via accepted computer modeling.	Required of each project; usually required by Code.
	Prereq. 3	Fundamental Refrigerant Man.	Required			Confirm the project does not use CFC refrigerants or provide phase out plan.	Required by Law. The use of CFCs in existing Central Plants is conditional.
	EA CR 1	Optimum Energy Performance				Base case / design case comparison using accepted computer modeling.	All completed projects must achieve a reduction in the yearly cost of energy determined against an ASHRAE 90.1 2004 Appendix G base case building. Modular buildings are particularly well suited to be energy efficient depending on assembly techniques.
	EA CR 2	On Site Renewable Energy				Evidence that qualifying renewable energy systems offset 1%, 5%, 9% or 13% of the yearly energy budget for 1, 3, 5 or 7 points respectively.	The application of renewable energy systems are not building type specific. Renewable energy systems can be integrated into the building and / or site. Systems such as photovoltaics or solar water heating panels can also serve as shading devices. They need only be a part of the project the modular is included in.
	EA CR 3	Enhanced Commissioning				Cx Qualifications, (6) required Cx tasks per Reference Guide and narrative.	Modular components that comprise finished projects, in whole or in part, are subject to the project's overall approach to the Prerequisite 1: Fundamental Commissioning an EA Credit 3: Enhanced Commissioning. There are no special considerations.
	EA CR 4	Enhanced Refrigeration Management				Template showing refrigerants used comply and narrative if special conditions.	Equipment used for space conditioning must meet the numeric index for refrigerant choices which is a function of system type size, refrigerant charge and the type of refrigerant selected. Small equipment such as refrigerators or water coolers can be exempt. The HVAC equipment must have compliant refrigerants.
	EA CR 5	Measurement and Verification				Confirm IPMVP Option and upload a copy of the plan.	Measurement and Verification plans are not building type specific. M&V is dependent on the nature of the energy consuming features of the completed project, their impact on ongoing operation and maintenance and the clients willingness to implement Option B or D of the IPMVP. Option B is for simple projects with limited systems and energy conservation measures. Option D is for more complex finished projects.
	EA CR 6	Green Power				Provide name of Green Power vendor or green tags supplier for 35% of load / year.	Green power can be applied to any project. The cost of this credit is reduced in response to E&A Credit 1 and the yearly electrical load of the completed project.
		E&A Section Totals					

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Materials and Resources and Modular Building

LEED Evaluation Matrix - Modular Building Institute							
	Credit	**Description**	**Y**	**M**	**N**	**Submittal Requirement**	**Modular Building Issues**
MATERIALS & RESOURCES	Prereq. 1	Storage and Collection of Recyclables	Required			Indicate recycling collection and storage areas, the materials recycled and narrative.	The finished project must illustrate how recycling will occur, or could occur, if there is no municipal recycling program.
	MR CR 1.1	Building Reuse: 75% Shell				Confirm the nature of the project. Tabulate the surfaces being reused of each structural / envelope element and provide a narrative if necessary.	These credits only apply to finished projects that involve existing buildings. Modular construction can be part of a finished project that involves existing buildings. If the portion of the new (modular) building exceeds the original existing building by 200% or twice the square footage of the existing building these credits do not apply. However, in this scenario the materials contained in the shell and / or interior of the existing building transfer in their entirety to Credit MR 2.1 Construction Waste Management.
	MR CR 1.2	Building Reuse: 95% Shell					
	MR CR 1.3	Building Reuse: 50% Interior				Same as CR 1.1 and 1.2 for interior elements.	
	MR CR 2.1	Construction Waste Management: 50%				Template with completed construction waste tables showing materials, receiving agent, quantities in tons or cu.yds and CWM Plan narrative.	Attaining these credits depends on construction waste management at the construction site. Modular building by its nature contributes very little to the construction waste management stream at the construction site. Projects using modular building should investigate construction waste management practices at the modular building manufacturing plant to see if exemplary waste management practices at those plants can contribute to a LEED ID Innovation point in the waste management category.
	MR CR 2.2	Construction Waste Management: 75%				Template with completed construction waste tables showing materials, receiving agent, quantities in tons or cu.yds and CWM Plan narrative.	
	MR CR 3.1	Material Reuse: 5%				Total project materials cost for Divisions 2-10 and % salvaged materials by cost. Include source, vendor and material costs. Narrative describing uses.	These credits are premised on the percentage of reused or aftermarket building materials that are included in the finished project. Thus, reused materials in the modular building component of the project can be added to others that make up the finished project. This includes site materials as well as materials in the project included in the non-modular portions of the work.
	MR CR 3.2	Material Reuse: 10%				Total project materials cost for Divisions 2-10 and % salvaged materials by cost. Include source, vendor and material costs. Narrative describing uses.	

Materials and Resources and Modular Building (cont)

LEED Evaluation Matrix - Modular Building Institute							
	Credit	Description	Y	M	N	Submittal Requirement	Modular Building Issues
MATERIALS & RESOURCES	MR CR 4.1	Recycled Content: 10%				Credit points are calculated against the total project materials cost for Divisions 2-10. The value of the eligible materials is determined as a % of preconsumer and post consumer recycled content calculated by weight in each building material considered. The source, vendor and material costs are listed in the template and supported by the narrative.	These credits are achieved by having 20% or 30% of the cost of the materials in the project in Divisions two thru ten represented by materials with recycled content. Modular building typically uses materials in the building envelope and finished that can comply with these credit requirements. Among these are structural insulated panels (SIPs), oriented strand board, light gauge steel framing, drywall products, carpet, acoustic ceiling panels, insulation, linoleum and other flooring options. The calculations are based on the completed project including materials used in site development.
	MR CR 4.2	Recycled Content: 20%					
	MR CR 5.1	Regional Materials: 10%				Credit points are calculated against the total project materials cost for Divisions 2-10. The value of the eligible materials is determined as a % of material content calculated by weight in each building material considered that are extracted, processed and manufactured within 500 miles of the project site. The source, vendor and material costs are listed in the template and supported by the narrative.	In order to qualify for these credits the modular unit must be purchased from within 500 miles of the project site. In addition, only those building components that have bee harvested, extracted, and assembled within 500 miles of the project site are eligible. The modular component supplier must be able to identify the source of the materials used in the manufacturing of the units, in whole or in part, and be able to determine by weight how much of the building components qualify for these points. These materials are then added to the remainder of the materials in the total project that are under consideration.
	MR CR 5.2	Regional Materials: 20%					
	MR CR 6	Rapidly Renewable Materials				The base calculations are the same as CR 5.1 and 5.2. A minimum of 2.5% of the total value of the materials in the project from Divisions 2 through 10 must be represented by materials whose components come to maturity within ten years.	Materials that comply with credit requirements typically include cork, agriculturally based wood substitute products such as wheatboard and soy based materials, components of linoleum, wool, bamboo and some woods used in plywood veneers and other composite wood products. Calculations are based on the weight of the product parts that comply.
	MR CR 7	Certified Wood				50% of the wood based products permanently installed in the project must come from Forest Stewardship Council (FSC) certified sources. This is determined by the dollar value all the wood based products installed, be they on site, exterior or interior of the finished building including the modular components.	The credit is possible dependent on the amount of wood based products permanently installed and whether a cost effective source for FSC wood based products can be located. It is calculated against the cost of all of the wood based products in the finished project, including site development, that are permanently affixed to the site and building(s). If the FSC wood comes from within 500 miles of the project site the project can take credit for the FSC materials in MR Credit 5.1.
		M&R Section Totals					

Indoor Environmental Quality and Modular Building

LEED Evaluation Matrix - Modular Building Institute							
	Credit	Description	Y	M	N	Submittal Requirement	Modular Building Issues
ENVIRONMENTAL QUALITY	Prereq. 1	Minimum IAQ Performance	Required			Design narrative and confirmation the project complies with ASHRAE 62 2004.	The HVAC of the modular units and the completed project as a whole must comply with all applicable ASHRAE Standards.
	Prereq. 2	ETS Control	Required			Confirmation via template the project meets smoking design restrictions.	The modular units must comply with this prerequisite as part of the finished project. In some projects this includes smoking in any part of the project once it is enclosed.
	Prereq. 3	Minimum Acoustical Performance in LEED For Schools projects only	Required			Meet Reverberation Time (RT) requirements of ANSI A12.60-2002 Acoustic Performance Criteria and STC ratings. Meet same standards for STC ratings for core learning spaces except for windows which must meet STC 35. And use methodology in annexes B through D of ANSI S12.60-2002 to achieve a maximum background level of 45 dBa, or, design core learning spaces to achieve a maximum mechanical system RC (N) Mark II level of 37 in accordance with the ASHRAE 2003 HVAC Applications Handbook, Chapter 47.	Modular construction must meet the overall acoustic design goals for all units used as core learning spaces. The minimum required STC of 35 for windows must be met. The combined STC ratings of the materials in the core learning spaces of less than 10,000 cubic feet must result in a maximum 1 hour A - weighted steady background noise level of 45 dBa or less and a reverberation time of 0.6 seconds in the midband frequencies of 500, 1000, and 2000 Hz. Spaces between 10,000 cu. ft. and 20,000 cu ft. must exhibit 45 dBa and 0.7 seconds, respectfully. Mixed requirements exist for spaces above 20,000 cu. ft. Completed designs must be reviewed for compliance. Mechanical equipment requirements must also be met.
	EQ CR 1	Outdoor Air Delivery Monitoring				Narrative, and dwgs that depict system intent, implementation and installation.	This credit must be evaluated against what constitutes regularly occupied areas. Individual modular units with packaged HVAC that meets these requirements can contribute to overall compliance of the finished project.
	EQ CR 2	Increased Ventilation				Increase ventilation rates in the breathing zone of all primary occupied spaces by 30% over ASHRAE 62-2004.	This credit must be evaluated against what constitutes regularly occupied areas. Individual modular units with packaged HVAC that meets these requirements can contribute to overall compliance of the finished project.
	EQ CR 3.1	Construction IAQ Management Plan: During Construction				Meet SMACNA IAQ Guidelines for Occupied Buildings Under Construction, 1995, Chapter 3, protect stored and installed building materials from moisture damage, use MERV 8 filters on all return air grills if HVAC equipment is used during construction and prohibit smoking in the building and within 25 feet of building entrances and openings once the building is enclosed.	Controlled conditions in Modular unit manufacturing plants contribute to meeting the intent of this credit. Similar care must be provided during shipment of modular components to insure the intent of the credit is met. MERV 8 filters are required during construction and the project as a whole must comply with all other credit requirements.
	EQ CR 3.2	Construction IEQ Management Plan: Before Occupancy				Confirm compliance approach, flush out etc., IAQ sampling survey or other evidence of compliance.	Modular units must be tested in place in context with the completed project using Option One - Flush Out or Option Two - IAQ Testing. Compliance is achieved by not containing materials that violate IAQ standards and accepted practice.
	EQ CR 4	Option One: Low Emitting Materials - Adhesives and Sealants				LEED for New Construction and Major Renovations is based on VOC and contaminant levels listed in the South Coast Standards, Greenseal Chapter Eleven and the Carpet and Rug Institute. LEED for Schools projects are based on the California Air Quality standards.	These credits are considered essential to good interior air quality and contribute to overcoming the association with modular buildings as less than desirable in that regard. The credits are only applicable to materials that are site applied or part of the on site construction process. Components assembled off site, which is the case in modular construction do not apply. However, compliance with IEQ Credit 3.1 and 3.2 require strict attention to all materials used in modular construction, especially those that contribute to good interior air quality.
		Option Two: Low Emitting Materials - Paints and Coatings					
		Option Three: Low Emitting Materials - Flooring Systems					
		Option Four: Low Emitting Materials - Composite Wood and Agrifibre Products					

Indoor Environmental Quality and Modular Building (cont)

LEED Evaluation Matrix - Modular Building Institute							
	Credit	Description	Y	M	N	Submittal Requirement	Modular Building Issues
ENVIRONMENTAL QUALITY	EQ CR 4	Option Five: Low Emitting Materials - Furniture and Furnishings				LEED for Schools accepts compliance with one or more of the following agencies and their testing procedures for furniture and furnishings: Method A: GREENGUARDTM Children and Schools Certified. Method B: US EPA Environmental Technology Verification (ETV) Large Chamber Testing Protocol for Measuring Emissions of VOCs and Aldehydes. Method C: BIFMA M7.1-2005 and X7.1-2005.	Modular construction typically does not include anything that is not permanently affixed. The completed project, including modular units, can be furnished or equipped with furniture components and systems that comply with these credits.
		Option Six: Low Emitting Materials - Ceiling and Wall Systems				See note in Options One Through Four above. Applies to LEED for Schools only.	See note in Options One Through Four above.
	EQ CR 5	Indoor Chemical Pollutant Source Control				Template confirming entry products, MERV filters and special M / P design.	LEED compliant walk off matts are required in DIV 12, Section 12692. DMS requires LEED compliant MERV 13 Filters or higher. Projects need to comply with exhaust air requirements for labs, large copiers, etc.
	EQ CR 6.1	Lighting System Design and Controllability				LEED for Schools differentiates between Administrative and other regularly occupied spaces and core learning spaces in determining lighting control strategies. Core learning spaces in turn must have general illumination and A/V lighting modes.	Lighting systems in Modular units must achieve the circuiting and control requirements listed. This can be easily done. In the best case the controls allow for optimizing available daylight.
	EQ CR 6.2	Thermal Comfort Controllability				LEED NC and LEED for Schools requires thermal comfort controllability for 50% of the building occupants in their normal work stations to control individual comfort requirements. Additional control must be provided to all multi-occupant shared spaces to suit group needs and preferences.	Control systems that comply with the credit requirements can contribute to the inventory of spaces that meet the overall project requirements. This must be coordinated with the project as a whole and be recognized in the energy modeling needed for Energy and Atmosphere Credit one - Optimum Energy Performance.
	EQ CR 7.1	Thermal Comfort: Design				Design HVAC systems to comply with ASHRAE 55-2004. Natatoriums must meet “Typical Natatorium Design Conditions” defined in Chapter 4.	See note in EQ Credit 6.2 above.
	EQ CR 7.2	Thermal Comfort: Verification				Construct and conduct a post occupancy survey and agree to correct deficiencies.	This survey must be completed by the building owner within one year of project completion.
	EQ CR 8.1	Daylight and Views: Daylighting 75% of Spaces				Effectively daylight 75%, 90% of the core learning spaces for 1 or 2 points. Daylight 75% of the other spaces for an additional point.	This credit is a function of room geometry, window selection and treatment and interior finishes. Modular units can meet this requirement and must be included in the overall project calculations for all spaces under consideration.
	EQ CR 8.2	Daylight and Views: Views for 90% of Spaces				Provide views per credit requirements for 90% of all the regularly occupied areas.	This credit is calculated on a room by room basis. Modular units can comply with credit requirements but must be included in the overall project calculations for all spaces under consideration.
	EQ CR 9	Enhanced Acoustical Performance				LEED for Schools only. Meet the reverberation times cited for the Prerequisite and reduce the background noise level to 40dBa and 35dBa for one or two points respectively OR reduce the RC levels to 32 and 37 for one or two points.	This credit is based on the requirements of EQ Prerequisite 3 and a comprehensive approach to reducing sound transmission between classrooms dependent on sound transmission coefficients and good mechanical system design. Modular construction can achieve these requirements.
	EQ CR 10	Mold Prevention				Meet EQ Credits 3.1, 7.1 and 7.2, install systems that maintain 60% relative humidity or lower during all load conditions, both occupied and unoccupied, and develop and implement an ongoing IAQ Management Plan based on EPA 402-F-91-102, December, 1991.	Modular construction can meet these requirements. The credits noted must be met and it is important to note that mold prevention is also dependent on good operation and maintenance.
Environmental Quality Section Totals							

Innovation and Design Process and LEED

LEED Evaluation Matrix - Modular Building Institute							
	Credit	**Description**	**Y**	**M**	**N**	**Submittal Requirement**	**Modular Building Issues**
INNOVATION IN DESIGN	ID CR 1.1	Innovation in Design				Innovation Credits and points can be achieved one of two ways: Go beyond the threshold requirements for the credit under consideration by the next increment, that is, accomplish exemplary performance based on the criteria for credit, or, propose something truly innovative and submit the Innovation in Design credit based on its merits. In this case the Credit must be able to be quantified and implemented based in the Credit Intent, the Requirements and the Strategies and Technologies proposed by the author. Modular building is efficient and in many ways innovative by nature. This is particularly true in the area of construction waste management, daylighting, HVAC and controls and good interior air quality; all dependent on construction techniques and materials.	
	ID CR 1.2	Innovation in Design					
	ID CR 1.3	Innovation in Design					
	ID CR 1.4	Innovation in Design					
	ID CR 1.5	Innovation in Design					
	ID CR 2	LEED Accredited Professional				Provide certificate of LEED AP designate	
ID Section Totals							

Regional Priority Credits and Project Totals

LEED Evaluation Matrix - Modular Building Institute							
REGIONAL PRIORITY CREDITS and SUMMARY	**Credit**	**Description**	**Y**	**M**	**N**	**Submittal Requirement**	**Modular Building Issues**
	RP CR 1.1	Region Specific Environmental Priority				The Regional Priority Credit Category contains four possible Regional Specific Environmental Priority credits. A database of Regional Priority credits is available on the USGBC website www.usgbc.org. Each is indexed to the project location via zip code. For instance, if the location in which the modular building project has listed Energy and Atmosphere Credit One – Optimum Energy Performance as a Regional Priority Credit the team is eligible for a point via that Regional Priority credit opportunity if the team scores well in the EA point. If the team exceeds the Regional Priority credit threshold for Water Efficiency Credit 3.2 the team is eligible for an additional point.	
	RP CR 1.2	Region Specific Environmental Priority					
	RP CR 1.3	Region Specific Environmental Priority					
	RP CR 1.4	Region Specific Environmental Priority					
		RP Section Totals				**Certified** 40 to 49 points, **Silver** 50 to 59 points, **Gold** 60 to 79 points, **Platinum** 80+ points	
		Project Totals					

Modular Building and the USGBC's LEED™ Building Rating System. Written for MBI by Robert Kobet, AIA

Robert J. Kobet, AIA, is president of Sustainaissance International Inc., a multifaceted architectural consulting firm specializing in sustainable design and development and environmental education. Beginning in 1977, Bob has specialized in environmentally conscious architecture and allergy free non toxic design for a variety of clients evolving a practice with projects in eight countries on five continents. Projects range from tree houses in a county park to consulting with the Cultural Section of the State Department on sustainable design and development in Argentina.

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All narrative expressed in this paper is written to correlate modular building practices with the United States Green Building Council's (USGBC's) LEED™ Building Rating System. LEED™ is a trademark of the USGBC and this paper is in no way intended to express the opinions or intent of the USGBC. This paper expresses the opinion and intent of the Modular Building Institute as guideline to the commercial modular construction industry on best practices for building in coordination with USBGC's LEED™ Building Rating System.

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About The MBI Educational Foundation (MBIEF)

The MBI Educational Foundation is the only organization established specifically to provide educational opportunities in the form of training and scholarships to individuals with an interest in commercial modular construction. The Foundation began in 2001 with the generous US$100,000 gift of Barry & Mary Gossett. Mr. Gossett is an industry veteran, member of the MBI Hall of Fame, recipient of the MBI Outstanding Achievement Award, and esteemed friend to many. Since 2001, the Foundation has trained over 1,000 industry professionals through its popular "Essentials of Commercial Modular Construction" educational series, begun intensive development of a modular buildings installation certificate program, and awarded student scholarships.

To learn more, visit:

modular.org

Founded in 1983, the Modular Building Institute is the only, international, non-profit trade association serving non-residential modular construction. Our regular membership includes wholesale manufacturers, direct manufacturers, and dealers of commercial modular buildings, while our associate members are companies supplying building components, services, and financing to the industry. It is MBI's mission to grow the industry and its capabilities by encouraging innovation, quality, and professionalism through communication, education, and recognition. MBI also administers an educational foundation. For more information, visit modular.org.