U.S. GREEN BUILDING COUNCIL

LEED™

LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

Reference Guide

For New Construction & Major Renovations

(LEED-NC)

Version 2.1

Second Edition
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U.S. Green Building Council
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Foreword

The New Reference Package

The second edition of the Reference Package corresponds to LEED Version 2.1 for New Construction and Major Renovations (LEED-NC). Printed components of the Reference Package include the updated Rating System and Reference Guide. The remainder of the Reference Package, provided in electronic form via download from a secure page on the USGBC Web site, contains the following:

- Bookmarked PDF files of the Reference Guide to allow convenient on-screen viewing while traveling, either stored on a laptop computer or through any computer with Internet access.
- LEED Version 2.1 Letter Template, a dynamic tracking and documentation tool that is used by project teams to track progress and prepare a LEED application. The Template is occasionally improved, uploaded and dated for reference.
- LEED Version 2.0 Reference Guide files, for professionals working on Version 2.0 projects.

The Revised Reference Guide

This edition of the Reference Guide was developed for two main reasons: to correspond with LEED-NC Version 2.1 Rating System, and to improve the content. In response to USGBC members and other LEED users, LEED-NC Version 2.1 provides technical clarifications and streamlines certification submittal requirements. Performance levels have not changed from Version 2.0 (see the Introduction section for related discussion), although calculation methodologies for several credits have been modified.

The Version 2.0 Rating System components—intent, requirements and submittals—were the first to be reviewed and judiciously altered for Version 2.1 by LEED technical committees with guidance from the LEED Steering Committee. The Letter Template approach to documentation and application submittal have been incorporated into the Reference Guide, as have clarifications made to LEED requirements.

The revised Reference Guide includes corrections and clarifications that have been requested by users (often through the Credit Interpretation process), technical committees and staff. Procurement details for referenced standards are more specific. Web site resource sections are now updated and in some cases expanded. General improvements have been made to content and text. *Please note that while key details for most prerequisites and credits remain unchanged from LEED Version 2.0 and its Reference Guide,* SS Credit 8 (Light Pollution), MR Credit 4 (Recycled Content) and EQ Credit 6 (Controllability of Systems) have been *substantially overhauled,* and thus should be thoroughly reviewed by LEED practitioners.

In addition, significant changes or corrections have been made, or helpful details added, to the requirements or calculation methodologies of SS Credit 3 (Brownfield Redevelopment), SS Credit 4.3 (Alternative Fuel Vehicles), SS Credit 6 (Stormwater Management), EA Commissioning Prerequisite and Credit, EA Energy Performance Prerequisite and Credit, EA Credit 6 (Green Power), MR Credit 7 (Certified Wood), IEQ Credit 4 (Low-Emitting Materials), and IEQ Credit 7.1 (Thermal Comfort: Compliance). Other sections may have been edited to a lesser extent but may still contain corrections and clarifications of interest.

Acknowledgements

At the October 2001 Board of Directors meeting, a Special Task Force was established to address important issues arising from the market uptake of the LEED Green Building Rating System. Pursuant to Special Task Force recommendations and the Board's directive, the charge to develop LEED Version 2.1 was given by the LEED Steering Committee to the LEED Version 2.x Committee and the LEED Technical Advisory Groups (TAGs), which consist of industry experts from USGBC member organizations. Some of the TAG recommendations could be not be implemented for Version 2.1 due to scope limitations. USGBC greatly appreciates their efforts during this process and looks forward to implementing more substantial improvements in the next version of LEED. The Reference Guide revision process was managed and implemented by USGBC staff and included review and suggestions by many core TAG members. We extend our deepest gratitude to all these individuals for their heroic volunteer efforts and constant support of USGBC's mission.

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About USGBC

The built environment has a profound impact on our natural environment, economy, health and productivity. Breakthroughs in building science, technology, products and operations are now available to designers, builders and owners who want to build green and maximize both economic and environmental performance.

The U.S. Green Building Council (USGBC) is leading a national consensus to produce a new generation of buildings that deliver high performance inside and out. Council members work together to develop industry standards, design guidelines, policy positions, conferences and educational tools that support the adoption of sustainable design and building practices. As the only national coalition that represents the entire building industry on environmental building matters, our unique perspective and collective power provides our members with enormous opportunity to initiate change in the way buildings are designed, built, and maintained.

Our membership is comprised of leaders representing the following categories:

Architectural Firms
Building Commissioning Providers
Building Control Service Contractors and Manufacturers
Building Owners, Managers, Users, and Brokers
Contractors and Builders
Consultants
Engineering Firms
Environmental Groups
Financial and Insurance Firms
Government
Manufacturers
Planners
Press
Professional Societies
Real Estate Developers
State, Local, and Federal Governments
Universities and Technical Research Institutes
Utilities

Since its inception in 1993, USGBC has played a vital role in providing a leadership forum and a unique, integrating force for the building industry. Council programs are:

Committee-Based

The heart of this effective coalition is our committees in which members design strategies that are implemented by staff and expert consultants. Our committees provide a forum for members to resolve differences, build alliances, and forge cooperative solutions for influencing change in all sectors of the building industry.

Member-Driven

The Council's membership is open and balanced and provides a platform for carrying out important programs and activities. We target the issues identified by our members as the highest priority. We conduct an annual review of achievements that allows us to set policy, revise strategies and devise work plans based on members' needs.

Consensus-Focused

We work together to promote green buildings and in doing so, we help foster greater economic vitality, environmental health and occupant well-being at lower cost. The various industry segments bridge ideological gaps to develop balanced policies that benefit the entire industry.

USGBC Membership

The strength and diversity of the USGBC coalition provides the advantages of significantly enhancing the resources and the effectiveness of its individual members. Our voice is credible and powerful because of the diversity and balance of our membership. We strongly encourage you to join the Council. Your involvement is crucial to the success and impact of our initiatives.

Member benefits include:

- Marketing, educational and networking opportunities through USGBC events, programs and publications
- Recognition as an industry leader in supporting a better built environment
- Opportunity to participate in local chapters
- Discounts on LEED certification, resource materials and training programs
- The USGBC newsletter

Join the Council and take advantage of this opportunity to accelerate change and help shape the green building industry.

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Introduction

Green Building Design

The term "green building" is synonymous with "high-performance building," "sustainable design and construction" as well as other terms that refer to a holistic approach to design and construction. There are many different conceptions of green building design due to the large scope of sustainability issues and the novelty of sustainable principles. Definitions of environmental sustainability range from broad concepts that incorporate all aspects of sustainability—meeting the needs of today without compromising the ability of future generations to meet their needs—to narrow definitions focused on one specific sustainable design feature such as energy-efficiency. Within this broad spectrum, green building design strives to balance environmental responsibility, resource efficiency, occupant comfort and well-being, and community sensitivity.

Green building design includes all players in an integrated development process, from the design team (building owners, architects, engineers and consultants), the construction team (materials manufacturers, contractors and waste haulers), maintenance staff, and building occupants. The green building process results in a high-quality product that maximizes the owner's return on investment.

Why Design Green?

The building sector has a tremendous impact on the environment. In 2002, there were more than 76 million residential buildings and nearly five million commercial buildings in the United States. According to the U.S. Department of Energy (DOE), buildings in the United States consume more than 30% of our total energy and 60% of our electricity annually. Five billion gallons of potable water are used to flush toilets daily. A typical North American commercial construction project generates up to 2.5 pounds of solid waste per square foot of floor space. Real estate development appropriates land from other uses such as natural habitats and agriculture.

Buildings are a major source of the pollutants that cause urban air quality problems and contribute to climate change. According to the DOE, buildings account for 49% of sulfur dioxide emissions, 25% of nitrous oxide emissions, and 10% of particulate emissions – all of which damage urban air quality. Buildings produce 35% of the country's carbon dioxide emissions. These are just a few examples of the environmental impacts associated with the construction and operation of buildings.

By the year 2010, another 38 million buildings are expected to be built. Green building practices can substantially reduce the negative environmental impacts associated with these buildings and reverse the trend of unsustainable construction activities. But that is only part of the story. Green design also reduces operating costs, enhances building marketability, potentially increases occupant productivity, and helps create a sustainable community. For example, energy efficiency measures have reduced operating expenses of the Denver Dry Goods building by approximately $75,000 per year. Students in daylit schools in North Carolina consistently score higher on tests than students in schools using conventional lighting fixtures. Studies of workers in green buildings reported productivity gains of up to 16%, including reductions in absenteeism and improved work quality, based on "people-friendly" green design. Waste management costs were reduced by 56% and 48 tons of waste were recycled during construction of a grocery store in Spokane, Washington. Resource-efficient buildings have less impact on local infrastructure. Green design has environmental, economic, and social elements that benefit all stakeholders, including owners, occupants and the general public.

The Leadership in Energy and Environmental Design™ (LEED™) Green Building Rating System

History of LEED

Following the formation of the U.S. Green Building Council (USGBC) in 1993, the membership quickly realized that a priority for the sustainable building industry was to have a system to define and measure that which should qualify as a "green building." The USGBC began to research existing green building metrics and rating systems. Less than a year after formation, the membership followed up on the initial findings with the establishment of a committee to focus solely on this topic. The diverse initial composition of the committee included architects, realtors, a building owner, a lawyer, an environmentalist and industry representatives. This cross-section of people and professions added a richness and depth both to the process and to the ultimate product.

As part of their investigations, the committee reviewed existing green building rating systems such as BREEAM (Building Research Establishment Environmental Assessment Method) and BEPAC (Building Environment Performance Assessment Criteria), both from the United Kingdom. Three options were assessed: (1) Accept the BREEAM rating system and use it in the U.S. market; (2) tailor the BREEAM system to the U.S. market; or (3) create a separate U.S. green building rating system. The third option was selected because the committee felt a strong need for a green building measurement tool specific to the U.S. building market.

By the fall of 1994, the committee had prepared a draft green building rating system for review. After additional development, the LEED Version 1.0 Pilot Program was launched at the USGBC Membership Summit in August 1998. Twelve projects completed the application process and were recognized as LEED Certified Pilot Projects in March 2000.

Based on the success of LEED Version 1.0, an expert review session was held at Pocantico, New York in 1999 to shape LEED Version 2.0. After extensive modifications, the revised rating system was presented to the USGBC membership for a review and comment period, and a final approval vote. LEED Version 2.0 was released in March 2000. Grants from the U.S. Department of Energy (Office of Building Technologies, State and Community Programs) provided start-up funding for the pilot program, the development of the LEED Reference Guides, and the initial LEED Training Workshop. Sustainable design and technology information can be found on the U.S. DOE Web pages, including www.eere.energy.gov/buildings and www.sustainable.doe.gov.

The LEED Committee has since divided into the Steering Committee, several product committees and credit category-specific Technical Advisory Groups (TAGs). The TAGs are subcommittees that consist of industry experts who assist in developing credit interpretations and technical improvements to the system.

The keys to making this process and product work have been a strong common goal to produce a consensus-based rating system, a continually positive approach throughout difficult decision-making discussions, and a diversity of committed team players. Since the collective knowledge regarding green buildings continues to increase, LEED will continue to be a dynamic and ever-changing system needing the input, scrutiny, and involvement of diverse stakeholders.

The LEED flagship product is now called LEED for New Construction and Major Renovations (LEED-NC). This distinction is necessary as rating system products are being developed and launched for other market sectors, such as existing buildings, commercial interiors, and core and shell (speculative development).

LEED-NC Version 2.1

Consistent with USGBC policy for the continuous improvement of LEED, Version 2.1 is an administrative update of LEED-NC Version 2.0. Its purpose is to address concerns raised by USGBC members and other LEED users by providing technical clarifications and streamlining the documentation requirements for LEED certification.

These improvements are expected to simplify the documentation process for project teams and to reduce the costs of documenting LEED credits while retaining the stringency and integrity of the LEED Version 2.0 standards. An approval vote by USGBC membership was not required for Version 2.1 because performance levels have not been altered. In a few instances, methodologies have changed in order that they may be more straightforward or more comprehensive. The new LEED Letter Template is a central component of the Version 2.1 improvements (see below for more information).

Features of the System

The LEED Green Building Rating System is a voluntary, consensus-based, market-driven building rating system that is based on accepted energy and environmental principles and strikes a balance between established practices and emerging concepts. It evaluates environmental performance from a whole-building perspective, providing a definitive standard for what constitutes a "green building." The development of LEED was instigated by the USGBC Membership, representing all segments of the building industry and has been open to public scrutiny.

LEED for New Construction and Major Renovations (LEED-NC) is a measurement system designed for rating commercial and institutional buildings, with a focus on office buildings. LEED-NC has also been applied to many other building types, including high-rise residential buildings.

The rating system is organized into five environmental categories: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources, and Indoor Environmental Quality. An additional category, Innovation & Design Process, addresses sustainable building expertise as well as design measures not covered under the five environmental categories.

LEED is a performance-oriented system where points are earned for satisfying performance criteria. Different levels of green building certification are awarded based on the total points earned. The system is designed to be comprehensive in scope, yet simple in operation.

LEED Reference Guide

The Reference Guide is the user's manual for LEED. The Guide is intended to assist project teams in understanding LEED criteria. The Guide includes examples of strategies, case studies of buildings that have implemented these strategies successfully, and links to other resources. The Guide does not provide an exhaustive list of strategies for meeting the criteria, nor does it provide all of the information that design teams need to determine the applicability of a credit to their project.

Prerequisite and Credit Format

Each prerequisite and credit chapter in the Reference Guide is organized in a standardized format for simplicity and quick reference. The first section summarizes key points regarding the measure's intent and requirements. The subsequent sections provide supportive information to help interpret, implement, and document performance. The standard chapter sections are described in the following paragraphs.

Intent identifies the main goal of the prerequisite or credit.

Requirements & Submittals specify the criteria to satisfy the prerequisite or credit, the number of points available, and the documentation required for the LEED application. The prerequisites *must* be achieved. Each credit is optional, but contributes to the project's point total. Some credits are divided into two or more subcredits with independent or cumulative points.

Summary of Referenced Standards cites the technical standard(s) that LEED uses for performance evaluation. A brief summary of the standard is also provided in this section. Users are strongly encouraged to review the standard and not rely solely on the summary, unless otherwise noted.

Green Building Concerns related to the prerequisite or credit are explained in this section and divided into environmental, economic and community issues.

Design Approach presents ideas and recommendations for the project design and specifications.

Synergies & Trade-Offs identify areas of significant interaction with other LEED credits. Users are advised to carefully evaluate the benefits and disadvantages of pursing these related credits.

Calculations are sample formulas or computations to assist with the determination of compliance for a particular prerequisite or credit. Some calculations have been programmed into the LEED Version 2.0 Calculator and the LEED Version 2.1 Letter Template, both Microsoft Excel spreadsheets. These files are made available to registered projects in order to facilitate the application process.

Resources such as Web sites and print media are provided for further research and to assist justification, design and calculations efforts.

A **Case Study** is provided to show how a project has served the goals stated for the prerequisite or credit. The selected project exemplifies one method to achieve the intent of the measure, although there may be other methods.

LEED Certification Process

Eligibility

All commercial buildings as defined by standard building codes are eligible for certification as a LEED building. Commercial occupancies include (but are not limited to) offices, retail and service establishments, institutional buildings (libraries, schools, museums, churches, etc.), and hotels and residential buildings of four or more habitable stories.

Hotels and residential buildings of three habitable stories or less are addressed by the LEED Version 2.0 Application Guide for Lodging, available for download from the USGBC Web site. If the application of LEED for a unique building type is questionable, USGBC encourages the project team to tally a potential point total using the checklist in the LEED Rating System.

Registration

Project teams interested in obtaining LEED certification for their project must first register through the USGBC Web site. The Web site includes information

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Project teams interested in obtaining LEED certification for their project must first register through the USGBC Web site. The Web site includes information on registration costs for USGBC member as well as non-members. Registration during the early phases of project design will ensure maximum potential for achieving certification.

Registration is an important step that establishes contact with the USGBC and provides access to essential information, software tools, and communications. Upon registration, project contacts receive access to resources that explain and facilitate the LEED application process.

Documentation

Once a project is registered, the project design team begins to prepare documentation to satisfy the prerequisite and credit submittal requirements. This documentation will become the bulk of the project's LEED Version 2.0 application, or the proof behind performance declarations in the Version 2.1 application. It is helpful to have a LEED Accredited Professional as the project contact and team member responsible for coordinating the certification process.

Projects may submit using either version's documentation path (it is simplest to create a LEED application pursuant to one method of documentation), or a mixed submittal of the two (per credit). Mixed submittals are recommended for projects that registered under Version 2.0, but would like to transition to Version 2.1 in order to take advantage of the streamlined Letter Template submittal path. Documentation should be gathered throughout the design and construction phases. Use the software tools and templates provided for Version 2.0 and/or Version 2.1 as appropriate.

LEED Version 2.0 submittal resources consist of the Welcome Packet, Calculator (spreadsheets) and Application Template (cover sheets for each credit). The Welcome Packet provides examples of the types of documents that LEED often requires to supplement the calculation tables and cover sheets in the application. The inclusion of extraneous documentation (anything that is not listed as a credit submittal requirement) is discouraged, as this slows the review process. Full building commissioning reports, for example, are not necessary because only the commissioning plan is required.

The LEED Version 2.1 Letter Template is a dynamic tracking and documentation tool that is used by project teams to track progress and prepare a LEED application. For each credit, the Letter Template prompts LEED practitioners for summary data and signed declarations of performance, indicates when documentation requirements have been adequately fulfilled for submittal, serves as a letter template for printing on letterhead, and summarizes progress. Some of the Template pages include spreadsheets for calculations, while others are simple declarations signed by an appropriate team member. The Version 2.0 Calculator spreadsheets are often useful when the Reference Guide calls for credit calculations but no corresponding spreadsheet exists in the Version 2.1 Letter Template.

During a Version 2.1 application review, the project team will be expected to provide supporting documents for a portion of the prerequisites and credits. Supporting documents are those which provide specific proof of meeting the required performance level – such as calculations, specifications, drawings, cutsheets, manufacturer's literature, and other source documents that were used as a basis to justify declarations of performance in the Letter Template. Many of these items are implicitly described in the Reference Guide's instructions.

Credit Interpretations

In some cases, project teams may encounter difficulties applying a LEED prerequisite or credit to a specific project. Questions sometimes arise when the Reference

Guide does not sufficiently address a specific issue or there is a special conflict that requires resolution. USGBC has established a uniform review process for registered project inquiries, called credit interpretation requests (CIRs), to ensure that rulings are consistent and available to other projects. If a question arises, project teams should:

1. Consult the Reference Guide for a detailed description of the credit intent, requirements and calculations.
2. Review the intent of the credit or prerequisite in question to self-evaluate whether the project meets this intent.
3. Review the Credit Interpretation (CIR) Web page for previously logged CIRs on relevant credits. All LEED registered project contacts have access to this page.
4. If a similar credit interpretation has not been logged, or does not answer the question sufficiently, submit a credit interpretation request using the online form. The inquiry should be succinct and based on information found in the Reference Guide, with emphasis on the intent of the prerequisite or credit.

Application

Consult the Web site for important details about the LEED application as well as the certification review process, schedule and fees. The applicant project must satisfactorily document achievement all of the prerequisites and a minimum number of points to attain the LEED ratings as listed below.

For more information, visit the LEED Web page on www.usgbc.org.

LEED Certification Levels

Certification Level	Points
Certified	26 to 32
Silver	33 to 38
Gold	39 to 51
Platinum	52 or more

Sustainable Sites

Development and construction processes are often destructive to local ecology. These activities also encroach on productive agricultural land areas and open space. Stormwater runoff from developed areas can impact water quality in receiving waters, hinder navigation and recreation, and disrupt aquatic life. Fortunately, steps can be taken to reduce impacts on previously undeveloped lands and to improve previously contaminated sites.

Selection of an appropriate project location can reduce the need for private automobile use and reduce urban sprawl. Locating developments on existing brownfield sites, in existing urban infill areas and on other non-greenfield locations may have economic benefits. For example, the infrastructure to service the development may already be in place.

When considering site alternatives, it is important to consider environmental criteria throughout the site selection process.

The major ecological features of the site should be identified, including the site geology, hydrology, vegetation, wildlife and prior site history. Communication with project stakeholders, including building occupants, the general public and site neighbors can be facilitated through public meetings, design charrettes and organized comment processes.

It is also important to minimize project impacts on surrounding areas after construction is complete and the building is occupied. By addressing heat island effects and reducing light pollution on the site, the site can become integrated into its surroundings and serve as a considerate and beneficial neighbor for the lifetime of the building.

Overview of LEED™ Prerequisites and Credits

SS Prerequisite 1
Erosion & Sedimentation Control

SS Credit 1
Site Selection

SS Credit 2
Urban Redevelopment

SS Credit 3
Brownfield Redevelopment

SS Credit 4
Alternative Transportation

SS Credit 5
Reduced Site Disturbance

SS Credit 6
Stormwater Management

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

SS Credit 8
Light Pollution Reduction

There are 14 points available in the Sustainable Sites category.

Erosion & Sedimentation Control

Required

Intent

Control erosion to reduce negative impacts on water and air quality.

Requirements

Design a sediment and erosion control plan, specific to the site, that conforms to United States Environmental Protection Agency (EPA) Document No. EPA 832/R-92-005 (September 1992), Storm Water Management for Construction Activities, Chapter 3, OR local erosion and sedimentation control standards and codes, whichever is more stringent. The plan shall meet the following objectives:

- Prevent loss of soil during construction by stormwater runoff and/or wind erosion, including protecting topsoil by stockpiling for reuse.
- Prevent sedimentation of storm sewer or receiving streams.
- Prevent polluting the air with dust and particulate matter.

Submittals

- ❑ Provide the LEED Letter Template, signed by the civil engineer or responsible party, declaring whether the project follows local erosion and sedimentation control standards or the referenced EPA standard. Provide a brief list of the measures implemented. If local standards and codes are followed, describe how they meet or exceed the referenced EPA standard.

Summary of Referenced Standard

Storm Water Management for Construction Activities (USEPA Document No. EPA 832R92005), **Chapter 3**

U.S. Environmental Protection Agency Office of Water, www.epa.gov/OW

Internet download link for Chapter 3 (72 pages): www.epa.gov/npdes/pubs/chap03_conguide.pdf. Download site for all sections: http://yosemite.epa.gov/water/owrccatalog.nsf, search by title index.

Hardcopy or microfiche (entire document, 292 pages): National Technical Information Service (order # PB92-235951), www.ntis.gov, (800) 553-6847

This standard describes two types of measures that can be used to control sedimentation and erosion. Stabilization measures include temporary seeding, permanent seeding and mulching. All of these measures are intended to stabilize the soil to prevent erosion. Structural control measures are implemented to retain sediment after erosion has occurred. Structural control measures include earth dikes, silt fencing, sediment traps and sediment basins. The application of these measures depends on the conditions at the specific site. If local provisions are substantially similar, they can be substituted for this standard if it is demonstrated that local provisions meet or exceed the EPA best management practices.

Credit Synergies

SS Credit 1
Site Selection

SS Credit 2
Urban Redevelopment

SS Credit 3
Brownfield Redevelopment

SS Credit 4
Alternative Transportation

SS Credit 5
Reduced Site Disturbance

SS Credit 6
Stormwater Management

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

WE Credit 1
Water Efficient Landscaping

Green Building Concerns

Site clearing and earth moving during construction often results in significant erosion problems because adequate environmental protection strategies are not employed. Erosion results from precipitation and wind processes, leading to degradation of property and sedimentation of local water bodies. This affects water quality as well as navigation, fishing and recreation activities. Fortunately, measures can be implemented to minimize site erosion during construction and to avoid erosion once the buildings are occupied.

Environmental Issues

Contaminated water that flows into receiving waters disrupts stream and estuary habitats. Contributors to erosion problems include destruction of vegetation that previously slowed runoff and reconfiguration of natural site grading. Controlling stormwater runoff reduces erosion and contamination of receiving waters.

Economic Issues

Erosion and sedimentation control does not necessarily add cost to a project. Reduction of sedimentation and erosion through landscaping and other measures can in fact reduce the size, complexity and cost of stormwater management measures. While there are additional costs associated with identifying soil conditions at the site, the knowledge gained can help avoid problems over the building lifetime. For instance, soil erosion issues associated with unstable foundations and potential loss of structural integrity can be avoided if soil conditions are documented in advance and used in the building design.

Landscaping activities to prevent soil erosion include augmentation of poor soil and inclusion of specialized plantings in the landscape design to retain soil in place. Excessive landscaping may require maintenance over time, resulting in additional operation costs. Use of native plants reduces both watering and maintenance requirements.

Community Issues

Communities benefit from reduced erosion and sedimentation control through improved water quality in local streams, rivers and lakes. These water bodies are valuable to communities for sustenance, navigation and recreation.

Design Approach

Strategies

As a general approach to achieve this credit: (1) identify the soil composition on the project site, (2) uncover potential site problems, and (3) develop mitigation strategies. Protect erosion-prone areas from construction activities, and implement a soil stabilization plan in susceptible areas. The plan should include stringent erosion control requirements in construction drawings and specifications to control erosion and sedimentation during construction activities. In addition to construction controls, design the project site to minimize erosion and sedimentation processes over the lifetime of the building.

Erosion and sedimentation control measures should be addressed in an Erosion Control Plan. This plan often covers stormwater management in addition to erosion control because these concepts are intimately linked. The document should include the following information:

1. Statement of erosion control and stormwater control objectives

2. Comparison of post-development stormwater runoff conditions with predevelopment conditions

3. Description of all temporary and permanent erosion control and stormwater control measures implemented on the project site

4. Description of the type and frequency of maintenance activities required for the chosen erosion control methods

Consider augmenting the project design team with an expert in sustainable landscape architecture and land planning. The expert should be familiar with local and state legal requirements for erosion control, as well as strategies and technologies to minimize erosion and sedimentation.

Technologies

Table 1 describes technologies for controlling erosion and sedimentation as recommended by the referenced standard.

Synergies and Trade-Offs

Measures for erosion and sedimentation control are dependent on site location and site design. These measures are often integrated with stormwater management plans because stormwater is a large contributor to erosion problems. Landscaping strategies have a significant effect on erosion. The most suitable areas on a site for a building in terms of passive solar gains or environmental quality benefits may be inappropriate due to problematic soil conditions. Conversely, landscaping that is planted for soil erosion mitigation might affect passive solar gains or wind currents used for natural ventilation.

Definitions

Erosion is a combination of processes in which materials of the earth's surface are loosened, dissolved or worn away, and transported from one place to another by natural agents.

Sedimentation is the addition of soils to water bodies by natural and human-related activities. Sedimentation decreases water quality and accelerates the aging process of lakes, rivers and streams.

Table 1: Technologies for Controlling Erosion & Sedimentation

Control Technology	Description
Stabilization	
Temporary Seeding	Plant fast-growing grasses to temporarily stabilize soils.
Permanent Seeding	Plant grass, trees, and shrubs to permanently stabilize soil.
Mulching	Place hay, grass, woodchips, straw, or gravel on the soil surface to cover and hold soils.
Structural Control	
Earth Dike	Construct a mound of stabilized soil to divert surface runoff volumes from disturbed areas or into sediment basins or sediment traps.
Silt Fence	Construct posts with a filter fabric media to remove sediment from stormwater volumes flowing through the fence.
Sediment Trap	Excavate a pond area or construct earthen embankments to allow for settling of sediment from stormwater volumes.
Sediment Basin	Construct a pond with a controlled water release structure to allow for settling of sediment from stormwater volumes.

Case Study

Donald Bren School of Environmental Science and Management
Santa Barbara, California

Courtesy of Zimmer Gunsul Frasca Partnership

Owner
University of California at Santa Barbara

The University of California at Santa Barbara's Donald Bren School of Environmental Science and Management is a LEED™ Version 1.0 Platinum Pilot Project. The Bren School houses campus facilities including research and teaching laboratories, and offices. An erosion control plan was instituted for the project to prevent contaminated runoff from leaving the site boundary. Construction stormwater controls included temporary silt fencing and straw-bale catch basins. Project specifications and plans included requirements to preserve topsoil and limit site disturbance. During construction, grading activities were scheduled in accordance with weather conditions. Construction materials stored on-site were protected from the elements to prevent contamination of stormwater volumes, and construction workers were informed of the stormwater control program. During building occupancy, stormwater system inspections are scheduled to occur annually, before and after storm events, and weekly to ensure proper operation of stormwater controls.

Site Selection

SS	WE	EA	MR	EQ	ID
Credit 1					

1 point

Intent

Avoid development of inappropriate sites and reduce the environmental impact from the location of a building on a site.

Requirements

Do not develop buildings, roads or parking areas on portions of sites that meet any one of the following criteria:

- Prime farmland as defined by the United States Department of Agriculture in the United States Code of Federal Regulations, Title 7, Volume 6, Parts 400 to 699, Section 657.5 (citation 7CFR657.5).
- Land whose elevation is lower than 5 feet above the elevation of the 100-year flood as defined by the Federal Emergency Management Agency (FEMA).
- Land which is specifically identified as habitat for any species on Federal or State threatened or endangered lists.
- Within 100 feet of any water including wetlands as defined by United States Code of Federal Regulations 40 CFR, Parts 230-233 and Part 22, and isolated wetlands or areas of special concern identified by state or local rule, OR greater than distances given in state or local regulations as defined by local or state rule or law, whichever is more stringent.
- Land which prior to acquisition for the project was public parkland, unless land of equal or greater value as parkland is accepted in trade by the public landowner (Park Authority projects are exempt).

Submittals

- ❑ Provide the LEED Letter Template, signed by the civil engineer or responsible party, declaring that the project site meets the credit requirements.

Summary of Referenced Standards

U.S. Department of Agriculture Definition of Prime Agricultural Land as stated in United States Code of Federal Regulations Title 7, Volume 6, Parts 400 to 699, Section 657.5 (citation 7CFR657.5) www.access.gpo.gov/nara/ (go to "browse your choice of CFR titles and/or volumes")

This standard states: "Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is also available for these uses (the land could be cropland, pastureland, rangeland, forest land, or other land, but not urban built-up land or water). It has the soil quality, growing season, and moisture supply needed to economically produce sustained high yields of crops when treated and managed, including water management, according to acceptable farming methods. In general, prime farmlands have an adequate and dependable water supply from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, acceptable salt and sodium content, and few or no rocks. They are permeable to water and air. Prime farmlands are not excessively erodible or saturated with water for a long period of time, and they either do not flood frequently or are protected from flooding. Examples of soils that qualify as prime farmland are Palouse silt loam, 0 to 7 percent slopes; Brookston silty clay loam, drained; and Tama silty clay loam, 0 to 5 percent slopes."

Federal Emergency Management Agency (FEMA) 100-Year Flood Definition

Federal Emergency Management Agency, www.fema.gov, (202) 646-4600

This referenced standard addresses flood elevations. FEMA defines a 100-Year Flood as the flood elevation that has a 1% chance of being reached or exceeded each year. It is *not* the most significant flood in a 100-year period. Instead, 100-year floods can occur many times within a 100-year period. See the FEMA Web site for comprehensive information on floods and other natural disasters such as wildfires and hurricanes.

Endangered Species Lists

U.S. Fish and Wildlife Service's List of Threatened and Endangered Species, endangered.fws.gov

This referenced standard addresses threatened and endangered wildlife and plants. The Service also maintains a list of plants and animals native to the United States that are candidates for possible addition to the federal list.

National Marine Fisheries Service's List of Endangered Marine Species, www.nmfs.noaa.gov/endangered.htm

Consult state agencies for state-specific lists of endangered or threatened wildlife and plant species.

Definition of Wetlands in the United States Code of Federal Regulations, 40 CFR, Parts 230-233, and Part 22

www.access.gpo.gov/nara/cfr/index.html, (888) 293-6498

This referenced standard addresses wetlands and discharges of dredged or filled material into waters regulated by states. The definition of wetland areas pertaining to this credit, found in Part 230, is as follows:

"Wetlands consist of areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."

SS	WE	EA	MR	EQ	ID

Credit 1

Green Building Concerns

As non-urban development increases, the importance of prudent site selection increases as well. Prevention of habitat encroachment is an essential element of sustainable site selection. The best strategy for selecting a building site is to choose a previously developed site. Since these sites have already been disturbed, damage to the environment is limited and sensitive land areas can be preserved.

The site surrounding a building defines the character of the building and provides the first impression for occupants and visitors to the building. Creative and careful site designs can integrate the natural surroundings with the building(s), providing a strong connection between the built and natural environments and minimizing adverse impacts on the non-built portions of the site.

Environmental Issues

Habitat preservation is the most effective means to meet the requirements of the Endangered Species Act and to minimize developmental impacts on indigenous wildlife. Not building on inappropriate sites preserves these areas for wildlife, recreation and ecological balance. Building on inappropriate sites such as floodplains can be detrimental to ecosystems.

Economic Issues

Site selection can play an important role in the way in which the public responds to, and is involved with, the proposed development. Channeling development away from sensitive ecological areas in favor of previously disturbed sites can encourage public support for a project and speed public review periods, thus minimizing or preventing obstacles traditionally encountered during project scoping. Economically, this can also save on mitigation costs that a developer would incur if the proposed development were approved within a sensitive area.

Appropriate site selection can reduce the risk of property damage due to natural events such as landslides, floods, sinkholes and soil erosion. Higher first costs may be encountered due to site survey and selection activities. Increased property values can offset these costs in the future.

Proper site selection can also avoid potential loss of property due to potential litigation resulting from harm to endangered species.

Community Issues

Prudent site selection can enhance property values within the community when development is integrated into the surrounding ecosystem. For example, by clustering buildings in a neighborhood, green space can be set aside for parks and community gathering spaces. Thoughtful site selection and planning can also allow the developer to integrate unique neighborhood characteristics during project design.

Design Approach

Strategies

Avoid developing sites that exhibit any of the characteristics listed in the restricted criteria. Consider the proposed use of the building, and set a preference for previously developed sites that complement the use, thereby reducing associated parking needs and vehicular miles traveled. The site selection process might include landscape architects, ecologists, environmental engineers and civil engineers, as well as local professionals who can provide site-specific expertise.

Have a government official, ecologist or other qualified professional perform a site survey to inventory the important environmental characteristics, including wetlands, sloped areas, unique habitat areas and forested areas. Zoning requirements of the local municipality and the community master plan should be integrated to the

Credit Synergies

SS Prerequisite 1
Erosion & Sedimentation Control

SS Credit 2
Urban Redevelopment

SS Credit 3
Brownfield Redevelopment

SS Credit 4
Alternative Transportation

SS Credit 5
Reduced Site Disturbance

SS Credit 6
Stormwater Management

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

SS Credit 8
Light Pollution Reduction

MR Credit 1
Building Reuse

EQ Credit 8
Daylight & Views

greatest extent possible. Community coordination and consideration of public comments can help pre-empt negative community reaction. Where feasible, integrate neighboring activities to create a development with shared amenities and spaces.

When designing the building, consider a smaller footprint, and set aside large contiguous areas for natural space on the project site. Build in dense blocks to limit the development footprint and site disturbance to the smallest area possible. Incorporate site features into the design such as natural features that already exist on the site, natural shelter from trees or terrain, natural areas for outdoor activities, and water features for thermal, acoustic and aesthetic benefit.

Synergies and Trade-Offs

Site selection is the basis of site design and affects all aspects of the site, including transportation amenities, natural areas, stormwater management, amount of impervious surfaces, and site lighting requirements. Water supply and management issues, especially landscape irrigation and stormwater reuse, are dependent on project location. Opportunities to increase the building's energy performance can be realized by locating the project in areas where natural ventilation and solar gains can be managed and based on the angles and location of the sun. The local climate and marketplace should influence choices of materials. Natural ventilation and daylight can benefit indoor environmental quality.

Resources

Web Sites

ESRI

www.esri.com/hazards/makemap.html

This software company creates tools for GIS mapping. Its Web site includes an option to make a map of all of the flood areas within a user-defined location.

Natural Resources Defense Council

www.nrdc.org, (212) 727-2700

NRDC uses law, science, and a large membership base for protection of wildlife and wild places to ensure a safe and healthy environment.

Print Media

Constructed Wetlands in the Sustainable Landscape by Craig Campbell and Michael Ogden, John Wiley & Sons, 1999.

Holding Our Ground: Protecting America's Farms and Farmland by Tom Daniels and Deborah Bowers, Island Press, 1997.

Saved By Development: Preserving Environmental Areas, Farmland by Rick Pruetz, Arje Press, 1997.

Wetland Indicators: A Guide to Wetland Identification, Delineation, Classification, and Mapping by Ralph W. Tiner, Lewis Publishers, 1999.

Definitions

A **Community** is an interacting population of individuals living in a specific area.

The **Development Footprint** is the area on the project site that has been impacted by any development activity. Hardscape, access roads, parking lots, non-building facilities and building structure are all included in the development footprint.

An **Ecosystem** is a basic unit of nature that includes a community of organisms and their nonliving environment linked by biological, chemical, and physical process.

An **Endangered Species** is an animal or plant species that is in danger of becoming extinct throughout all or a significant portion of its range due to harmful human activities or environmental factors.

A **Threatened Species** is an animal or plant species that is likely to become endangered within the foreseeable future.

Wetland Vegetation consists of plants that require saturated soils to survive as well as certain tree and other plant species that can tolerate prolonged wet soil conditions.

Development Density

SS	WE	EA	MR	EQ	ID
Credit 2					

1 point

Intent

Channel development to urban areas with existing infrastructure, protect greenfields and preserve habitat and natural resources.

Requirements

Increase localized density to conform to existing or desired density goals by utilizing sites that are located within an existing minimum development density of 60,000 square feet per acre (two story downtown development).

Submittals

- ❑ Provide the LEED Letter Template, signed by the civil engineer, architect or other responsible party, declaring that the project has achieved the required development densities. Provide density for the project and for the surrounding area.
- ❑ Provide an area plan with the project location highlighted.

Summary of Referenced Standard

There is no standard referenced for this credit.

Credit Synergies

SS Prerequisite 1
Erosion & Sedimentation Control

SS Credit 1
Site Selection

SS Credit 3
Brownfield Redevelopment

SS Credit 4
Alternative Transportation

SS Credit 5
Reduced Site Disturbance

SS Credit 6
Stormwater Management

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

MR Prerequisite 1
Storage & Collection of Recyclables

MR Credit 1
Building Reuse

MR Credit 2
Construction Waste Management

MR Credit 3
Resource Reuse

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 8
Daylight & Views

Green Building Concerns

The development of open space away from urban cores and other existing development may reduce a property's first cost, but this development paradigm has far-reaching negative consequences for the environment and the community. Building occupants become increasingly dependent on private automobiles for commuting. As travel distances increase, this results in more air and water pollution. Prime agricultural land is lost and previously developed urban sites fall into disuse and decay. Utility, transportation and community support infrastructure must also be developed to support the people who utilize new buildings. These infrastructure requirements increase the development's impact far beyond the initial project scope. In contrast, urban redevelopment is an effective strategy to curb suburban sprawl, tap into existing infrastructure and conserve rapidly disappearing greenfield space.

Environmental Issues

By maintaining density in cities, agricultural land and greenfield areas are preserved for future generations. Mass transportation in urban areas can be an attractive alternative mode of transportation, reducing impacts associated with automobile use. Building in urban areas reduces the number of vehicle miles traveled and, thus, reduces pollution caused by automobiles. The use of existing utility lines, roadways, parking, landscaping components and other services eliminates the environmental impacts of constructing these features for non-urban developments.

Economic Issues

A significant economic benefit of infill development is the reduction or elimination of new infrastructure, including roads, utility services and other amenities already in place. If mass transit serves the urban site, significant cost reductions are possible by downsizing the project parking capacity. Urban infill development sometimes requires significant additional costs when compared with suburban development due to site constraints, contaminated soils and other issues. Municipal and county incentives for urban infill projects may also be available.

Community Issues

Urban sprawl affects quality of life because commuters must spend increasing amounts of time in their automobiles. In addition, families often need more vehicles to accommodate family needs, resulting in a higher cost of living and less free time. The redevelopment of urban areas helps restore, invigorate and sustain established urban living patterns, creating a more stable and interactive community.

Design Approach

Strategies

The general approach for achieving this credit is to give preference to sites within an existing urban fabric. Work with local jurisdictions and follow the urban development plan to meet or exceed density goals. Consider synergies with neighbors and choose sites based on infrastructure, transportation and quality-of-life considerations. Sites with redevelopment plans that will achieve the required development density by the completion of the project should not be excluded from consideration. This credit can be achieved by choosing to develop a site where a community revitalization is occurring provided the required development density is achieved by the project's completion.

Synergies and Trade-Offs

Urban redevelopment affects all areas of site design including site selection, especially transportation planning, the overall building footprint and stormwater management. Urban sites often involve the rehabilitation of an existing building, with a reduction of construction waste and new material use. However, these sites may also have limited space available for construction waste management activities and occupant recycling programs. Urban sites may have negative IEQ aspects such as contaminated soils, undesirable air quality or limited daylighting applications.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. To determine the development density of a project, both the project density and the densities of surrounding developments must be calculated. The extent of neighboring areas to include in density calculations varies depending upon the size of the project. Larger projects are required to consider a greater number of neighboring properties than smaller projects. The density calculation process is described in the following steps:

1. Determine the total area of the project site and the total square footage of the building. For projects that are part of a larger property (such as a campus), define the project area as that which is defined in the project's scope. The project area must be defined consistently throughout LEED documentation.

2. Calculate the development density for the project by dividing the total square footage of the building by the total site area in acres. This development density must be equal to or greater than 60,000 square feet per acre (see **Equation 1**).

3. Convert the total site area from acres to square feet and calculate the square root of this number. Then multiply the square root by three to determine the appropriate density radius. (Note: the square root function is used to normalize the calculation by removing effects of site shape.) (see **Equation 2**).

4. Overlay the density radius on a map that includes the project site and surrounding areas, originating from the center of the site. This is the density boundary. Include a scale on the map.

5. For each property within the density boundary and for those properties that intersect the density boundary, create a table with the building square footage and site area of each property. Include all properties in the density calculations except for undeveloped public areas such as parks and water bodies. Do not include public roads and right-of-way areas. Information on neighboring properties can be obtained from your city or county zoning department.

6. Add all the square footage values and site areas. Divide the total square footage by the total site area to obtain the average property density within the density boundary. The average property density of the properties within the density boundary must be equal to or greater than 60,000 square feet per acre.

The following example illustrates the property density calculations: A 30,000-square-foot building is located on a 0.44-

Equation 1:

$$\text{Development Density}\left[\frac{\text{SF}}{\text{acre}}\right] = \frac{\text{Building Square Footage [SF]}}{\text{Property Area [acres]}}$$

Equation 2:

$$\text{Density Radius [LF]} = 3 \times \sqrt{\text{Property Area [acres]} \times 43{,}560\left[\frac{\text{SF}}{\text{acre}}\right]}$$

acre urban site and the calculations are used to determine the building density. The building density is above the minimum density of 60,000 square feet per acre required by the credit (see **Table 1**).

Next, the density radius is calculated. A density radius of 415 feet is calculated (see **Table 2**).

The density radius is applied to an area plan of the project site and surrounding area. The plan identifies all properties that are within or are intersected by the density radius. The plan includes a scale and a north indicator.

Table 3 below summarizes the information about the properties identified on the map. The building space and site area are listed for each property. These values are summed and the average density is calculated by dividing the total building space by the total site area.

For this example, the average building density of the surrounding area is greater than 60,000 square feet per acre, and, thus, the example qualifies for one point under this credit.

Resources

Web Sites

International Union for the Scientific Study of Population

www.iussp.org

IUSSP promotes scientific studies of demography and population-related issues.

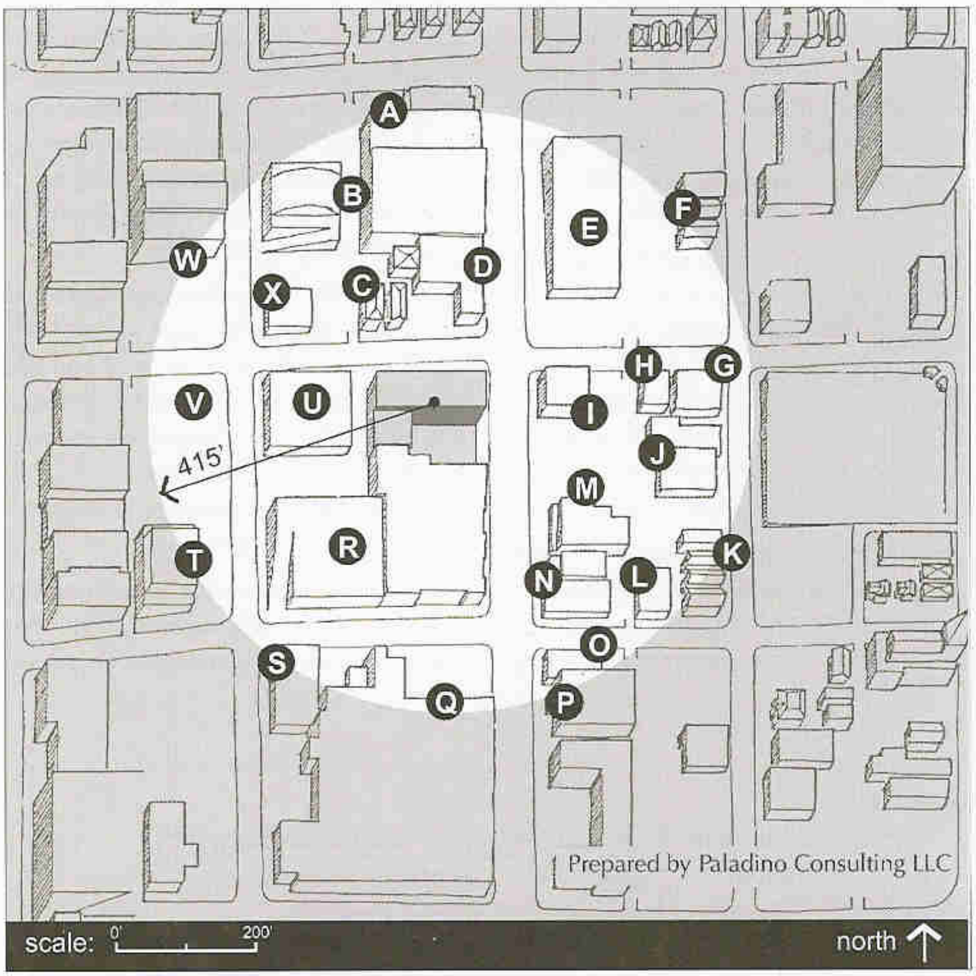


Figure 1: An Illustration of a Sample Area Plan

Table 1: Property Density Calculations

Project Buildings	Building Space [SF]	Site Area [acres]
Project	30,000	0.44
Density [SF/acre]		**68,182**

Table 2: Density Radius Calculation

Density Radius Calculation	
Site Area [acres]	0.44
Density Radius [LF]	415

Urban Land Institute

www.uli.org, (800) 321-5011

The Urban Land Institute is a nonprofit education and research institute that is supported by its members. Its mission is to provide responsible leadership in the use of land in order to enhance the total environment.

Print Media

Changing Places: Rebuilding Community in the Age of Sprawl by Richard Moe and Carter Wilkie, Henry Holt & Company, 1999.

Density by Design: New Directions in Residential Development, Steven Fader, Urban Land Institute, 2000.

Green Development: Integrating Ecology and Real Estate, by Alex Wilson et al., John Wiley & Sons, 1998.

Once There Were Greenfields: How Urban Sprawl Is Undermining America's Environment, Economy, and Social Fabric by F. Kaid Benfield et al., Natural Resources Defense Council, 1999.

Suburban Nation: The Rise of Sprawl and the Decline of the American Dream by Andres Duany et al., North Point Press, 2000.

SS | WE | EA | MR | EQ | ID

Credit 2

Table 3: Sample Area Properties

Buildings within Density Radius	Building Space [SF]	Site Area [acres]	Buildings within Density Radius	Building Space [SF]	Site Area [acres]
A	33,425	0.39	N	28,740	0.30
B	87,500	1.58	O	6,690	0.15
C	6,350	0.26	P	39,000	0.39
D	27,560	0.32	Q	348,820	2.54
E	66,440	1.17	R	91,250	1.85
F	14,420	1.36	S	22,425	0.27
G	12,560	0.20	T	33,650	0.51
H	6,240	0.14	U	42,400	0.52
I	14,330	0.22	V	-	0.76
J	29,570	0.41	W	19,200	0.64
K	17,890	0.31	X	6,125	0.26
L	9,700	0.31	Y	5,000	0.30
M	24,080	0.64	Z	4,300	0.24
			Total Building Space [SF]	997,665	
			Total Site Area [acres]		16.04
			AVERAGE DENSITY [SF/acres]		**62,199**

Definitions

A **Greenfield** is undeveloped land or land that has not been impacted by human activity.

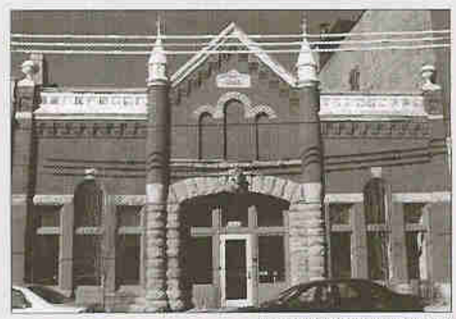
Property Area is the legal property boundary of a project and includes all areas of the site including constructed areas and non-constructed areas.

Site Area is defined the same as property area.

The **Square Footage** of a building is the total area in square feet of all rooms including corridors, elevators, stairwells and shaft spaces.

Case Study

KSBA Architects Office Building
Pittsburgh, Pennsylvania



Courtesy of KSBA Architects

Owner
KSBA Architects

The KSBA Architects office building is a LEED™ Certified Pilot Project located in the Lawrenceville section of Pittsburgh. The building is a rehabilitation project of a building originally constructed in 1888 and is part of a decade-long neighborhood revitalization program involving several local jurisdictions and community planning agencies. The two-story building is located in a neighborhood that includes a variety of businesses and industries, all within close proximity to downtown Pittsburgh. The location benefits the building occupants by providing a neighborhood that is conducive to walking, eating, entertainment, transportation and living.

Brownfield Redevelopment

SS	WE	EA	MR	EQ	ID
Credit 3					

1 point

Intent

Rehabilitate damaged sites where development is complicated by real or perceived environmental contamination, reducing pressure on undeveloped land.

Requirements

Develop on a site documented as contaminated (by means of an ASTM E1903-97 Phase II Environmental Site Assessment) OR on a site classified as a brownfield by a local, state or federal government agency. Effectively remediate site contamination.

Submittals

- ❑ Provide a copy of the pertinent sections of the ASTM E1903-97 Phase II Environmental Site Assessment documenting the site contamination OR provide a letter from a local, state or federal regulatory agency confirming that the site is classified as a brownfield by that agency.
- ❑ Provide the LEED Letter Template, signed by the civil engineer or responsible party, declaring the type of damage that existed on the site and describing the remediation performed.

Summary of Referenced Standards

ASTM E1903-97 Phase II Environmental Site Assessment

ASTM International, www.astm.org

This guide covers a framework for employing good commercial and customary practices in conducting a Phase II environmental site assessment of a parcel of commercial property. It covers the potential presence of a range of contaminants that are within the scope of CERCLA, as well as petroleum products.

EPA Brownfields Definition

EPA Sustainable Redevelopment of Brownfields Program, www.epa.gov/brownfields

With certain legal exclusions and additions, the term "brownfield site" means real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant or contaminant (source: Public Law 107-118, H.R. 2869 – "Small Business Liability Relief and Brownfields Revitalization Act"). See the Web site for additional information and resources.

SS	WE	EA	MR	EQ	ID

Credit 3

Credit Synergies

SS Prerequisite 1
Erosion & Sedimentation Control

SS Credit 1
Site Selection

SS Credit 2
Urban Redevelopment

SS Credit 4
Alternative Transportation

SS Credit 5
Reduced Site Disturbance

SS Credit 6
Stormwater Management

MR Credit 1
Building Reuse

MR Credit 2
Construction Waste Management

MR Credit 3
Resource Reuse

EQ Prerequisite 1
Minimum IAQ Performance

Green Building Concerns

Many potential building sites in urban locations have been abandoned due to real or perceived contamination from previous industrial or municipal activities. These sites can be remediated and redeveloped for reuse. Environmental and economic concerns are key issues when evaluating brownfield redevelopment. Costs incurred to remediate site contamination and land prices can be additive or can offset each other. Perception of the building site by the building owner and future building occupants must also be weighed. Building owners may be wary of cleanup requirements and the potential for liability associated with contaminants migrating off-site and impacting downstream neighbors. Building occupants may worry about health risks from breathing contaminated air or coming into contact with contaminated soil. These concerns must be investigated and resolved before making the final decision to redevelop a brownfield site.

Environmental Issues

Remediation efforts remove hazardous materials from brownfield sites' soil and groundwater. This reduces the exposure of humans and wildlife to health risks as a result of environmental pollution. Redevelopment of brownfield sites provides an alternate option to developing on greenfield sites. Preservation of greenfield sites for future generations decreases the overall environmental impact of development. Brownfields often have existing infrastructure improvements in place including utilities and roads, reducing the need for further environmental impacts due to construction of new infrastructure. In some instances, rather than remediate the contamination, it may be more sensible to leave contaminants in place, choosing instead to stabilize and isolate the contaminants from human exposure.

Economic Issues

Brownfields can offer an attractive location and are often inexpensive when compared to comparable uncontaminated properties. It is essential to weigh the value of the remediated property against cleanup costs to determine if the site is economically viable for redevelopment. Developers have been reluctant to redevelop brownfield sites in the past due to potential liability associated with taking responsibility for the cleanup of others' contamination. In recent years, the EPA and many state and local government agencies have begun to provide incentives for brownfield redevelopment by enacting laws that reduce the liability of developers who choose to remediate contaminated sites. Before embarking on a brownfield development effort, it is important to contact state and local regulators to determine the rules governing these sites and available financial assistance programs. It may also be helpful to contact the regional EPA's Office of Solid Waste and Emergency Response (OSWER), which may provide site characterization and remediation support.

Community Issues

Reclaiming contaminated sites can contribute to social and economic revitalization within neighborhoods by taking a local liability and turning it into an asset. Cleaning up contaminated properties can instill a new sense of pride in local residents, and it can also provide the incentive to improve nearby properties.

Design Approach

Strategies

Gain community support by highlighting the environmental, economic and community-related benefits of brownfield redevelopment. Negotiate with local municipalities and landowners for below-market purchase prices for brownfield real estate. Also, obtain tax incentives by meeting the locally applicable requirements of EPA brownfield tax credits. The advantages and disadvantages of brownfield redevelopment must be carefully considered during the site selection process.

Utilize remediation experts to develop a master plan for site remediation. Prioritize site remediation activities based on available funds and specific site considerations, and establish time frames for completing remediation activities. Test for toxicity and hazardous levels of pollution on the proposed site. To earn this credit, a site with existing hazardous substances present or potentially present must be selected, and remediation efforts must be performed to identify, contain and mitigate the hazard.

Clean the site using established technologies that have minimal disruption on the natural site features, both above ground and underground. Consider in-situ remediation schemes that treat contaminants in place instead of off-site. Once remediation is complete, continue to monitor the site for the identified contaminants to ensure that contamination problems do not return.

Technologies

Remediation efforts on brownfield sites are sometimes costly and time-intensive due to the potentially extensive effort required to characterize the contamination, evaluate cleanup options and perform cleanup activities. However, substantially lower property costs can offset remediation costs and time delays. The cost of remediation strategies varies by site and region. Several remediation strategies should be considered in order to identify the strategy with the greatest benefit and lowest cost to the property owner.

The appropriate technology for a specific site depends on the contaminants present, hydrogeologic conditions and other factors. Traditional remediation efforts for contaminated groundwater are termed "pump-and-treat." Pump-and-treat technologies involve pumping contaminated groundwater to the surface and treating the water using physical or chemical processes. Contaminated soils can be remediated in a variety of ways. Advanced technologies such as bioreactors and in-situ applications are sometimes more cost-effective than hauling large quantities of contaminated soil to an approved disposal facility. Innovative remediation efforts such as solar detoxification technologies are currently being developed and are expected to reduce remediation costs in the future. It is important to consider the environmental implications of all remediation strategies being investigated for your project to ensure the solution does not cause problems elsewhere.

Synergies and Trade-Offs

Brownfield redevelopment has an impact on all aspects of the site design and often works in concert with urban redevelopment efforts. Existing infrastructure can lower development costs and take advantage of connections with neighboring sites. Some brownfield sites include existing buildings that can be rehabilitated. However, it is always prudent to investigate potential contamination problems and their effect on indoor air quality and occupant health before selecting a remediation strategy.

Resources

Web Sites

Brownfields Non-Profits Network

www.brownfieldsnet.org,
(717) 230-9700

A collection of nonprofit organizations that provide information on brownfield redevelopment.

Brownfields Technology Support Center

www.brownfieldstsc.org

A public cooperative effort that provides technical support to federal, state and local officials on items related to site investigation and cleanup.

EPA Sustainable Redevelopment of Brownfields Program

www.epa.gov/brownfields

A comprehensive site on brownfields that includes projects, initiatives, tools, tax incentives and other resources to address brownfield remediation and redevelopment. For information by phone, contact your regional EPA office.

Print Media

ASTM Standard Practice E1739-95: Risk-Based Corrective Action Applied at Petroleum Release Sites, American Society for Testing & Materials, (610) 832-9585, www.astm.org

This document is a guide for risk-based corrective action (RBCA), a decision-making process that is specific to cleaning up petroleum releases at contaminated sites. It presents a tiered approach to site assessment and remedial actions. It also includes a comprehensive appendix with risk calculations and sample applications.

EPA OSWER Directive 9610.17: Use of Risk-Based Decision-Making in UST Correction Action Programs, U.S. Environmental Protection Agency, Office of Underground Storage Tanks, www.epa.gov/swerust1/directiv/od961017.htm, (703) 603-7149

This document addresses the application of risk-based decision-making techniques to properties where leaking underground storage tanks (USTs) have created risks to human health and the environment. Guidelines are included to assist in making decisions in a manner consistent with federal law, specifically CERCLA and RCRA programs. Risk-based decision-making is a method that utilizes risk and exposure assessment methodology to determine the extent and urgency of cleanup actions. The goal is to protect human health and the environment. This standard includes several examples of state programs that use risk-based decision-making in leaking UST legislation.

Definitions

Bioremediation involves the use of microorganisms and vegetation to remove contaminants from water and soils. Bioremediation is generally a form of in-situ remediation, and can be a viable alternative to landfilling or incineration.

CERCLA refers to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund. CERCLA addresses abandoned or historical waste sites and contamination. It was enacted in 1980 to create a tax on the chemical and petroleum industries and provided federal authority to respond to releases of hazardous substances.

Ex-Situ Remediation involves the removal of contaminated soil and groundwater. Treatment of the contaminated media occurs in another location, typically a treatment facility. A traditional method of ex-situ remediation is pump-and-treat technology that uses carbon filters and incineration. More advanced methods of ex-situ remediation include chemical treatment or biological reactors.

In-Situ Remediation involves treatment of contaminants in place using technologies such as injection wells or reactive trenches. These methods utilize the natural hydraulic gradient of groundwater and usually require only minimal disturbance of the site.

RCRA refers to the Resource Conservation and Recovery Act. RCRA focuses on active and future facilities. It was enacted in 1976 to give the EPA authority to control hazardous wastes from cradle to grave, including generation, transportation, treatment, storage and disposal. Some non-hazardous wastes are also covered under RCRA.

Remediation is the process of cleaning up a contaminated site by physical, chemical or biological means. Remediation processes are typically applied to contaminated soil and groundwater.

Risk Assessment is a methodology used to analyze for potential health effects caused by contaminants in the environment. Information from the risk assessment is used to determine cleanup levels.

A **Site Assessment** is an evaluation of above-ground (including facilities) and subsurface characteristics, including the geology and hydrology of the site, to determine if a release has occurred, as well as the extent and concentration of the release. Information generated during a site assessment is used to support remedial action decisions.

Case Study

Pennsylvania Department of Environmental Protection's South Central Regional Office Building
Harrisburg, Pennsylvania

The Pennsylvania Department of Environmental Protection's South Central Regional Office Building is a LEED™ Bronze Pilot Project that uses environmentally friendly technologies to significantly reduce energy consumption while creating a productive office atmosphere. The building is located on a site formerly used for various industrial and municipal activities. In the 1950s, the 13.5-acre site was quarried for shale. The site was converted into a municipal waste disposal facility in the 1960s and 1970s before being abandoned until the late 1990s. The Pennsylvania Department of Environmental Protection chose to redevelop the site to take advantage of the urban location and the depressed property cost. Remediation efforts included capping the entire site and installing methane and leachate collection systems to manage contaminant volumes leaving the site.

Courtesy of Pennsylvania Department of Environmental Protection

Owner
909 Partners

SS	WE	EA	MR	EQ	ID
Credit 4.1					

Alternative Transportation

Public Transportation Access

1 point

Intent

Reduce pollution and land development impacts from automobile use.

Requirements

Locate project within 1/2 mile of a commuter rail, light rail or subway station or 1/4 mile of two or more public or campus bus lines usable by building occupants.

Submittals

- ❑ Provide the LEED Letter Template, signed by an appropriate party, declaring that the project building(s) are located within required proximity to mass transit.

- ❑ Provide an area drawing or transit map highlighting the building location and the fixed rail stations and bus lines, and indicate the distances between them. Include a scale bar for distance measurement.

SS | WE | EA | MR | EQ | ID

Credit 4.2

1 point

Alternative Transportation

Bicycle Storage and Changing Rooms

Intent

Reduce pollution and land development impacts from automobile use.

Requirements

For commercial or institutional buildings, provide secure bicycle storage with convenient changing/shower facilities (within 200 yards of the building) for 5% or more of regular building occupants. For residential buildings, provide covered storage facilities for securing bicycles for 15% or more of building occupants in lieu of changing/shower facilities.

Submittals

- ❑ For commercial projects: provide the LEED Letter Template, signed by the Architect or responsible party, declaring the distance to bicycle storage and showers from the building entrance and demonstrating that these facilities can accommodate at least 5% of building occupants.

OR

- ❑ For residential projects: provide the LEED Letter Template, signed by the architect or responsible party, declaring the design occupancy for the buildings, number of covered bicycle storage facilities for securing bicycles, and demonstrating that these facilities can accommodate at least 15% of building occupants.

SS	WE	EA	MR	EQ	ID
Credit 4.3					

Alternative Transportation

Alternative Fuel Vehicles

1 point

Intent

Reduce pollution and land development impacts from automobile use.

Requirements

Provide alternative fuel vehicles for 3% of building occupants AND provide preferred parking for these vehicles, OR install alternative-fuel refueling stations for 3% of the total vehicle parking capacity of the site. Liquid or gaseous fueling facilities must be separately ventilated or located outdoors.

Submittals

- ❑ Provide the LEED Letter Template and proof of ownership of, or 2 year lease agreement for, alternative fuel vehicles and calculations indicating that alternative fuel vehicles will serve 3% of building occupants. Provide site drawings or parking plan highlighting preferred parking for alternative fuel vehicles.

OR

- ❑ Provide the LEED Letter Template with specifications and site drawings highlighting alternative-fuel refueling stations. Provide calculations demonstrating that these facilities accommodate 3% or more of the total vehicle parking capacity.

SS	WE	EA	MR	EQ	ID

Credit 4.4

1 point

Alternative Transportation

Parking Capacity

Intent

Reduce pollution and land development impacts from single occupancy vehicle use.

Requirements

Size parking capacity to meet, but not exceed, minimum local zoning requirements AND provide preferred parking for carpools or vanpools capable of serving 5% of the building occupants; OR add no new parking for rehabilitation projects AND provide preferred parking for carpools or vanpools capable of serving 5% of the building occupants.

Submittals

- ❑ For new projects: provide the LEED Letter Template, signed by the civil engineer or responsible party, stating any relevant minimum zoning requirements and declaring that parking capacity is sized to meet, but not exceed them. State the number of preferred parking spaces for carpools.

OR

- ❑ For rehabilitation projects: provide the LEED Letter Template, signed by the civil engineer or responsible party, declaring that no new parking capacity has been added.State the number of preferred parking spaces for carpools.

Summary of Referenced Standard

There is no standard referenced for this credit.

Green Building Concerns

As of the late 1990s, an estimated 200 million of the 520 million cars worldwide were located in the United States. The infrastructure (roadways and parking lots) used by automobiles dissects open expanses that wildlife relies on for migration and foraging. This impervious infrastructure also contributes to the erosion and pollution of receiving waters. The exhaust from automobiles pollutes the air and contributes to acid rain. Environmental impacts occur during extracting, refining and transporting crude oil for gasoline production. Reducing private automobile use saves energy and reduces associated environmental problems.

Fortunately, alternatives to conventional transportation methods exist. A surprisingly large number of people are willing to use alternative means of transportation such as bicycles, mass transit and carpools if they are convenient and facilities are provided to encourage their use. Alternative fuel vehicles lessen environmental impacts associated with automobiles. These vehicles use non-gasoline-based fuels such as electricity, natural gas and hydrogen-powered fuel cells. As a result, they require special refueling facilities to be viable alternatives to conventional vehicles.

Parking facilities for automobiles also have negative impacts on the environment because asphalt surfaces increase stormwater runoff and contribute to urban heat island effects. By restricting the size of parking lots and promoting carpooling activities, building occupants can benefit from increased green space.

Environmental Issues

Reduction of private automobile use reduces fuel consumption and the associated release of air and water pollutants in vehicle exhaust. Alternative fuel vehicles offer the possibility of reducing air pollutants from conventional gasoline-powered vehicles as well as reducing the environmental effects of producing gasoline. It is important to remember that vehicles using fuels such as natural gas and electricity still cause pollution at the tailpipe or power plant and are not otherwise environmentally benign. The use of electric vehicles eliminates tailpipe exhaust and centralizes the source of emissions at power plants, where emissions can be better controlled. According to the U.S. DOE, compressed natural gas vehicle emissions are 80% less than those from gasoline-powered vehicles.

Parking lots produce stormwater runoff and contribute to the urban heat island effect. They also diminish green space on the project site. Minimizing parking lot size reduces the development footprint and sets aside more space for natural areas or greater development densities.

Economic Issues

Reducing the size of parking areas based on anticipated use of bicycles, carpools and public transit by building occupants may lower initial project costs. If local utilities charge for stormwater runoff based on impervious surface area, minimization of these areas can result in lower stormwater charges.

The initial cost to design and construct a project in proximity to mass transit varies widely. During the site selection process, project owners should compare the cost of building sites in different areas to determine if a reduction in automobile use is possible and economical. Many occupants view proximity to mass transit as a benefit and this can influence the value and marketability of the building. Parking infrastructure and transportation requirements, disturbance of existing habitats, resource consumption, and future fuel costs should also be assessed.

Credit Synergies

SS Prerequisite 1
Erosion & Sedimentation Control

SS Credit 1
Site Selection

SS Credit 2
Urban Redevelopment

SS Credit 3
Brownfield Redevelopment

SS Credit 5
Reduced Site Disturbance

SS Credit 6
Stormwater Management

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

SS Credit 8
Light Pollution Reduction

WE Credit 2
Innovative Wastewater Treatment

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Prerequisite 1
Minimum IAQ Performance

The initial project cost increase for bike storage areas and changing facilities is nominal relative to the overall project cost. Initial costs for alternative vehicles are higher than for conventional vehicles and this may delay their purchase, decreasing the necessity for refueling stations. Different alternative fuel vehicles need different refueling stations, and the costs associated with these stations vary.

Community Issues

Building occupants can realize health benefits through bicycle and walking commuting strategies. Bicycling and walking also expose people to the community, encouraging interaction among neighbors and allowing for enjoyment of the area in ways unavailable to automobile passengers.

Electric vehicle engines do not contribute to noise pollution relative to internal combustion engines. Alternative fuel vehicles have low, or no, tailpipe emissions. Aside from health benefits, lower emissions can help cities meet federal regulations and qualify for transportation funding.

Design Approach

Strategies

Survey potential building occupants and determine if the available mass transportation options meet their needs. Use existing transportation networks to minimize the need for new transportation lines. Provide attractive, functional and direct sidewalks, paths and walkways to existing mass transit stops. Provide incentives such as transit passes to encourage occupants to use mass transit. Encourage employees to work from home if practical and design the building to account for the needs of telecommuting.

Design and construct safe bicycle pathways and secure bicycle storage areas for cyclists. Provide shower and changing areas for cyclists that are easily accessible from bicycle storage areas. For multifamily residential buildings, provide safe, easily accessible and adequately sized bicycle racks. Encourage carpooling through initiatives such as preferred parking areas for high-occupancy vehicles (HOV) and the elimination of parking subsidies for non-carpool vehicles. Explore the possibility of sharing facilities with other groups for parking, shuttles and bike paths. Install an adequate number of easy-to-use refueling stations for alternative fuel vehicles. For residential buildings, consider establishing carsharing programs.

Technologies

A variety of bicycle rack and locker products are currently available. The appropriate type and number of bicycle facilities depends on the number of bicyclists and the climate of the region.

The U.S. DOE defines alternative fuels as those that are substantially non-petroleum and yield energy security and environmental benefits. DOE recognizes the following as alternative fuels: methanol and denatured ethanol as alcohol fuels (alcohol mixtures that contain no less than 70% of the alcohol fuel), natural gas (compressed or liquefied), liquefied petroleum gas, hydrogen, fuels derived from biological materials, and electricity (including solar energy). Efficient gas-electric hybrid vehicles are included in this group for LEED purposes.

Electric vehicles (EVs) require a receptacle specifically designed for this purpose, usually 240 volts. EVs with conventional lead-acid batteries require recharging after 50 miles. Refueling stations for natural gas vehicles have compressors and dispensers that deliver compressed natural gas (CNG) at about 3,000 psi.

SS | WE | EA | MR | EQ | ID
Credit 4

Synergies and Trade-Offs

Transportation planning is affected by site selection and has a significant impact on site design. A building site near transit lines may have negative characteristics, such as site contamination, poor air quality, unsafe conditions or problematic drainage. Real estate costs may also be higher in areas close to transit lines.

Provisions for carpooling and the use of bicycles as a viable transportation mode for building occupants reduce the need for more parking spaces, thus reducing the need for impervious surfaces and potential water runoff problems. A reduction in hard surface parking areas could also increase the amount of open space on the site while reducing heat island effects and stormwater runoff volumes.

Shower and changing facilities can add to the building's footprint or decrease other usable building space. These facilities also increase water and material usage. While alternative fuel vehicles have lower impacts on the environment than conventional vehicles, they require energy and materials to produce, as well as land area for storage and mobility. Alternative fuel refueling stations require energy for operation as well as commissioning and measurement and verification attention.

Space allocation and installation of refueling stations may not be cost-effective without enough vehicles that require refueling at such stations. Building space may come at a premium, especially in projects rehabilitating existing buildings. Investigate the possibility of sharing facilities with other partners and businesses.

Calculations

The following calculation methodology is used to support the credit submittals.

Mass Transit

Use an area drawing to indicate mass transit stops within 1/2 mile of the project. Remember that the project is required to be within 1/2 mile of a commuter rail, light rail or subway station or within 1/4 mile of two or more bus lines. **Figure 1** shows two bus lines within 1/4 mile of the project location. The map includes a scale bar and a north indicator.

If private shuttle buses will be used to meet the requirements, they must connect to public transit and operate at least during the most frequent commuting hours.

Bicycle-Securing Apparatus and Changing/Showering Facilities

To determine the number of secure bicycle spaces and changing/showering facilities required for the building, follow the calculation methodology as follows:

1. Identify the total number of full-time and part-time building occupants.

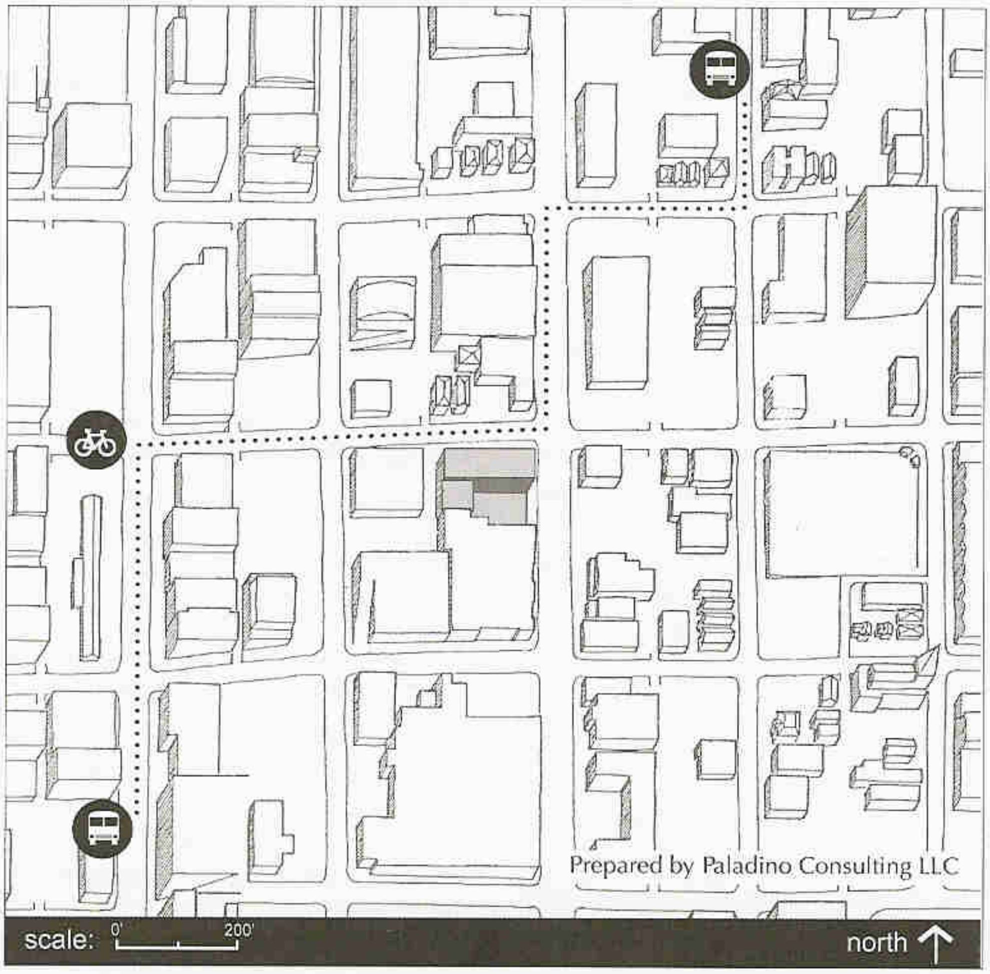
2. Calculate the Full-Time Equivalent (FTE) building occupants based on a standard eight-hour workday. A full-time worker has an FTE value of 1.0 while a half-time worker has a FTE value of 0.5 (see **Equation 1**).

3. Total the FTE values for each shift to obtain the total number of FTE building occupants. In buildings that house companies utilizing multiple shifts, select the shift with the greatest number of FTE building occupants.

4. The minimum number of **secure bicycle spaces** required is equal to 5% of the FTE building occupants during the maximum shift (see **Equation 2**). Secure bicycle spaces include bicycle racks, lockers and storage rooms. These spaces must be easily accessible by building occupants during all periods of the year, and free of charge.

5. The required number of **changing** and **showering facilities** for non-residential buildings is based on the number of bicycling occupants. A minimum of one shower for every eight bicycling occupants

Figure 1: Sample Area Drawing



is required to earn this point. (This number is based on recommended showering facilities for institutional spaces). Showering facilities can be unit showers or group showering facilities (see **Equation 3**). This calculation is not necessary for residential buildings.

For example, a building houses a company with two shifts. The first shift includes 240 full-time workers and 90 half-time workers. The second shift includes 110 full-time workers and 60 part-time workers. Calculations to determine the total FTE building occupants for each shift are included in **Table 1**.

The first shift is used for determining the number of bicycling occupants because it has the greatest FTE building occupant total. Based on a total of 285 FTE building occupants, the estimated number of bicycling occupants is 15. Thus, 15 secure bicycle spaces are required for this example. The required number of changing and showering facilities is one facility for every eight bicycling occupants. Thus, total number of required showering facilities in this example is two. More showers may be necessary for the building based on the number of actual bicycling occupants.

Equation 1:

$$\text{FTE} = \frac{\text{Worker Hours [hours]}}{8 \text{ [hours]}}$$

Table 1: Sample FTE Calculation

Shift	Full-Time Occupants		Part-Time Occupants		Full-Time Equivalent (FTE) Occupants
	Occupants	[hr]	Occupants	[hr]	Occupants
First Shift	240	8	90	4	285
Second Shift	110	8	60	4	140

Alternative Fuel Refueling Stations

To calculate the number of vehicles required to be serviced by alternative fuel refueling stations, multiply the total number of vehicle parking spaces by 3% (see **Equation 4**).

In the example above, the building has a parking area with 250 parking spaces. Therefore, alternative fuel refueling stations are required to service 3% of the 250 parking spaces, or eight vehicles. The required number of refueling stations depends on the number of vehicles (eight, in this case) and the service limits of the station (the time necessary for each complete refueling multiplied by the number of AFVs defined by **Equation 4**) in combination with the station's operating hours (i.e., if all vehicles are refueled within a short timeframe, or an eight-hour day, or nonstop).

Carpool Spaces

To calculate the number of carpool spaces required, multiply the number of FTE building occupants during the maximum shift (see the bicycle calculations above) by 5% and divide by two occupants per vehicle (see **Equation 5**). In the example above, a total of 285 FTE building occupants requires a minimum of eight carpool spaces.

Resources

Web Sites

Advanced Transportation Technology Institute

www.etvi.org, (423) 622-3884

A nonprofit organization that advances clean transportation technologies through research, education and technology transfer in order to promote a healthy environment and energy independence.

Equation 2:

$$\text{Secure Bicycle Spaces (non-residential buildings)} = \text{FTE Building Occupants} \times 5\%$$

$$\text{Secure Bicycle Spaces (residential buildings)} = \text{FTE Building Occupants} \times 15\%$$

Equation 3:

$$\text{Showering Facilities (non-residential buildings)} = \frac{\text{Bicyling Spaces}}{8}$$

Equation 4:

$$\text{Minimum Vehicle Refueling Capacity} = \text{Total Parking Spaces} \times 3\%$$

Equation 5:

$$\text{Required Number of Carpool Spaces} = \frac{\text{FTE Building Occupants} \times 5\%}{2}$$

Alternative Fuels Data Center

www.afdc.doe.gov, (800) 423-1363

A section of the DOE Office of Transportation Technologies that has information on alternative fuels and alternative fuel vehicles, a locator for alternative refueling stations, and other related information.

Electric Auto Association

www.eaaev.org

A nonprofit education organization that promotes the advancement and widespread adoption of electric vehicles.

Electric Vehicle Association of the Americas

www.evaa.org, (202) 508-5924

An industry association that promotes electric vehicles through policy, information and market development initiatives.

EV World

www.evworld.com

A Web site with current events, product reviews and other information related to electric vehicles.

Natural Gas Vehicle Association

www.ngvc.org, (202) 824-7360

An organization consisting of natural gas companies, vehicle and equipment manufacturers, service providers, environmental groups, and government organizations to promote the use of natural gas for transportation.

Print Media

Alternative Fuels: Technology & Developments, Society of Automotive Engineers, 1997.

Definitions

Alternative Fuel Vehicles are vehicles that use low-polluting, non-gasoline fuels such as electricity, hydrogen, propane or compressed natural gas, liquid natural gas, methanol, and ethanol. Efficient gas-electric hybrid vehicles are included in this group for LEED purposes.

A **Carpool** is an arrangement in which two or more people share a vehicle for transportation.

Mass Transit includes transportation facilities designed to transport large groups of persons in a single vehicle such as buses or trains.

Public Transportation is bus, rail or other transportation service for the general public on a regular, continual basis that is publicly or privately owned.

Case Study

PNC Firstside Center
Pittsburgh, Pennsylvania

Courtesy of Paladino Consulting LLC

Owner
PNC Bank

The PNC Firstside Center is a LEED™ Silver Project that functions as a banking facility. To assess transportation planning issues, the project team polled future building occupants to determine the percentage of occupants who would use personal vehicles, carpools, mass transportation, and other forms of transportation such as bicycles and walking. The owner used data from the poll to influence the local transit authority to construct a future mass transit stop adjacent to the building. Until the transit stop is in operation, building occupants are utilizing 11 bus routes located within _ mile of the building. The site is located adjacent to a city bikeway and the building has bicycle racks to accommodate 60 bicycles, as well as showering and changing facilities. Eight electric vehicle recharging stations have been installed for building occupants using personal vehicles. Finally, the owner reached agreement with the local parking authority to share a portion of a public 1200-space multilevel parking facility located across the street.

SS	WE	EA	MR	EQ	ID

Credit 5.1

1 point

Reduced Site Disturbance

Protect or Restore Open Space

Intent

Conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity.

Requirements

On greenfield sites, limit site disturbance including earthwork and clearing of vegetation to 40 feet beyond the building perimeter, 5 feet beyond primary roadway curbs, walkways and main utility branch trenches, and 25 feet beyond constructed areas with permeable surfaces (such as pervious paving areas, stormwater detention facilities and playing fields) that require additional staging areas in order to limit compaction in the constructed area; OR, on previously developed sites, restore a minimum of 50% of the site area (excluding the building footprint) by replacing impervious surfaces with native or adapted vegetation.

Submittals

- ❑ For greenfield sites: provide the LEED Letter Template, signed by the civil engineer or responsible party, demonstrating and declaring that site disturbance (including earthwork and clearing of vegetation) has been limited to 40 feet beyond the building perimeter, 5 feet beyond primary roadway curbs, walk ways and main utility branch trenches, and 25 feet beyond constructed areas with permeable surfaces. Provide site drawings and specifications highlighting limits of construction disturbance.

OR

- ❑ For previously developed sites: provide a LEED Letter Template, signed by the civil engineer or responsible party, declaring and describing restoration of degraded habitat areas. Include highlighted site drawings with area calculations demonstrating that 50% of the site area that does not fall within the building footprint has been restored.

SS | WE | EA | MR | EQ | ID

Credit 5.2

1 point

Reduced Site Disturbance

Development Footprint

Intent

Conserve existing natural areas and restore damaged areas to provide habitat and promote biodiversity.

Requirements

Reduce the development footprint (defined as entire building footprint, access roads and parking) to exceed the local zoning's open space requirement for the site by 25%. For areas with no local zoning requirements (e.g., some university campuses and military bases), designate open space area adjacent to the building that is equal to the development footprint.

Submittals

- ❑ Provide a copy of the local zoning requirements highlighting the criteria for open space. Provide the LEED Letter Template, signed by the civil engineer or responsible party, demonstrating and declaring that the open space exceeds the local zoning open space requirement for the site by 25%.

OR

- ❑ For areas with no local zoning requirements (e.g., some university campuses and military bases), designate open space area adjacent to the building that is equal to the development footprint. Provide a letter from the property owner stating that the open space will be conserved for the life of the building.

Summary of Referenced Standard

There is no standard referenced for this credit.

Green Building Concerns

Development of greenfield or undeveloped areas disturbs and destroys wildlife and plant habitat as well as wildlife corridors that allow animal migration. As animals are pushed out of existing habitat, they become increasingly crowded into smaller spaces. Eventually, their population exceeds the carrying capacity of these spaces and they begin to invade surrounding developments or perish due to overpopulation. Overall biodiversity, as well as individual plant and animal species, may be threatened by reduction of habitat areas. Minimizing site disturbance reduces habitat destruction.

Environmental Issues

The construction process is often damaging to site ecology, indigenous plants and regional animal populations. Ecological site damage can be avoided or minimized by limiting the extent of construction activities to certain areas on the site and by restricting the development footprint to the greatest extent possible. Protection of open space and sensitive areas through the use of strict boundaries reduces damage to the site ecology, resulting in preservation of wildlife corridors and habitat.

Economic Issues

Preserving topsoil, plants and trees on the site can reduce landscaping costs for the building and increase property values. Indigenous plantings often require less maintenance than exotic plantings and minimize inputs of fertilizers, pesticides, and water, reducing maintenance costs over the building lifetime. In some cases, trees and vegetation developed as specimens off-site are costly to purchase and may not survive transplanting. Purchasing and installing new plants can add to project cost. Saving existing site vegetation to replant after construction is complete may be a more cost-effective strategy.

Reducing the footprint of a structure on a given site can have varying economic impacts. Building a vertical structure with the same square footage as a horizontal structure may add a small percentage to first costs depending on building size and use. A structure with a smaller footprint is generally more resource-efficient, resulting in reduced material and energy costs. A more compact building with coordinated infrastructure can reduce initial project costs, as well as operations and maintenance costs. Reduced earthwork, shorter utility lines, and reduced surface parking and paved areas all can reduce initial project costs. Compact paving areas and buildings reduce operations and maintenance costs.

Design Approach

Strategies

Design a master plan for the project area, survey existing ecosystems and identify soil types on the site. Document existing water elements, soil conditions, ecosystems, wildlife corridors, trees and other vegetation, and map all potential natural hazards. Consider the impacts of the proposed development on existing natural and built systems and propose strategies to mitigate negative impacts.

Choose a building footprint and location that minimize disturbance to the existing ecosystem. Consider issues such as building orientation, daylighting, heat island effects, stormwater generation, significant vegetation and other sustainable building issues. Once the site and building location have been determined, design and construct a compact parking, road and building footprint layout in order to preserve open land. Reduce footprints by tightening program needs and stacking floor plans.

Encourage preservation, conservation and restoration of existing natural site amenities. Where appropriate, build on parts

Credit Synergies

SS Prerequisite 1
Erosion & Sedimentation Control

SS Credit 1
Site Selection

SS Credit 2
Urban Redevelopment

SS Credit 3
Brownfield Redevelopment

SS Credit 4
Alternative Transportation

SS Credit 6
Stormwater Management

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

SS Credit 8
Light Pollution Reduction

WE Credit 1
Water Efficient Landscaping

WE Credit 2
Innovative Wastewater Treatment

WE Credit 3
Water Use Reduction

EA Credit 2
Renewable Energy

MR Prerequisite 1
Storage & Collection of Recyclables

MR Credit 1
Building Reuse

MR Credit 2
Construction Waste Management

EQ Credit 8
Daylight & Views

of the site that are already degraded so as not to degrade undisturbed areas. Restore the native landscape of the site by preserving and planting native species to re-establish predevelopment site conditions. Restoration efforts will vary depending on the particular project site.

Volunteer efforts can reduce the cost of saving existing trees and plants. For example, a volunteer "plant rescue" effort was organized on the site of the new EPA complex in Research Triangle Park, North Carolina. Assisted by the neighboring National Institutes for Environmental Health Sciences and the North Carolina Botanical Gardens at Chapel Hill, this effort saved more than 2,000 plants that were transplanted elsewhere on the site or sent to other locations. A variety of local plant amnesty organizations exist that can help with plant and tree preservation and relocation.

During the construction process, establish clearly marked construction and disturbance boundaries and note these site protection requirements in construction documents. Delineate lay down, recycling and disposal areas, and use paved areas for staging activities. Erect construction fencing around the drip line of existing trees to protect them from damage and soil compaction by construction vehicles. Establish contractual penalties if destruction of protected areas outside of the construction boundaries occurs. Coordinate infrastructure construction to minimize the disruption of the site and work with existing topography to limit cut-and-fill efforts for the project.

For achievement of Credit 5.2 in areas with no established zoning requirements for open space, a project must show that an open space area equal to the building footprint has been established adjacent to the building.

Synergies and Trade-Offs

Balancing the verticality of a structure with open space requirements can be a challenging exercise. For instance, shading from tall structures may change the environmental character of the open space, and these structures may be intimidating and unwelcoming to building occupants. Furthermore, large expanses of open space may be a barrier to public transportation access. Conversely, retaining a high proportion of open space vegetation reduces stormwater runoff volumes and natural features may be available for wastewater or stormwater treatment. Preservation of certain trees may reduce passive solar gains. Check the siting of the structure to optimize solar opportunities and to preserve the most significant trees. Additional vegetation can assist with cooling breezes and noise reduction, and enhance the site air quality.

The site location and site design have a significant effect on open space and reduced habitat disturbance. Heat island effects, stormwater generation, and light pollution should all be considered when determining the site design. The landscape design and irrigation scheme is intimately tied with the site design and open space allotted. In addition, water reuse and on-site wastewater treatment strategies have an effect on non-building spaces.

Renewable energy technologies such as wind turbines and biomass generation require site space. Rehabilitation of existing buildings may dictate the amount of open space available. Construction waste management schemes may encroach on natural areas for storage of building wastes earmarked for recycling.

Resources

Web Sites

North American Native Plant Society

www.nanps.org, (416) 631-4438

A nonprofit association dedicated to the study, conservation, cultivation and restoration of native plants. Contains links to state/provincial associations.

Soil and Water Conservation Society

www.swcs.org, (515) 289-2331

An organization focused on fostering the science and art of sustainable soil, water and related natural resource management.

Print Media

Beyond Preservation: Restoring and Inventing Landscapes by A. Dwight Baldwin et al., University of Minnesota Press, 1994.

Design for Human Ecosystems: Landscape, Land Use, and Natural Resources by John Tillman Lyle and Joan Woodward, Milldale Press, 1999.

Landscape Restoration Handbook by Donald Harker, Lewis Publishers, 1999.

Definitions

The **Building Footprint** is the area on a project site that is used by the building structure and is defined by the perimeter of the building plan. Parking lots, landscapes and other non-building facilities are not included in the building footprint.

The **Development Footprint** is the area on the project site that has been impacted by any development activity. Hardscape, access roads, parking lots, non-building facilities and building structure are all included in the development footprint.

A **Greenfield** is defined as undeveloped land or land that has not been impacted by human activity.

Local Zoning Requirements are local government regulations imposed to promote orderly development of private lands and to prevent land use conflicts.

Native/Adapted Plants are those that are indigenous to a locality or have adapted to the local climate and are not invasive. Such plants do not require irrigation or fertilization once root systems are established in the soil.

Open Space Area is the property area minus the development footprint. Open space must be vegetated and pervious, thus providing habitat and other ecological services.

Case Study

Kandalama Hotel
Colombo, Sri Lanka


Courtesy of Green Technologies, Inc.

Owner
Kandalama Hotels Ltd.

The Kandalama Hotel, a LEED™ Bronze Pilot Project, is a 162-bedroom resort hotel located on a picturesque site with dense vegetation. The project site is an excellent example of how a sensitive natural site can be thoughtfully developed to protect the existing natural attributes. The design team chose to capitalize on the natural amenities of the site by minimizing construction extents and the overall building footprint. As a result, the total built area is only 10% of the total 55-acre site. Special efforts were made during construction to retain native vegetation and nestle the hotel into the existing lush trees and plants to provide shading for the guest rooms, restaurants and garden areas. A survey of the density and distribution of flora was used to document the existing site characteristics and the building design was altered to preserve existing trees and the natural topography of the site. Stilts and columns were used to elevate the buildings above existing natural features such as boulders and to reduce cut-and-fill needs.

Stormwater Management

Rate and Quantity

SS	WE	EA	MR	EQ	ID
Credit 6.1					

1 point

Intent

Limit disruption and pollution of natural water flows by managing stormwater runoff.

Requirements

If existing imperviousness is less than or equal to 50%, implement a stormwater management plan that prevents the post-development 1.5 year, 24 hour peak discharge rate from exceeding the pre-development 1.5 year, 24 hour peak discharge rate.

OR

If existing imperviousness is greater than 50%, implement a stormwater management plan that results in a 25% decrease in the rate and quantity of stormwater runoff.

Submittals

- ❑ Provide the LEED Letter Template, signed by the civil engineer or responsible party, declaring that the post-development 1.5 year, 24 hour peak discharge rate does not exceed the pre-development 1.5 year 24 hour peak discharge rate. Include calculations demonstrating that existing site imperviousness is less than or equal to 50%.

OR

- ❑ Provide the LEED Letter Template, signed by the civil engineer or responsible party, declaring and demonstrating that the stormwater management strategies result in at least a 25% decrease in the rate and quantity of stormwater runoff. Include calculations demonstrating that existing site imperviousness exceeds 50%.

Stormwater Management

1 point

Treatment

Intent

Limit disruption of natural water flows by eliminating stormwater runoff, increasing on-site infiltration and eliminating contaminants.

Requirements

Construct site stormwater treatment systems designed to remove 80% of the average annual post-development total suspended solids (TSS) and 40% of the average annual post-development total phosphorous (TP) based on the average annual loadings from all storms less than or equal to the 2-year/24-hour storm. Do so by implementing Best Management Practices (BMPs) outlined in Chapter 4, Part 2 (Urban Runoff), of the United States Environmental Protection Agency's (EPA's) *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*, January 1993 (Document No. EPA-840-B-92-002) or the local government's BMP document (whichever is more stringent).

Submittals

❑ Provide the LEED Letter Template, signed by the civil engineer or responsible party, declaring that the design complies with or exceeds EPA or local government Best Management Practices (whichever set is more stringent) for removal of total suspended solids and total phosphorous.

Summary of Referenced Standard

Guidance Specifying Management Measures for Sources of Non-Point Pollution in Coastal Waters, January 1993 (Document No. EPA 840B92002)

Internet location: www.epa.gov/owow/nps/MMGI

Hardcopy or microfiche (entire document, 836 pages): National Technical Information Service (order # PB93-234672), www.ntis.gov, (800) 553-6847

U.S. Environmental Protection Agency Office of Water, www.epa.gov/OW

This document discusses a variety of management practices that can be incorporated to remove pollutants from stormwater volumes. Chapter 4, Part II addresses urban runoff and suggests a variety of strategies for treating and infiltrating stormwater volumes after construction is completed. See the Resources section later in this credit for a summary of best management practices listed in the EPA document.

Green Building Concerns

The volume of stormwater generated from a site depends on the impervious surface area. In natural settings, the majority of precipitation infiltrates into the ground while a small portion runs off on the surface and into receiving waters. This surface runoff water is classified as stormwater runoff. As areas are constructed and urbanized, surface permeability is reduced, resulting in increased stormwater runoff volumes that are transported via urban infrastructure (e.g., gutters, pipes and sewers) to receiving waters. These stormwater volumes contain sediment and other contaminants that have a negative impact on water quality, navigation and recreation. Furthermore, conveyance and treatment of stormwater volumes requires significant municipal infrastructure and maintenance.

Reducing the generation of stormwater volumes maintains the natural aquifer recharge cycle. In addition, stormwater volumes do not have to be conveyed to receiving waters by the municipality, and receiving waters are not impacted.

Environmental Issues

Reduction and treatment of runoff volumes decrease or eliminate contaminants that pollute receiving water bodies. For instance, parking areas contribute to stormwater runoff that is contaminated with oil, fuel, lubricants, combustion byproducts, material from tire wear, and deicing salts. Minimizing the need for stormwater infrastructure also reduces construction impacts and the overall ecological "footprint" of the building. Finally, infiltration of stormwater on-site can recharge local aquifers, mimicking the natural water cycle.

Economic Issues

If natural drainage systems are designed and implemented at the beginning of site planning, they can be integrated economically into the overall development. Water detention and retention features require cost for design, installation and maintenance. However, these features can also add significant value as site amenities if planned early in the design. Water features may pose safety and liability problems, especially in locations where young children are playing outdoors. The use of infiltration devices such as pervious paving may reduce water runoff collection system costs.

Community Issues

Stormwater volume reduction leads to improved watershed quality that benefits the community through improved water quality, navigation and recreation activities. Reduced stormwater collection and treatment systems lessen the burden on municipalities for maintenance and repair, resulting in a more affordable and stable tax base.

Design Approach

Strategies

The most effective method to minimize stormwater runoff volume is to reduce the amount of impervious area. By reducing impervious area, stormwater infrastructure can be minimized or deleted from the project. To minimize impervious surfaces and to encourage the natural processes of evaporation and infiltration, consider such methods as designing a smaller building footprint, installing green roofs and paving with pervious materials.

Capture stormwater from impervious areas to reuse within the building. Stormwater harvesting from roofs and hardscapes can be used for non-potable

Credit Synergies

SS Prerequisite 1
Erosion & Sedimentation Control

SS Credit 1
Site Selection

SS Credit 2
Urban Redevelopment

SS Credit 3
Brownfield Redevelopment

SS Credit 4
Alternative Transportation

SS Credit 5
Reduced Site Disturbance

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

WE Credit 1
Water Efficient Landscaping

WE Credit 2
Innovative Wastewater Treatment

WE Credit 3
Water Use Reduction

MR Credit 1
Building Reuse

uses such as sewage conveyance, fire suppression and industrial applications.

For stormwater volumes that must be conveyed from the site to a receiving water body, design treatment practices to match the needs of the location and the specific drainage area. Design stormwater facilities to remove contaminants and release the volumes to local water bodies. Utilize biologically based and innovative stormwater management features for pollutant load reduction such as constructed wetlands, stormwater filtering systems, bioswales, bioretention basins, and vegetated filter strips. Use vegetated buffers around parking lots to remove runoff pollutants such as oil and grit. Specify and install water quality structures for pretreatment of runoff from surface parking areas. Do not disturb existing wetlands or riparian buffers when constructing ponds at the lowest elevations of a site. Design stormwater runoff to flow into vegetated swales rather than into structured pipes for conveyance to water quality ponds. Swales provide filtration for stormwater volumes and require less maintenance than constructed stormwater features. Install sequences of ponds whenever possible for more complete water treatment.

In some cases, such as heavily wooded sites where larger ponds are not feasible, distribute smaller bioretention areas that use subsurface compost and plantings to accelerate the filtering of contaminants around the site, instead of using one large pool. To moderate water runoff along drainage paths, construct water ponds to temporarily store stormwater flows. These ponds also improve water quality through settling and biodegradation of pollutants.

Technologies

Clustering or concentrating developments to reduce the amount of paved surfaces such as roads, parking lots and sidewalks minimizes impervious surfaces. Widths and lengths of roads, parking lots and sidewalks can also be minimized. For instance, turning lanes in roads can be removed to minimize the width of the paved surface. This requires the sharing of traveling and turning lanes.

Garden roofs or green roofs are vegetated surfaces that capture rainwater and return a portion of it back to the atmosphere via evapotranspiration. They consist of a layer of plants and soil, a cup layer for collection and temporary storage of stormwater, and a synthetic liner to protect the top of the building from stormwater infiltration. Garden roofs also provide insulating benefits and aesthetic appeal. Some garden roofs require plant maintenance and are considered active gardens while other garden roofs have

Table 1: Typical Runoff Coefficients

Surface Type	Runoff Coefficient	Surface Type	Runoff Coefficient
Pavement, Asphalt	0.95	Turf, Flat (0 - 1% slope)	0.25
Pavement, Concrete	0.95	Turf, Average (1 - 3% slope)	0.35
Pavement, Brick	0.85	Turf, Hilly (3 - 10% slope)	0.40
Pavement, Gravel	0.75	Turf, Steep (> 10% slope)	0.45
Roofs, Conventional	0.95	Vegetation, Flat (0 - 1% slope)	0.10
Roof, Garden Roof (< 4 in)	0.50	Vegetation, Average (1 - 3% slope)	0.20
Roof, Garden Roof (4 - 8 in)	0.30	Vegetation, Hilly (3 - 10% slope)	0.25
Roof, Garden Roof (9 - 20 in)	0.20	Vegetation, Steep (> 10% slope)	0.30
Roof, Garden Roof (> 20 in)	0.10		

grasses and plants that require no maintenance or watering. All types of garden roofs require semiannual inspection but are estimated to have a longer lifetime and require less maintenance than conventional roofs.

Pervious paving systems reduce stormwater runoff by allowing precipitation to infiltrate the undersurface through voids in the paving material. These systems can be applied to pedestrian traffic surfaces as well as low-vehicle traffic areas such as parking spaces, fire lanes, and maintenance roads. Use pervious paving materials such as poured asphalt or concrete with incorporated air spaces or use concrete unit paving systems with large voids that allow grass or other vegetation to grow between the voids.

Pervious paving has several options, including systems that use grass and a plastic grid system (90% pervious), concrete grids with grass (40% pervious), and concrete grids with gravel (10% pervious). Pervious paving requires different maintenance procedures than impervious pavement. With some systems, vacuum sweeping is necessary to prevent the voids from clogging with sediment, dirt and mud. Systems that use vegetation, such as grass planted in a plastic matrix over gravel, may require mowing like conventional lawns. Snow removal from pervious paving requires more care than from conventional paving. Check existing codes relating to the use of pervious surfaces for roadways.

To earn the second portion of this credit, stormwater volumes leaving the site must pass through a stormwater treatment system that removes total suspended solids and phosphorous to the required levels.

Packaged stormwater treatment systems can also be installed to treat stormwater volumes. These systems use filters to remove contaminants and can be sized for various stormwater volumes.

Synergies and Trade-Offs

Stormwater runoff is affected significantly by site selection and site design, especially transportation amenity design. It may be possible to reuse stormwater for nonpotable water purposes such as flushing urinals and toilets, custodial applications, and building equipment uses. Rehabilitation of an existing building may affect stormwater reduction efforts if large impervious surfaces already exist.

It is helpful to perform a water balance to determine the estimated volumes of water available for reuse. Stormwater runoff volumes can also be reduced by designing the building with underground parking, a strategy that also reduces heat island effects. Pervious paving systems usually have a limit on transportation loads and may pose problems for wheelchair accessibility and stroller mobility. If stormwater volumes are treated on site, additional site area may need to be disturbed to construct treatment ponds or underground facilities. Application of garden roofs reduces stormwater volumes that may be intended for collection and reuse for non-potable applications.

Calculations for Credit 6.1

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. Stormwater runoff volumes are affected by surface characteristics on the site as well as rainfall intensity over a specified time period. To simplify stormwater calculations, consider only the surface characteristics of the project site. Stormwater volumes generated are directly related to the net imperviousness of the project site. By reducing the amount of impervious surface on the site, stormwater volumes are reduced.

The calculation methodology to estimate the imperviousness of the project site is as follows:

1. Identify the different surface types on the site: roof areas, paved areas (e.g., roads and sidewalks), landscaped areas, and other areas.

2. Calculate the total area for each of these surface types using site drawings. Use **Table 1** to assign a runoff coefficient to each surface type. If a surface type is not included in the table, use a "best estimate" or manufacturer information. For instance, if pervious paving is used, consult the manufacturer to determine the imperviousness or percentage of the surface that does not allow infiltration.

3. Create a spreadsheet to summarize the area and runoff coefficient for each surface type. Multiply the runoff coefficient by the area to obtain an impervious area for each surface type. This figure represents the square footage of each surface area that is 100% impervious (see **Equation 1**).

4. Add the impervious areas for each surface type to obtain a total impervious area for the site.

5. Divide the total impervious area by the total site area to obtain the imperviousness of the site (see **Equation 2**).

Credit requirements state that for sites with imperviousness less than or equal to 50%, imperviousness must not increase from predevelopment to post-development conditions. For previously developed sites with imperviousness greater than 50%, imperviousness must be reduced by 25% from predevelopment to post-development conditions.

The following example describes the calculation method for site imperviousness. The example project is an office renovation and site improvements to an existing concrete parking lot of average slope. Surface types include sidewalks, parking areas, landscaping and the roof. The roof

Table 2: Design Case Imperviousness

Surface Type	Runoff Coefficient	Area [SF]	Impervious Area [SF]
Pavement, Asphalt	0.95	5,075	4,821
Pavement, Pervious	0.60	1,345	807
Roof, Garden Roof (4 - 8 in)	0.30	8,240	2,472
Vegetation, Average (1 -3% slope)	0.20	4,506	901
	TOTAL AREA	**14,660**	
	TOTAL IMPERVIOUS AREA		**8,100**
	IMPERVIOUSNESS		**55%**

Table 3: Baseline Case Imperviousness

Surface Type	Runoff Coefficient	Area [SF]	Impervious Area [SF]
Pavement, Concrete	0.95	19,166	18,208
	TOTAL AREA	**19,166**	
	TOTAL IMPERVIOUS AREA		**18,208**
	IMPERVIOUSNESS		**95%**

Equation 1:

$$\text{Impervious Area [SF]} = \text{Surface Area [SF]} \times \text{Runoff Coefficient}$$

Equation 2:

$$\text{Imperviousness [\%]} = \frac{\text{Total Pervious Area [SF]}}{\text{Total Site Area [SF]}}$$

area is assumed to be equal to the building footprint as determined from site drawings. **Table 2** shows calculations for the design case.

To reduce imperviousness, concrete sidewalks and asphalt parking lots can be substituted with pervious paving and vegetation in some areas. The building footprint is reduced and garden roofs are applied to reduce roof runoff.

Next, calculations are done for the baseline case or the existing site conditions (see **Table 3**). The original use of the site was for parking and, thus, the entire site was paved with concrete pavement.

The calculations demonstrate that the design case has an imperviousness of 47% and the baseline case has an imperviousness of 95%—a 50% reduction that exceeds the 25% required, thus earning one point.

Calculations for Credit 6.2

In most cases where projects choose to utilize standard EPA or local BMPs, no calculations are required to demonstrate compliance with the requirements of Credit 6.2. In instances where designs far different than accepted BMPs have been developed and implemented, the LEED Letter Template along with detailed engineering calculations may be required to demonstrate the TSS and phosphorus reductions that will be achieved.

Resources for Credit 6.2

Below is a summary of stormwater best management practices from the **EPA's Guidance Specifying Management Measures for Sources of Non-point Pollution in Coastal Waters**. For more information about this document, see Summary of Referenced Standard earlier in this credit.

Infiltration Basins and **Trenches** are devices used to encourage subsurface infiltration of runoff volumes through temporary surface storage. Basins are ponds that can store large volumes of stormwater. They need to drain within 72 hours to maintain aerobic conditions and to be available for the next storm event. Trenches are similar to infiltration basins except that they are shallower and function as a subsurface reservoir for stormwater volumes. Pretreatment to remove sediment and oil may be necessary to avoid clogging of infiltration devices. Infiltration trenches are more common in areas where infiltration basins are not possible.

Porous Pavement and **Permeable Surfaces** are used to create permeable surfaces that allow runoff to infiltrate into the subsurface. These surfaces are typically maintained with a vacuuming regime to avoid potential clogging and failure problems.

Vegetated Filter Strips and **Grassed Swales** utilize vegetation to filter sediment and pollutants from stormwater. Strips are appropriate for treating low-velocity surface sheet flows in areas where runoff is not concentrated. They are often used as pretreatment for other stormwater measures such as infiltration basins and trenches. Swales consist of a trench or ditch with vegetation and require occasional mowing. They also encourage subsurface infiltration, similar to infiltration basins and trenches.

Filtration Basins remove sediment and pollutants from stormwater runoff using a filter media such as sand or gravel. A sediment trap is usually included to remove sediment from stormwater before filtering to avoid clogging.

Constructed Wetlands are engineered systems that are designed to mimic natural wetland treatment properties. Advanced designs incorporate a wide variety of wetland trees, shrubs, and plants while basic systems only include a limited number of vegetation types.

Detention Ponds capture stormwater runoff and allow pollutants to drop out before release to a stormwater or water body. A variety of detention pond designs are available, with some utilizing only gravity while others use mechanical equipment such as pipes and pumps to facilitate transport. Some ponds are dry except during storm events; others permanently store water volumes.

Table 4 highlights the advantages, disadvantages and removal efficiency rates for the above stormwater control practices.

Table 4: EPA Best Management Practices

Practice	Advantages	Disadvantages	Removal Efficiency [%]	
			TSS (req. 80%)	TP (req. 40%)
Infiltration Basins & Infiltration Trenches	Provides groundwater recharge, high removal efficiency, provides habitat	Requires permeable soils, high potential for failure, requires maintenance	50 to 100	50 to 100
Porous Pavement	Provides groundwater recharge, no space requirement, high removal efficiency	Requires permeable soils, not suitable for high-traffic areas, high potential for failure, requires maintenance	60 to 90	60 to 90
Vegetated Filter Strips	Low maintenance, good for low-velocity flows, provides habitat, economical	Not appropriate for high-velocity flows, requires periodic repair and reconstruction	40 to 90	30 to 80
Grassy Swales	Small land requirements, can replace curb and gutter infrastructure, economical	Low removal efficiency	20 to 40	20 to 40
Filtration Basins	Provides groundwater recharge, peak volume control	Requires pretreatment to avoid clogging	60 to 90	0 to 80
Constructed Wetlands	Good for large developments, peak volume control, high removal efficiency, aesthetic value	Not economical for small developments, requires maintenance, significant space requirements	50 to 90	0 to 80
Dry Ponds	Peak flow control, less space and cost vs. wet pond	Space, maintenance, limited soil groups	70 to 90	10 to 60
Wet Ponds	Peak flow control, prevents scour and resuspension	Space, cost, maintenance, limited soil groups	50 to 90	20 to 90

Source: EPA840B92002 Tables 4-5 and 4-7

Other technologies may also satisfy the credit's performance requirements.

Definitions

A **Constructed Wetland** is an engineered system designed to simulate natural wetland functions for water purification. Constructed wetlands are essentially treatment systems that remove contaminants from wastewaters.

Impervious Surfaces promote runoff of precipitation volumes instead of infiltration into the subsurface. The imperviousness or degree of runoff potential can be estimated for different surface materials.

Stormwater Runoff consists of water volumes that are created during precipitation events and flow over surfaces into sewer systems or receiving waters. All precipitation waters that leave project site boundaries on the surface are considered to be stormwater runoff volumes.

Total Phosphorous (TP) consists of organically bound phosphates, poly-phosphates and orthophosphates in stormwater, the majority of which originates from fertilizer application. Chemical precipitation is the typical removal mechanism for phosphorous.

Total Suspended Solids (TSS) are particles or flocs that are too small or light to be removed from stormwater via gravity settling. Suspended solid concentrations are typically removed via filtration.

Case Study

Philips Eco-Enterprise Center
Minneapolis, Minnesota

Courtesy of Paladino Consulting LLC

Owner
The Green Institute

The Phillips Eco-Enterprise Center is a mixed-use building that houses environmental and energy efficiency organizations, consultants and manufacturers. The landscape on the project site was designed using xeriscape principles and requires no irrigation volumes. The native prairie grasses and wildflowers survive solely on precipitation. Stormwater that is not used by the plants or infiltrated into the subsurface is treated in a restored wetland and enhanced bio-filtration system. The system removes oil and sediment from stormwater and diverts 1.5 million gallons of runoff from entering the municipal stormwater system annually. Finally, a 4,000-square-foot section of the roof was designed as a garden roof to reduce stormwater runoff, provide superior insulation, and create a natural area that building occupants may enjoy.

SS	WE	EA	MR	EQ	ID
Credit 7.1					

Heat Island Effect

Non-Roof

1 point

Intent

Reduce heat islands (thermal gradient differences between developed and undeveloped areas) to minimize impact on microclimate and human and wildlife habitat.

Requirements

Provide shade (within 5 years) and/or use light-colored/high-albedo materials (reflectance of at least 0.3) and/or open grid pavement for at least 30% of the site's non-roof impervious surfaces, including parking lots, walkways, plazas, etc.; OR place a minimum of 50% of parking spaces underground or covered by structured parking; OR use an open-grid pavement system (less than 50% impervious) for a minimum of 50% of the parking lot area.

Submittals

- ❑ Provide the LEED Letter Template, signed by the civil engineer or responsible party, referencing the site plan to demonstrate areas of paving, landscaping (list species) and building footprint, and declaring that:
  - ❑ A minimum of 30% of non-roof impervious surfaces areas are constructed with high-albedo materials and/or open grid pavement and/or will be shaded within five years
  - ❑ OR a minimum of 50% of parking spaces have been placed underground or are covered by structured parking
  - ❑ OR an open-grid pavement system (less than 50% impervious) has been used for a minimum of 50% of the parking lot area.

Heat Island Effect

Roof

1 point

Intent

Reduce heat islands (thermal gradient differences between developed and undeveloped areas) to minimize impact on microclimate and human and wildlife habitat.

Requirements

Use ENERGY STAR® compliant (highly reflective) AND high emissivity roofing (emissivity of at least 0.9 when tested in accordance with ASTM 408) for a minimum of 75% of the roof surface; OR install a "green" (vegetated) roof for at least 50% of the roof area. Combinations of high albedo and vegetated roof can be used providing they collectively cover 75% of the roof area.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, civil engineer or responsible party, referencing the building plan and declaring that the roofing materials comply with the ENERGY STAR® Label requirements and have a minimum emissivity of 0.9. Demonstrate that high-albedo and vegetated roof areas combined constitute at least 75% of the total roof area.

OR

- ❑ Provide the LEED Letter Template, signed by the architect, civil engineer or responsible party, referencing the building plan and demonstrating that vegetated roof areas constitute at least 50% of the total roof area.

Summary of Referenced Standards

ASTM E408-71(1996)e1—Standard Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques, www.astm.org, (610) 832-9585

This standard describes how to measure total normal emittance of surfaces using a portable inspection-meter instrument. The test methods are intended for large surfaces where non-destructive testing is required. See the standard for testing steps and a discussion of thermal emittance theory.

ASTM E903-96—Standard Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres, www.astm.org, (610) 832-9585

Referenced in the ENERGY STAR roofing standard, this test method uses spectrophotometers and need only be applied for initial reflectance measurement. Methods of computing solar-weighted properties from the measured spectral values are specified. This test method is applicableto materials having both specular and diffuse optical properties.Except for transmitting sheet materials that are inhomogeneous, patterned, or corrugated, this test method is preferred over Test Method E1084.

The ENERGY STAR roofing standard also allows the use of reflectometers to measure solar reflectance of roofing materials. See the roofing standard for more details.

EPA Energy Star Roofing Guidelines

U.S. Environmental Protection Agency ENERGY STAR® Program, www.energystar.gov, (888) 782-7937

The EPA's ENERGY STAR program allows for voluntary partnerships between the U.S. Department of Energy, the U.S. Environmental Protection Agency, product manufacturers, local utilities, and retailers. ENERGY STAR is dedicated to promoting energy efficiency, reducing air pollution, and saving money for businesses and residences through decreased energy use. In addition to several other building product categories, the ENERGY STAR program identifies roofing products that reduce the amount of air-conditioning needed in buildings, and can reduce energy bills by up to 50% (source: EPA). Roofing products with the ENERGY STAR logo meet the EPA criteria for reflectivity and reliability. Roof solar reflectance requirements for ENERGY STAR roofing products are summarized in **Table 1**.

See the ENERGY STAR Roofing Web site for technical criteria, a list of qualifying products and additional information.

Table 1: EPA Energy Star Roof Criteria

Roof Type	Slope	Initial Solar Reflectance	3-Year Solar Reflectance
Low-Slope Roof	≤ 2:12	0.65	0.50
Steep-Slope Roof	> 2:12	0.25	0.15

Credit Synergies

SS Prerequisite 1
Erosion & Sedimentation Control

SS Credit 1
Site Selection

SS Credit 2
Urban Redevelopment

SS Credit 4
Alternative Transportation

SS Credit 5
Reduced Site Disturbance

SS Credit 6
Stormwater Management

WE Credit 1
Water Efficient Landscaping

EA Credit 1
Optimize Energy Performance

MR Credit 1
Building Reuse

EQ Credit 7
Thermal Comfort

Green Building Concerns

As the built environment grows and replaces natural settings, it also relinquishes associated ecological services. Vegetation cools the area surrounding it via shade and evapotranspiration. The use of dark, nonreflective surfaces for parking, roofs, walkways and other surfaces contributes to heat island effects created when heat from the sun is absorbed and radiated back to surrounding areas. As a result of heat island effects, ambient temperatures in urban areas can be artificially elevated by more than 10°F when compared with surrounding suburban and undeveloped areas. This results in increased cooling loads in the summer, requiring larger HVAC equipment and energy for building operations. Heat island effects can be mitigated through the application of shading and the use of materials that reflect the sun's heat instead of absorbing it.

Figure 1 illustrates heat island effects in various cities throughout the United States. The greater amount of cooling degree-days in urban locations means that air-conditioning systems must work harder and use more energy to maintain thermal comfort in buildings.

Environmental Issues

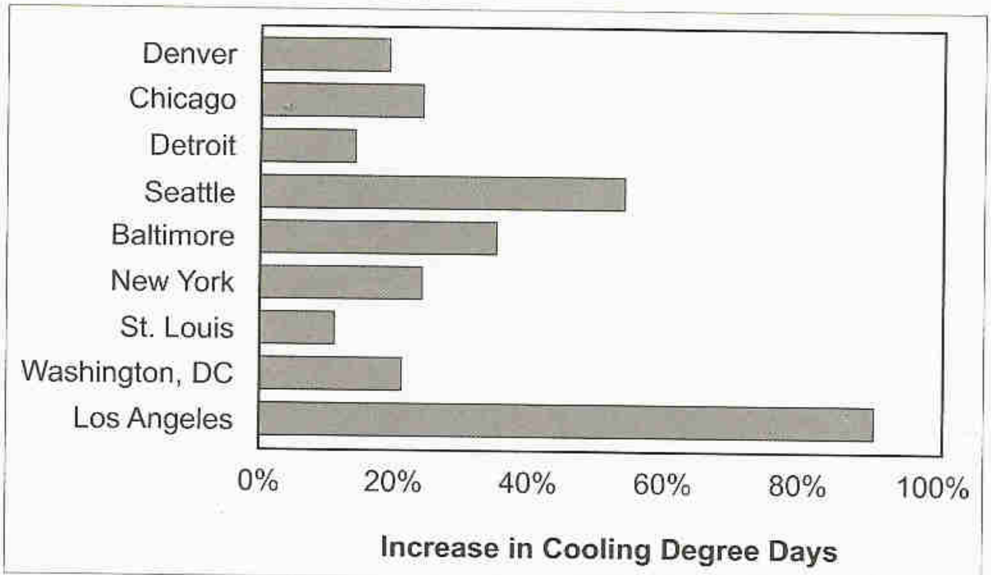
Heat island effects are detrimental to site habitat, wildlife and migration corridors. Plants and animals are sensitive to higher temperatures and may not thrive in areas that are unnaturally hot. Reduction of heat island effect minimizes disturbance of local microclimates. This can reduce summer cooling loads that in turn reduce energy use and infrastructure requirements.

Economic Issues

According to the EPA, about $40 billion is spent annually in the United States to air-condition buildings—one-sixth of all electricity generated in a year. Reduction in heat islands lowers the cost of cooling and HVAC equipment needs. Energy to cool buildings is a substantial cost over a building's lifetime.

Higher initial costs may result from installation of additional trees and architectural shading devices. However, these items have an acceptable payback when integrated into a whole systems approach that maximizes energy savings.

Figure 1: Percentage Increase in Cooling Degree Days for Select Cities



Design Approach

Strategies

Shade constructed surfaces (e.g. roof, roads and sidewalks) on the site with landscape features and minimize the overall building footprint. Consider replacing constructed surfaces with vegetated and/or permeable surfaces such as garden roofs and open grid paving or specify high-albedo materials to reduce heat absorption.

Technologies: Non-Roof

Paving Materials generally exhibit low reflectance. Asphalt's reflectance ranges from 0.05 to 0.10 when new and 0.10 to 0.15 when weathered. Standard gray-cement concrete reflectance is 0.35 to 0.40 when new and 0.20 to 0.30 when weathered. White-cement concrete reflectance is 0.70 to 0.80 when new and 0.40 to 0.60 when weathered. Note that the stated reflectance values are for pavements created in a laboratory. Concrete made with white cement may cost up to twice as much as that made with gray cement. Some blended cements (e.g., slag cements) are very light in color and cost the same as gray cement (Source: "Albedo: A Measure of Pavement Surface Reflectance," R&T Update #3.05, June 2002, American Concrete Pavement Association, www.pavement.com/techserv/RT3.05.pdf). Because pavement is ubiquitous, even a small improvement in albedo can make an impact. A simulation by Lawrence Berkeley National Laboratory predicted that increasing the reflectivity of 1250 km of pavement in Los Angeles by 0.25 would result in $15 million worth of energy savings and reduce smog-related medical and lost-work expenses by $76 million per year.

Coatings and integral colorants can be used in parking surfaces to improve solar reflectance. If reflective coatings, light concrete or gravel cannot be used, consider an open-grid paving system that increases perviousness by at least 50%, which remains cooler because of evaporation.

Vegetation can shade buildings and pavements from solar radiation and cool the air through evapotranspiration. Provide shade using native or climate-tolerant trees, large shrubs and non-invasive vines. Trellises and other exterior structures can support vegetation to shade on parking lots, walkways and plazas. Deciduous trees allow buildings to benefit from solar heat gain during the winter months. On site locations where tree planting is not possible, use architectural shading devices to block direct sunlight radiance.

Technologies: Roof

To maximize energy savings and minimize heat island effects, materials must exhibit a high solar reflectance and a high thermal emittance over the life of the product. Read the manufacturer's data when selecting a product based on a material's reflective properties. Not all manufacturers conduct solar reflectance and thermal emittance testing as a matter of course, although research on urban heat islands has helped to expose the problem and encourage such testing. Far more often, manufacturers measure visible reflectance.

Visible reflectance correlates to solar reflectance, but the two quantities are not equal because solar gain covers a wider range of wavelengths than visible light. A material that exhibits a high visible reflectance usually has a slightly lower solar reflectance. For example, a good white coating with a visible reflectance of 0.8 typically has a solar reflectance of 0.7. Therefore, it is necessary to measure the solar reflectance of the material even if the visible reflectance is known.

Visit the ENERGY STAR® Web site to look for compliant roofing products and cross-reference with the emissitance data on the Lawrence Berkeley National Laboratory's Cool Roofing Materials Database (eetd.lbl.gov/CoolRoofs) and the Cool Roof Rating Council Web site (www.coolroofs.org).

Table 2 provides example values to give a general idea of initial solar reflectance and infrared emittance for common roofing materials. Typically, white roofing products exhibit higher performance characteristics than nonwhite products. Performance varies by roofing material as well as brand.

The information below is a summary of relevant information from the Lawrence Berkeley National Laboratory's Cool Roofing Materials Database.

Asphalt Roofing exhibits rather low reflectance. Premium white shingles are only about 30% reflective, and other colors reflect less. Thermal emittance is generally high. Thus, white asphalt roofing might achieve credit requirements for a steep-slope application.

Coatings contain transparent polymeric materials and a white pigment to make them opaque and reflective. White coatings typically reflect 65% or more of the sun's energy and protect the polymer material and/or substrate underneath from UV damage. Coatings are applied in thicknesses of at least 20 mils (for maximum reflectance), and up to 50 mils (for greater durability). Reflectivity performance will benefit from occasional cleaning. Tinted (colored) coatings cost more and reflect less sunlight.

Garden Roofs minimize heat island effects and have aesthetic value. Garden roofs or green roofs are vegetated surfaces that capture rainwater and return a portion of it back to the atmosphere through evapotranspiration, which cools trees and the surrounding air. Vegetation experiences lower peak temperatures—60 to 100 degrees Fahrenheit compared to 190 degrees on traditional rooftops—because it contains moisture. Garden roofs can potentially save energy used for heating and cooling. Some garden roofs require plant maintenance and are considered active gardens, while other garden roofs have grasses and plants that require no maintenance or watering. All types of garden roofs require periodic inspection but are expected to have longer lifetimes than conventional roofs because the underlying waterproof membrane is shielded from the effects of ultraviolet radiation and weather.

Membrane Roofing is fabricated from strong, flexible, waterproof materials. There are four types of cool roofing membranes: EPDM, CSPE, PVC and TPO. These membranes typically exhibit solar reflectance of 0.75. When a dark membrane (or other roofing such as modified bitumen) is surfaced with roofing granules such as gravel, the roof has the solar reflectance of asphalt shingles, which is quite low.

Metal Roofing is typically steel or aluminum based, although there is still a small amount of copper and tin roofing used today. Bare and coated metal roofing products typically have a solar reflectance of 60% to 80%, and a low thermal emittance.

Table 2: Cool Roofing Materials

Roofing Material	Initial Solar Reflectance	Infrared Emittance
Coating, White	0.75	0.80 – 0.90
Membrane, White	0.75	0.80 – 0.90
Concrete Tile, White	0.73	0.80 – 0.90

Source: LBNL Cool Roofing Materials Database: eetd.lbl.gov/CoolRoofs
Note: This table shows common or possible values. Values vary per specific brand and product.

Synergies and Trade-Offs

Site selection and site planning have a significant effect on urban heat islands. Shading from evergreen trees and architectural shading devices may interfere with possible solar benefits. Deciduous trees will allow for solar heat gain during the winter months. Shading strategies should be integrated with solar strategies such as daylighting, solar heating and photovoltaic cells.

Garden roofs reduce stormwater volumes that may be collected for non-potable purposes. If water reuse and garden roof strategies are applied together, it is necessary to perform a water balance to determine the estimated volumes of water available for reuse. Stormwater runoff volumes from garden roofs depend on the local climate, depth of soil, type of plants used and other variables. However, all garden roofs decrease stormwater volumes substantially.

Light-colored pavements may create glare from reflection, posing a hazard to vehicle traffic and annoyance for building occupants. Buildings in very cold climates may not experience year-round energy benefits from reflective roofing and other surfaces, due to the inverse impact that lower heat absorptivity and higher emittance have on heating energy needs. Increasing the reflectance of a roof reduces annual cooling energy use in almost all climates.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit.

Shading of Non-Roof Impervious Surfaces

1. Identify all non-roof impervious surfaces on the project site and sum the total area.

2. Identify all trees that contribute shade to non-roof impervious surfaces. Calculate the shade coverage provided by these trees after five years on the non-roof impervious surfaces on June 21 at noon solar time to determine the maximum shading effect. Add the total area of shade provided for non-roof impervious surfaces.

3. Shade must be provided for at least 30% of non-roof impervious surfaces to earn this point (see **Equation 1**).

Impervious Surface Calculations

1. Calculate the total parking lot area of the project. Parking lots include parking spaces and driving lanes. Exclude parking spaces that do not receive direct sun (e.g., underground parking and stacked parking spaces), sidewalks, roadways and other impervious surfaces that cannot support vehicle loads.

2. Calculate the parking area that is designed with pervious paving materials.

3. A minimum of 50% of the total parking area must be comprised of paving materials that exhibit less than 50% imperviousness (see **Equation 2**).

Equation 1:

$$\text{Shade [\%]} = \frac{\text{Shaded Impervious Area [SF]}}{\text{Total Impervious Area [SF]}}$$

Equation 2:

$$\text{Pervious Portion [\%]} = \frac{\text{Pervious Parking Area [SF]}}{\text{Total Parking Area [SF]}}$$

Equation 3:

$$\text{Vegetated Roof [\%]} = \frac{\text{Vegetated Roof Area [SF]}}{\text{Total Roof Area [SF]}}$$

Vegetated Roof Calculations

1. Calculate the total roof area of the project. Deduct areas with equipment and other appurtenances.

2. Calculate the area of roof that is surfaced with a vegetated roof system.

3. Calculate the percentage of the total roof area that is covered with a green vegetated roof system (see **Equation 3**).

Resources

Web Sites

American Concrete Pavement Association

www.pavement.com, 847-966-2272

See R&T Update #3.05, June 2002, "Albedo: A Measure of Pavement Surface Reflectance," www.pavement.com/techserv/RT3.05.pdf, for reflectance data and related information.

Cool Roof Rating Council

www.coolroofs.org, (866) 465-2523

Created in 1998 to develop accurate and credible methods for evaluating and labeling the solar reflectance and thermal emittance (radiative properties) of roofing products and to disseminate the information to all interested parties.

ENERGY STAR® Roofing Products

www.energystar.gov, (888) 782-7937

Provides solar reflectance levels required to meet U.S. EPA ENERGY STAR labeling requirements, a list of compliant products (by manufacturer) for low-slope and steep-slope roofs, and additional information.

Greenroofs.com

www.greenroofs.com

An independent clearinghouse for information about vegetated roofs.

Lawrence Berkeley National Laboratory Heat Island Group

eetd.lbl.gov/HeatIsland/graphic, 510-486-7437

Presents research on the effects of heat islands and provides specific information and data on roofing materials. For reflectance and emissivity data, see eetd.lbl.gov/CoolRoofs.

Sacramento Cool Community Program

www.energy.ca.gov/coolcommunity/strategy/coolpave.html

A program of the Sacramento Tree Foundation that promotes the use of vegetation strategies, cool roofing and cool pavements to reduce the city's heat island. Sacramento's parking lot shading ordinance is provided, as well as other resources helpful for local governments.

Definitions

Albedo is synonymous with solar reflectance (see below).

Heat Island Effects occur when warmer temperatures are experienced in urban landscapes compared to adjacent rural areas as a result of solar energy retention on constructed surfaces. Principal surfaces that contribute to the heat island effect include streets, sidewalks, parking lots and buildings.

Infrared or Thermal Emittance is a parameter between 0 and 1 (or 0% and 100%) that indicates the ability of a material to shed infrared radiation (heat). The wavelength range for this radiant energy is roughly 3 to 40 micrometers. Most building materials (including glass) are opaque in this part of the spectrum, and have an emittance of roughly 0.9. Materials such as clean, bare metals are the most important exceptions to the 0.9 rule. Thus clean, untarnished galvanized steel has low emittance, and aluminum roof coatings have intermediate emittance levels.

Open-Grid Pavement is defined for LEED purposes as pavement that is less than 50% impervious.

Solar Reflectance (albedo) is the ratio of the reflected solar energy to the incoming solar energy over wavelengths of approximately 0.3 to 2.5 micrometers. A reflectance of 100% means that all of the energy striking a reflecting surface is reflected back into the atmosphere and none of the energy is absorbed by the surface. The best standard technique for its determination uses spectro-photometric measurements with an integrating sphere to determine the reflectance at each different wavelength. An averaging process using a standard solar spectrum then determines the average reflectance (see ASTM Standard E903).

Underground Parking is a "tuck-under" or stacked parking structure that reduces the exposed parking surface area.

Light Pollution Reduction

SS	WE	EA	MR	EQ	ID
Credit 8					

1 point

Intent

Eliminate light trespass from the building and site, improve night sky access and reduce development impact on nocturnal environments.

Requirements

Meet or provide lower light levels and uniformity ratios than those recommended by the Illuminating Engineering Society of North America (IESNA) *Recommended Practice Manual: Lighting for Exterior Environments* (RP-33-99). Design exterior lighting such that all exterior luminaires with more than 1000 initial lamp lumens are shielded and all luminaires with more than 3500 initial lamp lumens meet the Full Cutoff IESNA Classification. The maximum candela value of all interior lighting shall fall within the building (not out through windows) and the maximum candela value of all exterior lighting shall fall within the property. Any luminaire within a distance of 2.5 times its mounting height from the property boundary shall have shielding such that no light from that luminaire crosses the property boundary.

Submittals

- ❑ Provide the LEED Letter Template, signed by a lighting designer or an appropriate party, declaring that the credit requirements have been met.

Summary of Referenced Standard

IESNA Recommended Practice Manual: Lighting for Exterior Environments (IESNA RP-33-99)

Illuminating Engineering Society of North America, www.iesna.org, (212) 248-5000

This standard provides general exterior lighting design guidance and acts as a link to other IESNA outdoor lighting Recommended Practices (RPs). IESNA RP documents address the lighting of different types of environments. RP-33 was developed to augment other RPs with subjects not otherwise covered and is especially helpful in the establishment of community lighting themes and in defining appropriate light trespass limitations based on environmental area classifications. RP-33 addresses visual issues such as glare, luminance, visual acuity and illuminance. Also covered are exterior lighting design issues including community-responsive design, lighting ordinances, luminaire classification, structure lighting, and hardscape and softscape lighting. Light level recommendations in RP-33 are lower than in many other RPs, since RP-33 was written to address environmentally sensitive lighting.

Another useful Recommended Practice is RP-20-98, "Lighting for Parking Facilities." RP-20 discusses lighting design issues and makes light level recommendations for open and covered parking facilities. Not all the light level recommendations in the RP-20, or in any of the RPs, are appropriate for lighting in environmentally sensitive areas, so it is important to try to use the lowest recommended values. It is also important to recognize that, as a whole, different IESNA RP documents are not in agreement on all lighting issues and many of the RPs will be revised to include recommendations based on environmental zones. The designer must interpret related documents to find a recommendation that uses the lowest light levels while still addressing specific project issues. **Table 1** provides suggested light trespass limitations based on different types of environmental zones. Illuminance values are measured at the eye on a plane perpendicular to the line-of-sight.

Table 1: Light Trespass Limitations

Environmental Zone	Description	Recommended Maximum Illuminance Levels [fc]
E1: Intrinsically Dark	Parks and residential areas where controlling light pollution is a high priority	0.1
E2: Low Ambient Brightness	Outer urban and rural residential areas	0.1
E3: Medium Ambient Brightness	Urban residential areas	0.2
E4: High Ambient Brightness	Urban areas having both residential and commercial use and experiencing high levels of nighttime activity	0.6

Note: Table 1 has been adapted from IESNA RP-33-99. "Post Curfew" recommendations have been used for all values to ensure that light trespass is minimized for each environmental zone. It is recognized that in situations where the property line is very close to the area of development (commonly referred to as "zero property line"), and where lighting is required for emergency egress purposes, it may not be possible to meet the Table 1 recommendations. These situations should be carefully explained and documented.

SS	WE	EA	MR	EQ	ID

Credit 8

Green Building Concerns

Outdoor lighting is necessary for illuminating connections between buildings and support facilities such as sidewalks, parking lots, roadways and community gathering places. However, light trespass from poorly designed outdoor lighting systems can affect the nocturnal ecosystem on the site, and light pollution limits night sky access. Through thoughtful design and careful maintenance, outdoor lighting can address night sky visibility issues and site illumination requirements, while minimizing the negative impact on the environment.

Environmental Benefits

Sensitively designed outdoor lighting can extend access and use of many areas into the nighttime hours. We can gain a unique appreciation for a place at night because of sensitively and creatively designed lighting systems. But any time lighting is added to an exterior environment, light pollution and the potential for light trespass increase. Even with the best full cutoff luminaires and the lowest wattage lamp packages, the added light will be reflected off surfaces and into the atmosphere. Using the minimum amount of lighting equipment, limiting or eliminating all landscape lighting, and avoiding light pollution and trespass through the careful selection of lighting equipment and controls allow nocturnal life to thrive while still providing for nighttime activity.

Economic Benefits

Carefully designed exterior lighting solutions can reduce infrastructure costs and energy use when compared to common practice solutions. Energy and maintenance savings over the lifetime of the project can be substantial.

Community Benefits

Minimizing light pollution and trespass allows for night sky access by the surrounding community. Another key benefit is better visual comfort and improved visibility. Sensitively designed lighting systems that minimize glare and provide more uniform light at lower levels will help create aesthetically pleasing environments that are safer and more secure. A carefully designed and maintained outdoor lighting system can help a project be a non-intrusive member of the community.

Design Approach

Strategies

Eliminate all unshielded fixtures (floodlights) on the project site. Interpret between existing standards and design for the lowest possible light levels while addressing safety, security, access, way finding, identification and aesthetics. Use IESNA designation "full cutoff" luminaires for lamp packages with more than 3500 initial lumens and provide shielding for luminaires with lamps having more than 1000 initial lumens. The shielding of low brightness luminaires can vary depending on the ambient brightness of the surrounding environment and on the type of environmental zone (as described in IESNA RP-33-99) that best describes the project. For example, in sites where there is low ambient brightness and there is a great potential for glare and light trespass, even sources with very low lumen output may need to be fully shielded to maintain the highest levels of visual comfort. In these situations, a luminaire with IESNA full cutoff designation might be appropriate. In high ambient brightness areas where less shielding is required, a luminaire with IESNA semi-cutoff or non-cutoff designations may be appropriate. The designer should take care in making the decision on how much shielding is required.

Minimize or eliminate lighting of architectural and landscape features. Where lighting is required for safety, security,

Credit Synergies

SS Credit 1
Site Selection

SS Credit 4
Alternative Transportation

SS Credit 5
Reduced Site Disturbance

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

egress or identification, utilize downlighting techniques rather than uplighting. For example, in environments that are intrinsically dark, no landscape features should be lighted, and architectural lighting should be designed only as a last resort when other strategies have failed to provide the minimum amount of required lighting. In areas of high ambient brightness, some low level (subtle) lighting of features, facades or landscape areas may be appropriate in pedestrian environments or for identification and way finding in other areas where light trespass is not likely to be an issue. However, even in areas of high ambient brightness, all non-essential lighting, including landscape and architectural lighting, should be minimized or turned off after hours. If shielded, low brightness sources are used to selectively light features, they should be properly aimed so that light from the luminaires cannot be measured across project boundaries. In all cases, controls should be used wherever possible to turn off lighting after normal operating hours or in post-curfew periods. Consider at least the following strategies when designing the exterior lighted environment:

1. Employ a lighting professional to assess the project's lighting needs and provide recommendations based specifically on lighting for a sustainable design environment.

2. Carefully review and respond to any local or regional lighting ordinances or bylaws that might impact the lighting design for the project site.

3. Consult IESNA RP-33 and determine the type of environmental zone that the project falls under from Intrinsically Dark (Zone E1) to High Ambient Brightness (Zone E4). Understand the design implications of the environmental zone that best fits the project and study neighboring areas to identify potential light trespass problems.

4. Use the least amount of lighting equipment possible to achieve the goals of the project, but balance the quantity of equipment used with the need to provide for glare control and uniform lighting. In most cases, it is better to have two luminaires with lower light output and good glare control than one higher output luminaire.

5. Select all lighting equipment carefully. Any type of luminaire, whether it is full cutoff, semi-cutoff or non-cutoff, can produce excessive brightness in the form of glare. For example, horizontal lamp positions in full cutoff luminaires tend to produce much less glare than vertical lamps. Selecting high-performance equipment of good quality is not only essential in maintaining visual quality, but also will quickly pay for itself in reduced maintenance costs.

6. Design exterior lighting to produce minimal upward illumination from direct or reflected light sources. Select luminaire locations carefully to control glare and contain light within the design area. Pay special attention to luminaires that are located near the property line to ensure that no measurable light from these luminaires crosses the project boundary.

7. Use the minimum amount of light necessary and only light areas that require it. Design and develop a control scheme to minimize or turn lighting off after hours or during post-curfew periods.

8. Create a computer model of the proposed electric lighting design and simulate system performance. Use this tool to provide point by point horizontal illuminance information or an isofootcandle contour map demonstrating that illuminance values are zero (or near zero) at the project boundary. Where luminaires are within 2.5 times their mounting height from the project boundary and the light levels are not zero at the boundary, light trespass is more likely to be a problem. In this case a simple calculation can be performed to show that the "line of sight" illuminance limits for light trespass listed in **Table 1** have been met. A procedure for evaluating light trespass is outlined in the calculations section.

9. After the lighting system is constructed, it should be commissioned to ensure that it is installed and operating properly. Maintenance should be performed on the system on a regular basis to ensure that it continues to operate correctly, and that light pollution and trespass are minimized.

Technologies

Design site lighting and select lighting equipment and technologies to have minimal impact off-site and minimal contribution to sky glow (light pollution). Employ luminaires with the proper optics and shielding. Use low-reflectance ground covers and minimize the use of highly reflective and specular surfaces that may be a source of reflected glare. When surfaces are used to reflect light, use lower wattage light sources to reduce light levels and overall brightness. Even low brightness luminaires should be aimed carefully to eliminate glare and light trespass. Aiming angles greater than 45 degrees above vertical should be avoided. Luminaires with lockable aiming should be used in instances where glare control is very important or where special aiming must be maintained. Use motion sensors, photocells, stepped dimming, automatic switching and time clocks to control exterior lighting during pre- and post-curfew periods. Exterior signs that must be lighted should be made as small as possible and internally lighted signs should have letters and images on a dark background. Externally lighted signs should be downlighted from the top whenever possible, and the luminaires used should be full cutoff with additional shielding as necessary to control stray light that does not illuminate the sign.

Synergies and Trade-Offs

Exterior lighting strategies are affected by the transportation program, as well by as the total area of developed space on the project site. In addition to energy efficiency, the exterior lighting system requires commissioning and measurement & verification. ASHRAE 90.1–1999 (see EA Credit 1) includes provisions for exterior facade lighting and addresses automatic lighting controls, control devices, minimum lamp efficacy and lighting power limits. The standard requires separate calculations for interior and exterior lighting loads and, thus, trade-offs between interior and exterior loads are not permitted. See the standard for more information.

Education is one of the most important aspects of sustainable lighting design. Some people believe incorrectly that lower levels of outdoor lighting will create safety or security problems. However, it can be easily demonstrated that the quality of the lighting design has a much greater impact on safety and the perception of security than does light level. Low light level environments with good uniformity of light and controlled glare are often environments that provide good visibility. Environments with good visibility are usually safer and more secure. These environments also use less energy, and they cause less light pollution and trespass. It is not only acceptable, but also sometimes preferred not to light an environment.

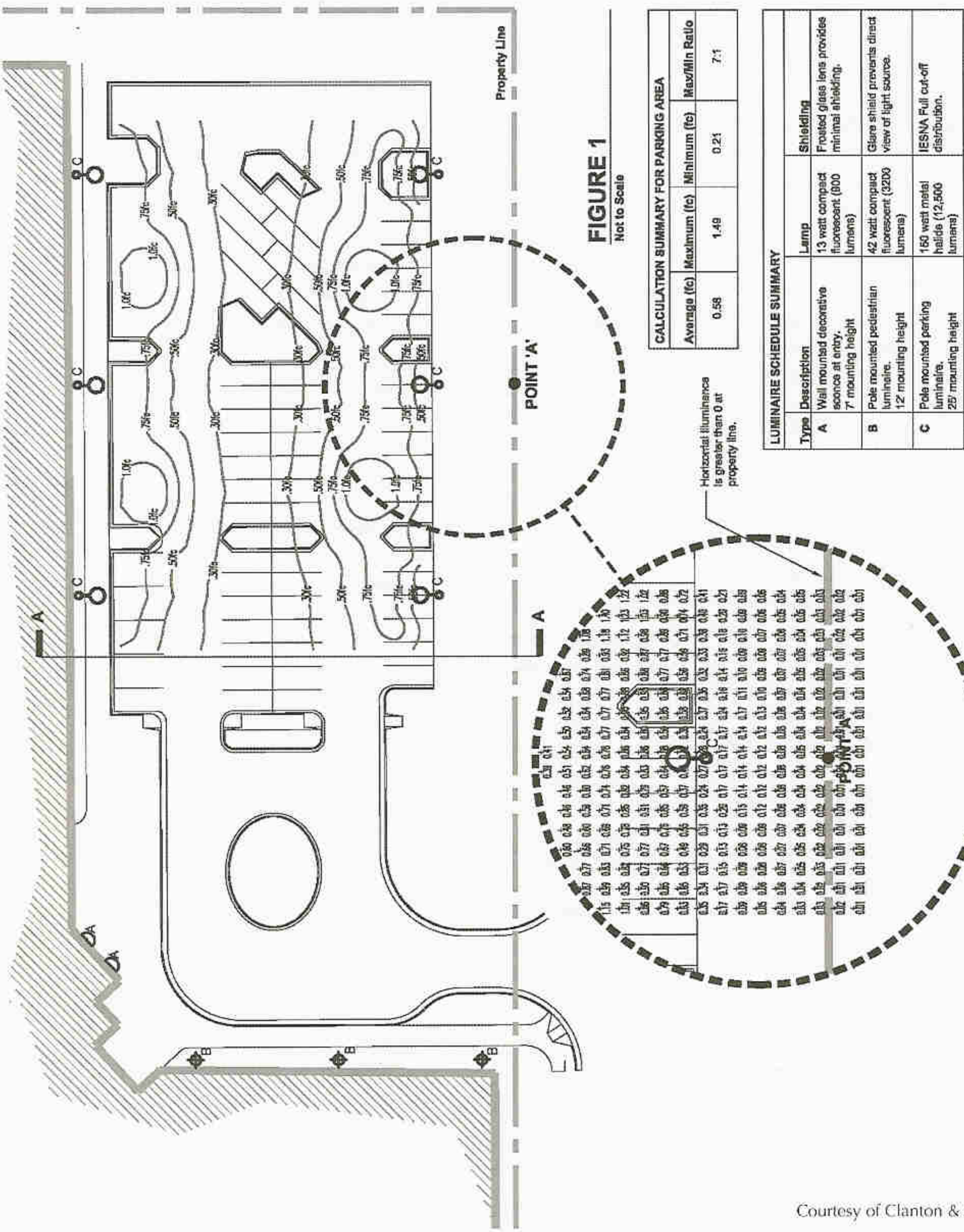
Calculations

The following materials are recommended to support the credit:

1. Provide an exterior site plan showing:

- All buildings, parking and pedestrian areas, trees and landscape features
- A luminaire schedule showing the type, style, location, height, orientation, shielding and aim-

Figure 1: Example of a Site Lighting Plan



CALCULATON SUMMARY FOR PARKING AREA			
Average (fc)	Maximum (fc)	Minimum (fc)	Max/Min Ratio
0.58	1.49	0.21	7:1

LUMINAIRE SCHEDULE SUMMARY			
Type	Description	Lamp	Shielding
A	Wall mounted decorative sconce at entry. 7' mounting height	13 watt compact fluorescent (800 lumens)	Frosted glass lens provides minimal shielding.
B	Pole mounted pedestrian luminaire. 12' mounting height	42 watt compact fluorescent (3200 lumens)	Glare shield prevents direct view of light source.
C	Pole mounted parking luminaire. 25' mounting height	150 watt metal halide (12,500 lumens)	IESNA Full cut-off distribution.

Courtesy of Clanton & Associates

ing of all light sources and all lighting control devices

- A computer-generated lighting calculation indicating horizontal illuminance on a 10'x10' minimum grid and a minimum of 10 feet beyond the lot or property boundary for areas that are representative of each design condition (Isofootcandle contours are also acceptable for showing light levels). Include maximum to minimum uniformities for each specific type or area of use, and any associated light loss factors (LLF) used in the procedure. RP-33 references appropriate RPs for various design conditions. Consult these RPs for recommended criteria.

2. Provide a calculation for "line of sight illuminance" (light trespass) for luminaires near the property line where the calculated light levels did not reach zero. See **Table 1** for light trespass limits. To calculate line of site illuminance (E_{line}): multiply the horizontal illuminance (E_{horz}) (at ground level for LEED calculation purposes) on the property line by one over the sine of the angle ($1/\sin\theta$), where the angle is between the ground plane at the point of measurement and a line drawn from that point to the light source.

3. Catalog cut sheets for all exterior luminaires with more that 3500 lumen lamps, demonstrating that they meet the Full Cutoff IESNA Classification, and indicating lamp type, distribution type and any additional shielding.

4. Catalog cut sheets for all exterior luminaires with more than 1000 lumen lamps, demonstrating that they are appropriately shielded for the project's Environmental Zone.

5. Provide interior lighting design drawings for the building's perimeter areas demonstrating that the maximum candela value of interior lighting falls within the building and not out through the windows.

The site lighting plan illustrated in **Figure 1** includes a parking lot and office building in an area of low ambient brightness (Environmental Zone 2). The luminaire schedule describes the light source used in each luminaire and the shielding classification provided to meet the credit requirements. Note that a summary is used in this example for illustration purposes. A complete schedule is required.

The site lighting plan indicates major site features, luminaire layout and calculated point-by-point illuminance values at ground level on a grid that is less than 10'x10', or indicated by isofootcandle lines. The maximum to minimum uniformity ratio is 7:1, which meets the criteria in IESNA RP-20, which RP-33 references for parking facilities.

The lighting point-by-point calculation plan shows that the illuminance value at the property line does not reach 0 at Point A (E_{horz} at Point A is 0.01fc). Therefore, the "line of site illuminance" must be calculated for the adjacent luminaire. The calculation $E_{line}=(1/\sin 33°)(0.01\text{fc})$ yields a result of 0.018fc. Since this value is less than the 0.1fc limitation given by IESNA RP-33-99, the LEED requirement has been met for Point A.

The angle of the maximum candela value for interior luminaires is determined from the luminaire photometry. It is then diagramed on the building section. The site and building sections in **Figure 2** illustrates that the maximum candela values for luminaire types "X" and "Y" fall within the building.

Courtesy of Clanton & Associates

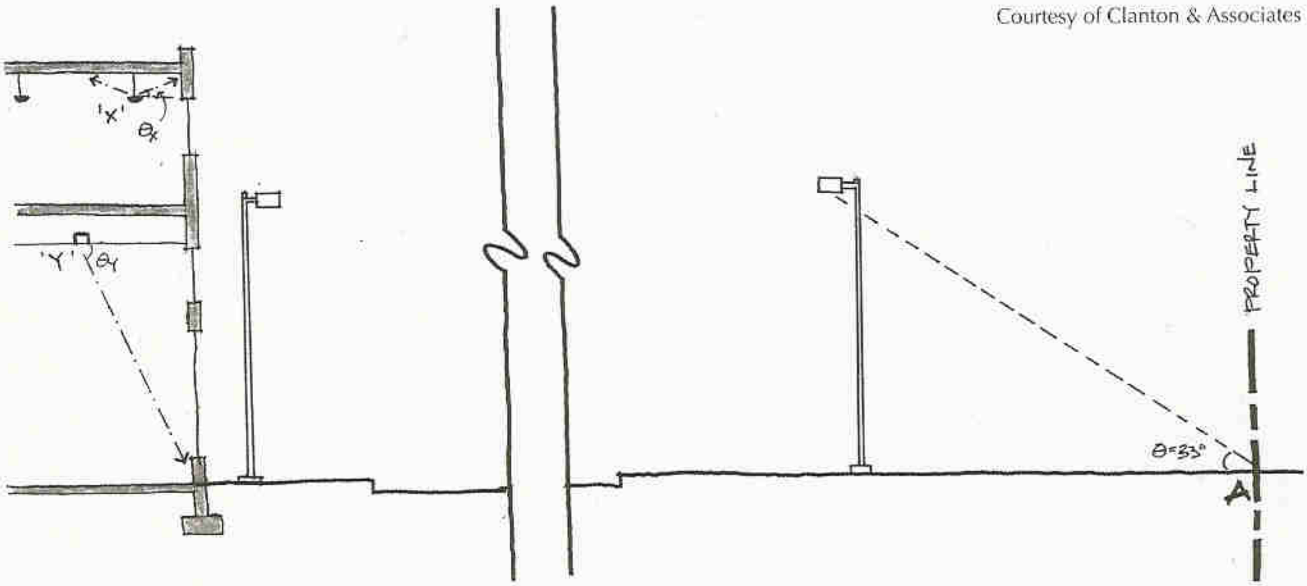


Figure 2: Building and Site Sections

Resources

Web Sites

Illuminating Engineering Society of North America

www.iesna.org, (212) 248-5000

The most comprehensive source for lighting information.

International Dark Sky Association

www.darksky.org, (520) 293-3198

A nonprofit organization dedicated to providing education and solutions for light pollution and light trespass.

Lighting Research Center

www.lrc.rpi.edu

A leading university-based research center devoted to providing objective information about lighting technologies, applications and products to aid facility managers, utilities, lighting designers, engineers and electrical contractors. The Web site includes the National Lighting Product Information Program (NLPIP), which provides free publications about lighting topics (such as light pollution) and products.

New England Light Pollution Advisory Group (NELPAG)

cfa-www.harvard.edu/cfa/ps/nelpag.html

A volunteer group that educates professionals and the public on the virtues of efficient, appropriately sited glare-free outdoor night lighting by addressing safety, right to privacy, light trespass, night sky vision and energy issues.

Print Media

Outdoor Lighting Manual for Vermont Municipalities, PTI Publications Center, (301) 490-2188, Order No. DG/95-308.

Definitions

Curfew Hours are locally determined times when greater lighting restrictions are imposed.

Cutoff Angle is the angle between the vertical axis of a luminaire and the first line of sight (of a luminaire) at which the light source is no longer visible.

SS	WE	EA	MR	EQ	ID
Credit 8					

Illuminance is the amount of light falling on a surface, measured in units of footcandles (fc) or lux (lx).

A **Footcandle** (fc) is a measure of light falling on a given surface. One footcandle is equal to the quantity of light falling on a one-square-foot area from a one candela light source at a distance of one foot. Footcandles can be measured both horizontally and vertically by a footcandle or "light meter."

A **Full Cutoff** luminaire has zero candela intensity at an angle of 90 degrees above the vertical axis (nadir) and at all angles greater than 90 degrees from nadir. Additionally, the candela per 1000 lamp lumens does not numerically exceed 100 (10 %) at an angle of 80 degrees above nadir. This applies to all lateral angles around the luminaire.

Glare is the sensation produced by luminance within the visual field that is significantly greater than the luminance to which the eyes are adapted, which causes annoyance, discomfort or loss in visual performance and visibility

Light Pollution is caused by stray light from unshielded light sources and light reflecting off surfaces that enters the atmosphere where it illuminates and reflects off dust, debris and water vapor to cause an effect know as "sky glow." Light pollution can substantially limit visual access to the night sky, compromise astronomical research, and adversely affect nocturnal environments. Stray light that enters the atmosphere does not increase nighttime safety or security and needlessly consumes energy and natural resources.

Light Trespass is commonly thought of as "the light shining in my window." It is defined as obtrusive light that is unwanted, because of quantitative, directional or spectral attributes. Light trespass causes annoyance, discomfort, distraction or a loss of visibility

Luminance is what we commonly call brightness or the light coming from a surface or light source. Luminance is composed of the intensity of light striking an object or surface and the amount of that light reflected back toward the eye. Luminance is measured in footlamberts (fl) or candela per square meter (cd/m2).

Shielding is a non-technical term that describes devices or techniques that are used as part of a luminaire or lamp to limit glare, light trespass and light pollution.

Case Study

The Aspen Skiing Company Sundeck Restaurant
Aspen, Colorado

The Aspen Skiing Company Sundeck Restaurant is a LEED™ Version 1.0 Bronze Pilot Project located atop Aspen Mountain. Interior and exterior lighting plans were designed to minimize impacts on the surrounding natural areas. Blackout curtains were installed for interior service areas where unshielded fixtures are located to block light from spilling out of windows. Lighting fixtures were chosen carefully to eliminate direct glare from light sources and indirect glare from expected viewing angles. Reflectance of interior surfaces that can be viewed from off-site is limited to 40%. Exterior lighting is limited to code requirements and outdoor fixtures are baffled to reduce light trespass. All exterior lighting is automatically shut off at 11 pm. Reflective surfaces on the project site were minimized and snow is removed from below windows to reduce the potential for light reflection.


Courtesy of The Aspen Skiing Company

Owner
The Aspen Skiing Company

Water Efficiency

In the United States, approximately 340 billion gallons of fresh water are withdrawn per day from rivers, streams and reservoirs to support residential, commercial, industrial, agricultural and recreational activities. This accounts for about one-fourth of the nation's total supply of renewable fresh water. Almost 65% of this water is discharged to rivers, streams and other water bodies after use and, in some cases, treatment.

Additionally, water is withdrawn from underground aquifers. In some parts of the United States, water levels in these aquifers have dropped more than 100 feet since the 1940s. On an annual basis, the water deficit in the United States is currently estimated at about 3,700 billion gallons. In other words, Americans extract 3,700 billion gallons per year more than they return to the natural water system to recharge aquifers and other water sources.

On a positive note, U.S. industries today use 36% less water than they did in 1950 although industrial output has increased significantly. This reduction in water use is largely due to the rigorous water reuse strategies in industrial processes. In addition, the Energy Policy Act of 1992 mandated the use of water-conserving plumbing fixtures to reduce water use in residential, commercial and institutional buildings.

Using large volumes of water increases maintenance and life-cycle costs for building operations and increases consumer costs for additional municipal supply and treatment facilities. Conversely, facilities that use water efficiently can reduce costs through lower water use fees, lower sewage volumes to treat energy and chemical use reductions, and lower capacity charges and limits. Many water conservation strategies involve either no additional cost or rapid paybacks. Other water conservation strategies such as biological wastewater treatment, rainwater harvesting and graywater plumbing systems often involve more substantial investment.

Water efficiency measures in commercial buildings can easily reduce water usage by 30% or more. In a typical 100,000-square-foot office building, low-flow fixtures coupled with sensors and automatic controls can save a minimum of 1 million gallons of water per year, based on 650 building occupants each using an average of 20 gallons per day. Non-potable water volumes can be used for landscape irrigation, toilet and urinal flushing, custodial purposes and building systems. Utility savings, though dependent on the local water costs, can save thousands of dollars per year, resulting in rapid payback on water conservation infrastructure.

Overview of LEED™ Credits

WE Credit 1
Water Efficient Landscaping

WE Credit 2
Innovative Wastewater Technologies

WE Credit 3
Water Use Reduction

There are 5 points available in the Water Efficiency category.

SS	WE	EA	MR	EQ	ID
Credit 1.1					

Water Efficient Landscaping

50% Reduction

1 point

Intent

Limit or eliminate the use of potable water for landscape irrigation.

Requirements

Use high-efficiency irrigation technology OR use captured rain or recycled site water to reduce potable water consumption for irrigation by 50% over conventional means.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, engineer or responsible party, declaring that potable water consumption for site irrigation has been reduced by 50%. Include a brief narrative of the equipment used and/or the use of drought-tolerant or native plants.

SS	WE	EA	MR	EQ	ID

Credit 1.2

1 point
in addition to
WE 1.1

Water Efficient Landscaping

No Potable Use or No Irrigation

Intent

Limit or eliminate the use of potable water for landscape irrigation.

Requirements

Use only captured rain or recycled site water to eliminate all potable water use for site irrigation (except for initial watering to establish plants), OR do not install permanent landscape irrigation systems.

Submittals

- ❏ Provide the LEED Letter Template, signed by the responsible architect and/or engineer, declaring that the project site will not use potable water for irrigation. Include a narrative describing the captured rain system, the recycled site water system, and their holding capacity. List all the plant species used. Include calculations demonstrating that irrigation requirements can be met from captured rain or recycled site water.

OR

- ❏ Provide the LEED Letter Template, signed by the landscape architect or responsible party, declaring that the project site does not have a permanent landscape irrigation system. Include a narrative describing how the landscape design allows for this.

Summary of Referenced Standards

There is no standard referenced for this credit.

Green Building Concerns

Landscape irrigation practices in the United States consume large quantities of potable water. For example, in urban areas of Texas, residential and commercial landscape irrigation accounts for an estimated 25% of total water consumption. Irrigation typically uses potable water, although water volumes of lower quality water (i.e., non-potable water) are equally effective for irrigating landscapes. Sources of non-potable water volumes include captured rainwater from roof runoff as well as graywater from building systems (e.g., sinks and showers) or a municipal recycled water supply system. High-efficiency irrigation systems are another method to reduce potable water use for irrigation. These systems deliver up to 95% of the water supplied versus conventional irrigation systems that are as little as 60% efficient.

Environmental Issues

Native landscapes that have lower irrigation requirements tend to attract native wildlife, including birds, mammals and insects, creating a building site that is integrated with the natural surroundings. In addition, native plantings require less fertilizer and fewer pesticides and, thus, reduce water quality impacts.

Economic Issues

Utility rates for potable water are expected to escalate in future years as a result of overconsumption and finite potable water resources. Currently, the most effective strategy to avoid escalating water costs is simply to use less potable water.

The cost of irrigation systems can be reduced or eliminated through thoughtful irrigation planning. Although the cost for micro-irrigation systems is generally higher than for conventional systems due to additional design costs, the payback period can be rapid due to lower water use and maintenance requirements. Generally, micro-irrigation systems are comprised of fewer materials, rely on less mechanical components for operation, and are easy to repair in the event of breakage.

Initial landscaping costs can be reduced if the existing plants on the site are retained. These plants are typically well-adapted to the project site and reduce landscaping maintenance costs due to minimal water, chemical and energy requirements. Xeriscapes or dry landscapes are another way to reduce landscaping costs by eliminating the need for irrigation.

Community Issues

Water-efficient landscaping helps to conserve local and regional potable water resources. Maintaining natural aquifer conditions is important to providing reliable water sources for future generations. Consideration of water issues during planning can encourage development when resources can support it and prevent development if it exceeds the resource capacity.

Design Approach

Strategies

Perform a soil and climate analysis to determine which plants will adapt best to the site's soil and climate, and specify plants that are most suitable to site conditions. However, do not expect the resulting landscapes to require "no maintenance," as nearly all landscapes require some routine upkeep. Therefore, compile and follow a seasonal maintenance schedule for optimizing a healthy landscape. This schedule should address specific times for pruning, watering and pest inspection. In addition, use techniques such as integrated pest management, mulching, alternative mowing and composting to maintain plant health. These practices conserve water and help foster optimal soil conditions. Develop a landscaping water use baseline as described in the Calculations section.

Synergies

SS Prerequisite 1
Erosion & Sedimentation Control

SS Credit 1
Site Selection

SS Credit 5
Reduced Site Disturbance

SS Credit 6
Stormwater Management

SS Credit 7
Landscape and Exterior Design to Reduce Heat Islands

WE Credit 3
Water Use Reduction

EA Prerequisite 1
Fundamental Building Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 7
Thermal Comfort

EQ Credit 8
Daylight & Views

SS	WE	EA	MR	EQ	ID

Credit 1

Design the site landscape with indigenous plants. Also specify and install a diversity of plants that are adapted to site conditions (climate, soils and natural water availability) and that do not need watering from municipal potable water after establishment. It is up to the landscape designer to provide documentation that the species selected will not require permanent irrigation once established. The generally accepted timeframe for temporary irrigation is one to two years.

Specify and install a roof-water or groundwater collection system. Use metal, clay or concrete-based roofing materials and take advantage of gravity water flows whenever possible. Roofs made of asphalt or roofs with lead-containing materials contaminate collected rainwater and render it undesirable for reuse. The filtration of collected rainwater for irrigation can be achieved through a combination of graded screens and paper filters. It is important to check local rainfall quantity and quality as collection systems may be inappropriate in areas with very low rainfall. Also, rainwater that is highly acidic or has high mineral content may damage reuse systems. Conversely, rainwater may have a lower mineral content than the local water supply and may therefore be advantageous for use in appliances such as water heaters and washers.

Check with local health code departments for guidelines regarding the collection of rainwater, since such collection is not federally regulated. If collected rainwater is to be used for potable or irrigation purposes, certain health code departments might require back-flow prevention devices to avoid the risk of contaminating public drinking water supplies.

Technologies

High-efficiency irrigation strategies include micro-irrigation systems, moisture sensors, clock timers and weather database controllers. These systems are widely available and significantly more water-efficient than conventional irrigation systems.

Graywater systems can be used to recover water volumes from building sewage. Graywater consists of wastewater from lavatories, showers, washing machines and other building activities that do not involve human waste or food processing. These graywater volumes can be stored in cisterns on the site and used in the irrigation system. Also, stormwater volumes can be collected from hardscape surfaces on the site, such as roofing, and used in the landscape irrigation system.

Synergies and Trade-Offs

Landscape design is highly dependent on the site location and design. It may be advantageous to couple the landscape design with water reuse strategies. Landscape plantings may be designed to mitigate climate conditions and reduce overall energy consumption. Plants can be a natural aid to passive solar design, serve as windbreaks, and decrease noise. Irrigation and water reuse schemes will affect building energy performance and typically require commissioning and measurement & verification attention. High-efficiency irrigation systems do not work in the same manner as conventional irrigation systems and it is important to understand system operations. It is often necessary to train maintenance staff and to monitor regularly the irrigation system to ensure that it is working properly. The reuse of an existing building may dictate water reuse strategies. Landscape design may affect ventilation, daylighting and thermal comfort for the building.

Calculations

The following calculation methodology is used to support the credit submittals as listed on the first page of this credit. In order to quantify water-efficient landscaping measures, it is necessary to calculate irrigation volumes for the designed landscape irrigation system for the month of July and compare this with irrigation volumes required for a baseline landscape irrigation system. The resulting water savings is the difference between the two systems. The factors that must be calculated to determine irrigation volumes are explained in detail in the following paragraphs and summarized in **Table 1**.

The Landscape Coefficient (K_L) indicates the volume of water lost via evapotranspiration and is dependent on the landscape species, the microclimate and the planting density. The formula for determining the landscape coefficient is given in **Equation 1**.

The Species Factor (k_s) accounts for variation of water needs by different plant species. The species factor can be divided into three categories (high, average and low) depending on the plant species considered. To determine the appropriate category for a plant species, use plant manuals and professional experience. This factor is somewhat subjective but landscape professionals should have a general idea of the water needs of particular plant species. Landscapes can be maintained in acceptable condition at about 50% of the reference evapotranspiration (ET_0) value and thus, the average value of k_s is 0.5. (Note: If a species does not require irrigation once it is established, then the effective $k_s = 0$ and the resulting $K_L = 0$.)

Equation 1:

$$K_L = k_s \times k_d \times k_{mc}$$

The Density Factor (k_d) accounts for the number of plants and the total leaf area of a landscape. Sparsely planted areas will have lower evapotranspiration rates than densely planted areas. An average k_d is applied to areas where ground shading from trees is in the range of 60-100%. This is also equivalent to shrubs and ground cover shading 90-100% of the landscape area. Low k_d values are found where ground shading from trees is less than 60% or shrub and groundcover is less than 90%. For instance, a 25% ground shading from trees results in a k_d value of 0.5. In mixed landscape plantings where trees cover understory groundcover and shrubs, evapotranspiration increases. This represents the highest level of landscape density and the k_d value should be between 1.0 and 1.3.

The Microclimate Factor (k_{mc}) accounts for environmental conditions specific to the landscape, including temperature, wind and humidity. For instance, parking lot areas increase wind and temperature effects on adjacent landscapes. The average k_{mc} is 1.0 and this refers to conditions where the landscape evapotranspiration rate is unaffected by buildings, pavements, reflective surfaces and slopes. Higher k_{mc} conditions occur where evaporative potential is increased due

Table 1: Landscape Factors

Vegetation Type	Species Factor (k_s)			Density Factor (k_d)			Microclimate Factor (k_{mc})		
	low	average	high	low	average	high	low	average	high
Trees	0.2	0.5	0.9	0.5	1.0	1.3	0.5	1.0	1.4
Shrubs	0.2	0.5	0.7	0.5	1.0	1.1	0.5	1.0	1.3
Groundcovers	0.2	0.5	0.7	0.5	1.0	1.1	0.5	1.0	1.2
Mixed: trees, shrubs, groundcovers	0.2	0.5	0.9	0.6	1.1	1.3	0.5	1.0	1.4
Turfgrass	0.6	0.7	0.8	0.6	1.0	1.0	0.8	1.0	1.2

to landscapes surrounded by heat-absorbing and reflective surfaces or are exposed to particularly windy conditions. Examples of high k_{mc} areas include parking lots, west sides of buildings, west and south sides of slopes, medians, and areas experiencing wind tunnel effects. Low microclimate areas include shaded areas and areas protected from wind. North sides of buildings, courtyards, areas under wide building overhangs, and north sides of slopes are low microclimate areas. **Table 1** provides suggested values for k_s, k_{mc}, and k_d.

Once K_L is determined, the evapotranspiration (ET) rate of the specific landscape (ET_L) can be calculated. K_L is multiplied by the reference evapotranspiration (ET_0) to obtain ET_L as shown in **Equation 2**. The **evapotranspiration rate** is a measurement of the total amount of water needed to grow plants and crops. Different plants have different water needs, and thus different ET rates. Irrigation calculations are simplified by using ET_0, which is an average rate for a known surface, such as grass or alfalfa, used as a reference point and expressed in millimeters or inches.

The values for ET_0 in various regions throughout the United States can be found in regional agricultural data (see Resources section). The ET_0 for July is used in the LEED calculation because this is typically the month with the greatest evapotranspiration effects and, therefore, the greatest irrigation demands.

To calculate irrigation volumes, apply the **irrigation efficiency** (IE). **Table 2** lists irrigation efficiencies for sprinkler and drip irrigation systems.

The **Total Potable Water Applied** (TPWA) to a given area (A) is calculated in **Equation 3**.

This equation indicates that a smaller landscape area, a smaller ET_L value, and a larger IE value result in a lower TPWA value. This is sensible because smaller landscape areas require less water to irrigate, a smaller ET_L value means less water loss due to evapotranspiration, and a higher IE means that irrigation water is being used more efficiently.

Equation 2:

$$ET_L\,[in] = ET_0\,[in] \times K_L$$

To determine the water savings for the designed landscaping irrigation system, perform the above calculations for the **design case** as well as a baseline case.

1. Use **Table 1** to determine the appropriate landscape factors for each specific landscape area in the design case (e.g., k_s, k_{mc}, and k_d). Use a spreadsheet to summarize the different landscape areas and the associated factors.

2. Calculate the landscape coefficient (K_L) for each landscape area using the appropriate landscape factors and Equation 1.

3. Calculate the specific landscape evapotranspiration rate (ET_L) of each landscape area using the corresponding landscape coefficient (K_L) and the ET_L formula in Equation 2.

4. Calculate the TPWA to each landscape area using Equation 3 and the applicable surface area, specific landscape evapotranspiration rate and irrigation efficiency data.

Repeat the above steps for the **baseline case** using conventional plant species and plant densities as determined by the project's landscape consultant. Differences between the two cases result from plant species choices, plant densities and irrigation system choices. Planting types should approximately correspond in both the baseline and design cases (i.e., it is unreasonable to assume that

Table 2: Irrigation Types

Irrigation Type	IE
Sprinkler	0.625
Drip	0.90

Equation 3:

$$\text{TPWA [gal]} = \text{A [SF]} \times \frac{\text{ET}_\text{L}\text{ [in]}}{\text{IE}}$$

the baseline is 100% turfgrass if a project clearly intends to include trees, shrubs and planting beds). Do not change the landscape areas, microclimate factors or reference evapotranspiration rates.

An **example** of irrigation calculations is presented below. An office building in Austin, Texas, has a total site area of 6,000 square feet. The site consists of three landscape types: groundcover, mixed vegetation and turf grass. All of the site areas are irrigated with a combination of potable water and graywater harvested from the building. The reference evapotranspiration rate (ET_0) for Austin in July was obtained from the local agricultural data service and is equal to 8.12.

The high-efficiency landscape irrigation case utilizes drip irrigation with an efficiency of 90% and reuses an estimated 9,000 gallons of graywater during the month of July. **Table 3** shows the calculations to determine potable water use for the design case.

The baseline case uses the same reference evapotranspiration rate and total site area. However, the baseline case uses sprinklers for irrigation (IE = 0.625), does not take advantage of graywater harvesting, and uses only shrubs and turf grass. Calculations to determine potable water use for the baseline case are presented in **Table 4**.

The example illustrates that the design case has an irrigation water demand of 23,474 gallons. Graywater reuse provides 4,200 gallons towards the demand, and this volume is treated as a credit in the water calculation. Thus, the total potable water applied to the design case in July is 19,274 gallons. The baseline case has an irrigation demand of 62,518 gallons and reuses no graywater. The difference between the two cases results in potable water savings of 69% for the design case.

It is important to note that the LEED calculation provides an indication of the general efficiency gains provided by the green design. For more accurate under-

Table 3: Design Case (July)

Landscape Type	Area [SF]	Species Factor (k_s)		Density Factor (k_d)		Microclimate Factor (k_{mc})		K_L	ET_L	IE	TPWA [gal]
Shrubs	1,200	Low	0.2	Avg	1.0	High	1.3	**0.3**	2.11	Drip	2,815
Mixed	3,900	Low	0.2	Avg	1.1	High	1.4	**0.3**	2.50	Drip	10,837
Turfgrass	900	Avg	0.7	Avg	1.0	High	1.2	**0.8**	6.82	Sprinkler	9,822
										Subtotal [gal]	23,474
										July Graywater Harvest [gal]	(4,200)
										Net GPWA [gal]	**19,274**

Table 4: Baseline Case (July)

Landscape Type	Area [SF]	Species Factor (k_s)		Density Factor (k_d)		Microclimate Factor (k_{mc})		K_L	ET_L	IE	TPWA [gal]
Shrubs	1,200	Avg	0.5	Avg	1.0	High	1.3	**0.7**	5.28	Sprinkler	10,134
Turfgrass	4,800	Avg	0.7	Avg	1.0	High	1.2	**0.8**	6.82	Sprinkler	52,384
										Net GPWA [gal]	**62,518**

standing of water use and efficiency opportunities, an annual water balance is required. For example, graywater volumes may or may not be consistently available throughout the year because these volumes are dependent on building occupant activities. In a typical office building, graywater volumes will change slightly due to vacation schedules and holidays but should be relatively consistent over the year. In contrast, graywater volumes in a school building will substantially decrease in summer months as a result of reduced building occupancy, and, therefore, graywater volumes may not be available for irrigation. Graywater systems should be modeled to predict graywater volumes generated on a monthly basis as well as optimal storage capacity of the graywater system. It is also important to address possible treatment processes needed for reuse and design of a makeup water system if graywater volume is not sufficient to satisfy reuse demands.

Rain harvest volume depends on the amount of precipitation that the project site experiences and the rainwater collection surface's area and efficiency. See **Equation 4** and consult a rainwater harvesting guide for more detailed instruction. Rainfall data is available from the local weather service (see the Resources section). Within the credit calculations, project teams may either use the collected rainwater total for July based on historical average precipitation, or use the historical data for each month in order to model collection and reuse throughout the year. The latter method allows the project team to determine what volume of water is expected to be in the storage cistern at the beginning of July and add it to the expected rainwater volume collected during the month. This approach also allows the project team to determine the optimal size of the rainwater cistern.

Resources

Web Sites

American Rainwater Catchment Systems Association

www.arcsa-usa.org

Includes a compilation of publications, such as the *Texas Guide to Rainwater Harvesting.*

A Guide to Estimating Irrigation Needs of Landscape Plantings

www.owue.water.ca.gov/docs/wucols00.pdf, (916) 653-1097

Provides detailed methodology for calculating irrigation needs for a wide variety of landscape types. Also includes specific data for California climates.

The Irrigation Association

www.irrigation.org/about_et_list.htm, (703) 536-7080

A nonprofit organization focused on promoting products for the efficient use of water for irrigation applications. This specific Web link is for evapotranspiration data contacts for each U.S. state.

National Climatic Data Center

www.ncdc.noaa.gov/oa/climate/stateclimatologists.html

Useful for researching local climate data, such as rainfall data for rainwater harvesting calculations. Includes links to state climate offices.

Native Plant Societies

Your state or regional native plant society is an excellent resource for identifying climate-appropriate vegetation.

Equation 4:

Rainwater Volume [gal] = collection area [SF] x collection efficiency [%] x average rainfall [in] x 0.6233 gal/in

Texas Evapotranspiration Web Site

texaset.tamu.edu/index.php

An evapotranspiration data Web site for the State of Texas with a discussion of evapotranspiration and sprinkler efficiencies.

U.S. Department of the Interior – Bureau of Reclamation

www.usbr.gov/main/water

The Bureau's Agrimet Data System provides evapotranspiration rates for several regions in the U.S.

WaterWiser: The Water Efficiency Clearinghouse

www.waterwiser.org, (800) 926-7337

A Web clearinghouse with articles, reference materials and papers on all forms of water efficiency.

Water Efficient Landscaping

muextension.missouri.edu/xplor/agguides/hort/g06912.htm, (573) 882-7216

A Web site that has general descriptions and strategies for water efficiency in gardens and landscapes.

Print Media

ASCE Manuals and Reports on Engineering Practice No. 70, "Evapotranspiration and Irrigation Water Requirements," ASCE, 1990.

Estimating Water Requirements of Landscape Plantings, University of California Cooperative Extension, Division of Agriculture and Natural Resources, Leaflet 21493.

Landscape Irrigation: Design and Management, by Stephen W. Smith, John Wiley and Sons, 1996.

Turf Irrigation Manual, Fifth Edition, by Richard B. Choate, Telsco Industries, 1994.

Definitions

Blackwater is wastewater from toilets and kitchen sinks that contains organic materials.

Drip Irrigation is a high-efficiency irrigation method in which water drips to the soil from perforated tubes or emitters.

Evapotranspiration is the loss of water by evaporation from the soil and transpiration from plants.

Graywater is wastewater from lavatories, showers, bathtubs, washing machines and sinks that are not used for disposal of hazardous or toxic ingredients or wastes from food preparation.

Potable Water is water that is suitable for drinking and is supplied from wells or municipal water systems.

Xeriscape or "dry landscape" designs adopt water conservation as the primary objective. Xeriscape landscapes are based on sound horticultural practices and incorporate native plant species that are adapted to local climate conditions.

Case Study

Monsanto Company Life Sciences Incubator
St Louis, Missouri

The Monsanto Company Life Sciences Incubator building is a LEED Version 1.0 Silver Pilot Project that houses research facilities committed to finding solutions to growing global needs for food and health. The building design was inspired by a circular stone Shaker barn in New England and includes two above-ground cisterns to harvest rainwater volumes from the roof for landscape irrigation. Rainwater is collected via a passive gravity-fed collection system and up to 12,000 gallons of water can be stored in the cisterns. This water is then applied manually to the landscape as needed, saving an estimated 28,000 gallons of potable water annually.

Courtesy of Monsanto Company

Owner
Monsanto Company

Innovative Wastewater Technologies

SS	WE	EA	MR	EQ	ID
Credit 2					

1 point

Intent

Reduce generation of wastewater and potable water demand, while increasing the local aquifer recharge.

Requirements

Reduce the use of municipally provided potable water for building sewage conveyance by a minimum of 50%, OR treat 100% of wastewater on site to tertiary standards.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, MEP engineer or responsible party, declaring that water for building sewage conveyance will be reduced by at least 50%. Include the spreadsheet calculation and a narrative demonstrating the measures used to reduce wastewater by at least 50% from baseline conditions.

OR

- ❑ Provide the LEED Letter Template, signed by the civil engineer or responsible party, declaring that 100% of wastewater will be treated to tertiary standards on site. Include a narrative describing the on-site wastewater treatment system.

Summary of Referenced Standard

There is no standard referenced for this credit.

Synergies

SS Credit 1
Site Selection

SS Credit 5
Reduced Site Disturbance

SS Credit 6
Stormwater Management

WE Credit 3
Water Use Reduction

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

Green Building Concerns

Conventional wastewater systems require significant volumes of potable water to convey waste to municipal wastewater treatment facilities. However, graywater volumes from sinks, showers and other sources can be substituted for potable water to flush toilets and urinals. Water can also be harvested from roof runoff volumes that would otherwise be absorbed into the ground or released to local water bodies. Low-flow fixtures, automatic controls, and dry fixtures such as composting toilets and waterless urinals can be used to reduce sewage volume generation.

Once wastewater has been conveyed to treatment facilities, extensive treatment is required to remove contaminants before discharging to a receiving water body. A more efficient method for handling wastewater is to treat it on-site. On-site wastewater strategies reduce regional wastewater infrastructure costs as well as provide autonomy from the public treatment works. A variety of on-site wastewater treatment options are available including conventional biological treatment facilities similar to regional treatment plants and "living machine" systems that mimic natural processes to treat wastewater.

Environmental Issues

On-site wastewater treatment systems transform perceived "wastes" into resources that can be used on the building site. These resources include treated water volumes for potable and non-potable use, as well as nutrients that can be applied to the site to improve soil conditions. Reducing wastewater treatment at the local wastewater treatment works minimizes public infrastructure, energy use and chemical use. In rural areas, onsite wastewater treatment systems avoid aquifer contamination problems prevalent in current septic system technology.

Economic Issues

Commercial and industrial facilities that generate large amounts of wastewater can realize considerable savings by recycling graywater. For example, carwashes and truck maintenance facilities generate large volumes of graywater that can be effectively treated and reused. Often, a separate tank, filter and special emitters are necessary for a graywater irrigation system. The dual plumbing lines installed during initial construction will approximately double the cost of plumbing. However, water storage is the highest cost in any rainwater collection system, much greater than costs for the catchment area, water conveyance, filtration and distribution components. Storage tanks and cisterns in a variety of sizes and materials are regionally available. In some systems, there are additional energy costs required for operation.

Water recovery systems are most cost-effective in areas where there is no municipal water supply, where the developed wells are unreliable, or if well water requires treatment. Collecting and using rainwater or other site water volumes reduces site runoff and the need for runoff devices. It also minimizes the need for utility-provided water, thus reducing some initial and operating costs. In some areas with a decentralized population, collection of rainwater offers a low-cost alternative to a central piped water supply.

Wastewater treatment systems and water recovery systems involve an initial capital investment in addition to the maintenance requirements over the building's lifetime. These costs must balance with the anticipated savings in water and sewer bills. This savings can minimize the amount of potable water that a municipality must provide, thereby leading to more stable water rates.

A constructed wetland for wastewater treatment can add value to a development as a site enhancement. Wetlands are beneficial because they provide flood protection and stabilize soils on site. Currently, packaged biological wastewater systems have an initial high cost relative to the overall building cost due to the novelty of the technology.

Community Benefits

By reducing potable water use, the local aquifer is conserved as a water resource for future generations. In areas where aquifers cannot meet the needs of the population economically, rainwater and other recovered water is the least expensive alternative source of water. Reserving potable water only for specific applications benefits the entire community through lower utility rates and taxes.

Design Approach

Strategies

Develop a wastewater inventory and determine areas where graywater can be used for functions that are conventionally served by potable water. These functions might include sinks, showers, toilets, landscape irrigation, industrial applications and custodial applications. Also estimate the demand for these applications and the availability of graywater generated on the site. Finally, determine the amount of wastewater that will require treatment and select the most suitable treatment strategy.

Potable water is used for many functions that do not require high-quality water. Graywater systems reuse the wastewater from sinks, showers and other sources for the flushing of toilets, landscape irrigation, and other functions that do not require potable water. Roof-water or groundwater collection systems harvest water that otherwise would be absorbed into the ground or released to local water bodies. If it is likely that a graywater system will be used in the future, install dual plumbing lines during the initial construction to avoid the substantial costs and difficulty in adding them later.

Figure 1 depicts an example design for rain harvesting reuse. Precipitation volumes are captured on the roof and transported to a basement storage tank via gutters and downspouts. The basement storage tank has an overflow device if the volume of runoff exceeds capacity and potable water makeup (***device?) if the runoff volume is less than the minimum volume required for reuse. The runoff volumes are then filtered and pumped to water closets and washing machines in the building as needed.

Check with the local health department for regulations governing the use of a graywater system and the permits required. Each state has its own standards for graywater irrigation systems. Texas and California, for example, have standards that encourage the use of graywater systems. Other states have regulations that may limit or prohibit graywater use. In many areas, irrigation with graywater must be subsurface, although some regions allow above-ground irrigation.

Consider an on-site wastewater treatment system such as constructed wetlands, a mechanical recirculating sand filter, or an aerobic biological treatment reactor.

Technologies

The construction of artificial wetlands for wastewater treatment can be incorporated on multiple scales to accommodate projects ranging from individual buildings to larger developments. As wastewater moves through the wetlands or bodies of water, plants and microbes naturally remove water contaminants. Another technology involves creating an aquaculture system, where contaminants in the wastewater become food for fish and plants.

Remember to check with local health code departments regarding current regulations governing the use of biological wastewater systems. Most require permits for these systems. Regularly scheduled

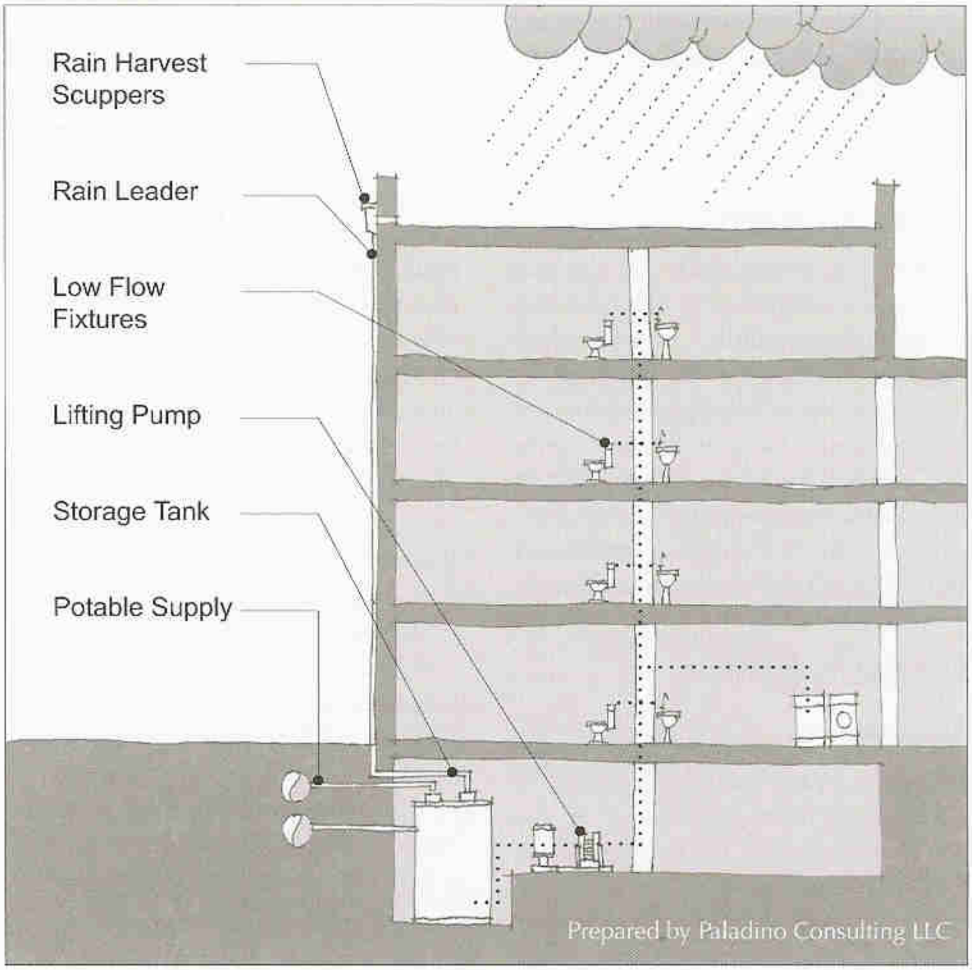


Figure 1: An Illustration of a Rain Harvesting System

maintenance on these systems will increase their lifetimes and reduce operations problems. An EPA study found that ecological systems are comparable in cost to conventional wastewater treatment only for volumes of 50,000 gallons per day or less. An aquaculture system is usually a high-cost and high-maintenance system, yet it can yield food and fertilizer in return.

Modular wastewater treatment systems can be purchased to remove wastewater contaminants including TSS and TP. Some systems imitate natural ecosystems to treat wastewater volumes biologically while other systems are designed with physical, chemical and biological technologies similar to publicly owned treatment works. Both types of systems produce effluents that can be used for non-potable applications such as irrigation and toilet flushing.

Synergies and Trade-Offs

The necessity and availability of wastewater reuse and treatment strategies is heavily influenced by the building location. In remote locations, it may be cost-effective to use an on-site wastewater treatment system.

Conversely, a project located in a dense area with little site area, and with limited wastewater treatment, graywater or stormwater reuse facilities, may not be able to capture this credit. This credit has close ties to water efficiency efforts because a greater amount of potable water saved often results in less blackwater generated. For instance, water efficient water closet and urinal fixtures not only reduce potable water demand but also reduce blackwater volumes created. Thus, performance results will often overlap with those of WE Credit 3.

Energy use may be needed for treatment plant operation or for reuse strategies. These systems also require commissioning and measurement & verification attention. Reuse of an existing building could hinder adoption of an on-site wastewater treatment facility.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. Wastewater calculations are based on the annual generation of blackwater volumes from plumbing fixtures such as water closets and urinals. The calculations compare the design case with a baseline case. The steps to calculate the **design case** are as follows:

1. Create a spreadsheet listing each type of blackwater-generating fixture and frequency of use data. Frequency-of-use data includes the number of female and male daily uses, and the sewage generated per use. Using these values, calculate the total sewage generated for each fixture type and gender (see **Equation 1**).

2. Sum all of the sewage generation volumes used for each fixture type to obtain male and female daily sewage generation volumes.

3. Multiply the male and female sewage generation volumes by the number of male and female building occupants and sum these volumes to obtain the daily total sewage generation volume (see **Equation 2**).

4. Multiply the total daily sewage volume by the number of workdays in a typical year to obtain the total annual sewage generation volume for the building (see **Equation 3**).

5. If rainwater harvest or graywater reuse strategies are employed in the building, subtract these annual volumes from the annual sewage generation volume. The result shows how much potable water is used for sewage conveyance annually.

Repeat the above calculation methodology for the **baseline case**. Use Energy Policy Act of 1992 fixture flow rates for the baseline case (see WE Credit 3, Table 1). Do not change the number of building occupants, the number of workdays, or the frequency data. Do not include graywater or rainwater harvest volumes.

Table 1 shows **example** potable water calculations for sewage conveyance for a two-story office building with a capacity of 300 occupants. The calculations are based on a typical 8-hour workday. It is assumed that building occupants are 50% male and 50% female. Male occupants are assumed to use water closets once and urinals twice in a typical work day. Fe-

Equation 1:

$$\text{Sewage Volume [gal]} = \text{Uses} \times \text{Duration [mins or flushes]} \times \frac{\text{Water Volume [gal]}}{\text{Use [min or flush]}}$$

Equation 2:

$$\text{Daily Sewage Generation [gal]} = \text{Male Occupants} \times \text{Male Sewage Generation [gal]} + \text{Female Occupants} \times \text{Female Sewage Generation [gal]}$$

Equation 3:

$$\text{Annual Sewage Generation [gal]} = \text{Total Sewage Generation} \left[\frac{\text{gal}}{\text{day}}\right] \times \text{Workdays [days]}$$

Table 1: Design Case

Fixture Type	Daily Uses	Flowrate [GPF]	Occupants	Sewage Generation [gal]
Low-Flow Water Closet (Male)	0	1.1	150	0
Low-Flow Water Closet (Female)	3	1.1	150	495
Composting Toilet (Male)	1	0.0	150	0
Composting Toilet (Female)	0	0.0	150	0
Waterless Urinal (Male)	2	0.0	150	0
Waterless Urinal (Female)	0	0.0	150	0
			Total Daily Volume [gal]	495
			Annual Work Days	260
			Annual Volume [gal]	128,700
			Rainwater or Graywater Reuse Volume [gal]	(36,000)
			TOTAL ANNUAL VOLUME [gal]	**92,700**

male occupants are assumed to use water closets three times.

First, the design case is considered to determine annual potable water usage for sewage conveyance. The designed building has fixtures that use non-potable water for sewage conveyance (i.e., rainwater) or no water for sewage conveyance (i.e., waterless urinals and composting toilets). **Table 1** summarizes the sewage generation rates and indicates that 92,700 gallons of potable water are used annually for sewage conveyance.

When using graywater and rainwater volumes, calculations are required to demonstrate that these reuse volumes are sufficient to meet water closet demands. These quantities are then subtracted from the gross daily total because they reduce potable water usage. In the example, 36,000 gallons of rainwater are harvested and directed to water closets for flushing.

Next, the baseline potable water usage for sewage conveyance is developed using conventional fixtures that comply with the Energy Policy Act of 1992. Toilets are 1.6 gallons per flush (GPF) and urinals are 1.0 GPF. All fixtures drain to the existing municipal sewer system.

Table 2 provides a summary of baseline calculations. The baseline case estimates that 327,600 gallons of potable water per year for sewage conveyance.

Comparison of the baseline to the designed building indicates that a 72% reduction in potable water volumes used for sewage conveyance is realized (1 – 92,700/327,600). Thus, this strategy earns one point for this credit. When developing the baseline, only the fixtures, sewage generation rates and the water reuse credit are different from the designed building. Usage rates, occupancy and number of workdays are identical for the designed case and the baseline case. See **Table 3** for sample fixture flow rates.

When reusing graywater volumes from the building, it is necessary to model the system on an annual basis to determine graywater volumes, generated storage capacity of the system and any necessary treatment processes before reusing the water volumes. Graywater volumes may or may not be consistently available throughout the year because these vol-

Table 2: Baseline Case

Fixture Type	Daily Uses	Flowrate [GPF]	Occupants	Sewage Generation [gal]
Water Closet (Male)	1	1.6	150	240
Water Closet (Female)	3	1.6	150	720
Urinal (Male)	2	1.0	150	300
Urinal (Female)	0	1.0	150	0
			Total Daily Volume [gal]	1,260
			Annual Work Days	260
			TOTAL ANNUAL VOLUME [gal]	**327,600**

Table 3: Sample Fixture Types and GPFs

Fixture Type	[GPF]
Conventional Water Closet	1.6
Low-Flow Water Closet	1.1
Ultra Low-Flow Water Closet	0.8
Composting Toilet	0.0
Conventional Urinal	1.0
Waterless Urinal	0.0

umes are dependent on building occupant activities. For instance, in a typical office building, graywater volumes will change slightly due to vacation schedules and holidays but should be relatively consistent over the year.

In contrast, graywater volumes in a school building will substantially decrease in summer months due to the school calendar, and, therefore, graywater volumes may not be available for irrigation.

If the project uses rainwater volume as a substitute for potable volumes in water closets or urinals, it is necessary to calculate water savings over a time period of one year. Rain harvest volume depends on the amount of precipitation that the project site experiences and the rainwater collection surface's area and efficiency. See **Equation 4** and consult a rainwater harvesting guide for more detailed instruction. Rainfall data is available from the local weather service (see the Resources section). Rainwater volume depends on variations in precipitation, and, thus, it is necessary to model the reuse strategy on an annual basis. A model of rainwater capture based on daily precipitation and occupant demand is helpful to determine the rainwater volumes captured and storage tank size. Subtract annual rainwater use for sewage conveyance in the design case calculations.

Resources

Web Sites

American Rainwater Catchment Systems Association

www.arcsa-usa.org

Includes a compilation of publications, such as the *Texas Guide to Rainwater Harvesting*.

Equation 4:

Rainwater Volume [gal] = collection area [SF] x collection efficiency [%] x average rainfall [in] x 0.6233 gal/in

How to Conserve Water and Use it Wisely

www.epa.gov/OW/you/chap3.html

A U.S. EPA document that provides guidance for commercial, industrial and residential water users on saving water and reducing sewage volumes.

National Climatic Data Center

www.ncdc.noaa.gov/oa/climate/stateclimatologists.html

Useful for researching local climate data, such as rainfall data for rainwater harvesting calculations. Includes links to state climate offices.

Print Media

Constructed Wetlands for Wastewater Treatment and Wildlife Habitat: 17 Case Studies, EPA 832/B-93-005, 1993.

Mechanical & Electrical Equipment for Buildings, Eighth Edition, by Benjamin Stein and John Reynolds, John Wiley and Sons, 1992.

Sustainable Building Technical Manual, Public Technology, Inc., 1996 (www.pti.org).

Definitions

Aquatic Systems are ecologically designed treatment systems that utilize a diverse community of biological organisms (e.g., bacteria, plants and fish) to treat wastewater to advanced levels.

On-Site Wastewater Treatment uses localized treatment systems to transport, store, treat and dispose of wastewater volumes generated on the project site.

Potable Water is defined as water that meets drinking water quality standards and is approved for human consumption by the state or local authorities having jurisdiction.

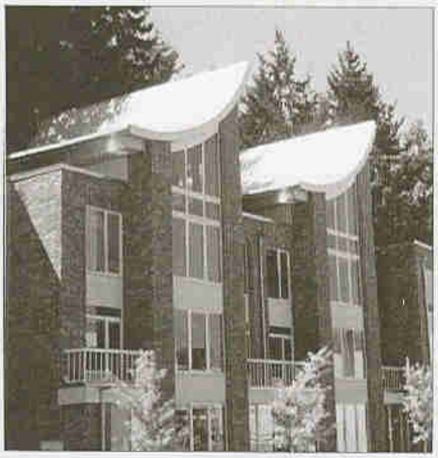
Tertiary Treatment is the highest form of wastewater treatment and includes removal of organics, solids and nutrients as well as biological or chemical polishing, generally to effluent limits of 10 mg/L BOD_5 and 10 mg/L TSS.

Also see WE Credit 1 definitions.

Case Study

C.K. Choi Building for the Institute of Asian Research
Vancouver, British Columbia

The C.K. Choi Building for the Institute of Asian Research at the University of British Columbia is a campus research building. The building incorporates two strategies to reduce wastewater generation. All toilets in the building are composting toilets that function without water and transform human wastes into compost that can be applied to the site landscape. Liquid wastes from the composting toilets and other building sources (lavatories, kitchen sinks and urinals) are directed through a simulated wetland system. This system doubles as a landscape feature next to the building and treats the liquid wastes before application to the site landscape. These strategies allow for the building to be disconnected from the existing sanitary sewer infrastructure.



Courtesy of Paladino Consulting LLC

Owner
University of British Columbia

Water Use Reduction

20% Reduction

SS	WE	EA	MR	EQ	ID
Credit 3.1					

1 point

Intent

Maximize water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems.

Requirements

Employ strategies that in aggregate use 20% less water than the water use baseline calculated for the building (not including irrigation) after meeting the Energy Policy Act of 1992 fixture performance requirements.

Submittals

- ❑ Provide the LEED Letter Template, signed by the MEP engineer or responsible party, declaring that the project uses 20% less water than the baseline fixture performance requirements of the Energy Policy Act of 1992.
- ❑ Provide the spreadsheet calculation demonstrating that water-consuming fixtures specified for the stated occupancy and use of the building reduce occupancy-based potable water consumption by 20% compared to baseline conditions.

SS WE EA MR EQ ID

Credit 3.2

1 point
in addition to
WE 3.1

Water Use Reduction

30% Reduction

Intent

Maximize water efficiency within buildings to reduce the burden on municipal water supply and wastewater systems.

Requirements

Employ strategies that in aggregate use 30% less water than the water use baseline calculated for the building (not including irrigation) after meeting the Energy Policy Act of 1992 fixture performance requirements.

Submittals

- ❑ Provide the LEED Letter Template, signed by the MEP engineer or responsible party, declaring that the project uses 30% less water than the baseline fixture performance requirements of the Energy Policy Act of 1992.
- ❑ Provide the spreadsheet calculation demonstrating that water-consuming fixtures specified for the stated occupancy and use of the building reduce occupancy-based potable water consumption by 30% compared to baseline conditions.

Summary of Referenced Standard

The Energy Policy Act (EPAct) of 1992

This Act was promulgated by the U.S. government and addresses energy and water use in commercial, institutional and residential facilities. The water usage requirements of the Energy Policy Act of 1992 are provided in **Table 1**.

Table 1: EPACT Fixture Ratings

Fixture	Energy Policy Act of 1992 Flow Requirement
Water Closets [GPF]	1.6
Urinals [GPF]	1.0
Showerheads [GPM]*	2.5
Faucets [GPF]*	2.5
Replacement Aerators [GPM]*	2.5
Metering Faucets [gal/CY]	0.25

*At flowing water pressure of 80 pounds per square inch (psi)

Green Building Concerns

The Energy Policy Act of 1992 established water conservation standards for water closets, shower heads, faucets and other uses to save the United States an estimated 6.5 billion gallons of water per day. Toilet flushing uses the most water in residential and commercial buildings, accounting for approximately 4.8 billion gallons per day. Older toilets use 4 to 8 gallons of water per flush, while all new toilets must have a maximum flush volume of 1.6 gallons.

While the EPAct is a good starting point, there are many ways to exceed this standard and achieve even greater water savings. Effective methods to reduce potable water use include reusing roof runoff volumes for non-potable applications, installing sensors and flow restrictors on water fixtures, and installing dry fixtures such as composting toilets and waterless urinals.

Environmental Issues

The reduction of potable water use in buildings for toilets, shower heads and faucets reduces the total amount withdrawn from rivers, streams, underground aquifers and other water bodies. Another benefit of potable water conservation is reduced energy use and chemical inputs at municipal water treatment works.

Economic Issues

Reductions in water consumption minimize overall building operating costs. Reductions can also lead to more stable municipal taxes and water rates. By handling reduced water volumes, water treatment facilities can delay expansion and maintain stable water prices.

Accelerated installation of high-efficiency plumbing fixtures, especially 1.6 gallon per flush (GPF) toilets, through incentive programs has become a cost-effective way for some municipalities to defer, reduce or avoid capital costs of needed water supply and wastewater facilities.

For example, New York City invested $393 million in a 1.6 GPF toilet-rebate program that has reduced water demand and wastewater flow by 90.6 million gallons per day (MGD), equal to 7% of the city's total water consumption. The rebate program accomplished a net present value savings of $605 million from a 20-year deferral of water supply and wastewater treatment expansion projects. Another successful water efficiency program was instituted in Santa Monica, where the toilet replacement program achieved permanent reductions in water usage and wastewater flows of over 1.9 MGD, representing a 15% reduction in average total water demand and a 20% reduction of average total wastewater flow. The cost of the rebate program was $5.4 million. The program will have a net savings of $6 million in the year 2002 due to avoided costs of water imports and wastewater treatment.

Water-conserving fixtures that use less water than requirements in the Energy Policy Act of 1992 may have higher initial costs. Additionally, there may be a longer lead time for delivery because of their limited availability.

The first cost of composting toilets is significantly higher than conventional water closets and they may initially require additional maintenance attention. Some composting toilets also carry an ongoing energy cost to run fans and other system equipment. Nonetheless, significant operational savings are realized through eliminated potable water use and sewage generation.

Community Issues

Water use reductions, in aggregate, allow municipalities to reduce or defer the capital investment needed for water supply and wastewater treatment infrastructure. These strategies protect the natural water

Synergies

SS Credit 1
Site Selection

SS Credit 5
Reduced Site Disturbance

SS Credit 6
Stormwater Management

WE Credit 1
Water Efficient Landscaping

WE Credit 2
Innovative Wastewater Technologies

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

cycle and save water resources for future generations.

Design Approach

Strategies

Develop a water use inventory that includes all water-consuming fixtures, equipment and seasonal conditions according to the methodology outlined in the Calculations section. Consider developing the inventory in conjunction with WE Credit 2. Use this to identify significant potable water demands and determine methods to minimize or eliminate these demands.

Specify water-conserving plumbing fixtures that exceed the fixture requirements stated in the Energy Policy Act of 1992. Consider ultra-high efficiency fixture and control technologies, including toilets, faucets, showers, dishwashers, clothes washers and cooling towers. A variety of low-flow plumbing fixtures and appliances are currently available in the marketplace and can be installed in the same manner as conventional fixtures.

Technologies

Water-efficient shower heads are available that require less than 2.5 GPM. Bathroom faucets are typically used only for wetting purposes and can be effective with as little as 1.0 GPM. Water-saving faucet aerators can be installed that do not change the feel of the water flow. Specify self-closing, slow-closing or electronic sensor faucets, particularly in high-use public areas where it is likely that faucets may be carelessly left running.

Water closets are a significant user of potable water. There are a number of toilets that use considerably less than 1.6 GPF, including pressure-assisted toilets and dual flush toilets that have an option of 0.8 GPF or 1.0 GPF. Unfortunately, it is currently difficult to obtain these fixtures in North America.

Consider dry fixtures such as waterless urinals and composting toilets. These technologies use no water volumes to cope with human waste. Waterless urinals use advanced hydraulic design and a buoyant fluid instead of water to maintain sanitary conditions. Composting toilets mix human waste with organic material to produce a nearly odorless end product that can be used as a soil amendment. These fixtures have been used successfully but to a limited extent in commercial settings. Composting toilets may not be acceptable by health code departments in some areas, and, thus, it is important to check with the local health code department to uncover regulations governing the use of both composting toilets and waterless urinals. Also, if the building allows for public access to restroom facilities, it is important to educate users about system operation and purpose. Signage in restrooms is a good way to educate users, and signs should include instructions and a brief description of how the system functions. This is especially true for composting toilets that do not function in the same manner as conventional water closets.

Consider specifying water-efficient cooling towers that use delimiters to reduce drift and evaporation. Couple cooling towers with water recovery systems to operate with graywater or stormwater volumes. However, keep in mind that delimiters may require larger fans in the cooling tower system, resulting in increased energy use.

Synergies and Trade-Offs

Water use strategies depend on the site location and site design. Project sites with no access to municipal potable water service typically use groundwater wells to satisfy potable water demands. Sites with significant precipitation volumes may determine that reuse of these volumes is more cost-effective than creating stormwater treatment facilities. Potable water use is significant for irrigation applications and is directly correlated with the amount of wastewater generated onsite. Strategies and performance results may overlap with those of WE Credit 2.

Some water-saving technologies impact energy performance and require commissioning and measurement & verification attention. Reuse of existing buildings may hinder water efficiency measures due to space constraints or existence of plumbing fixtures.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. To calculate the potable water savings for a building, the design case must be compared with a baseline case. The steps to calculate the **design case** are as follows:

1. Create a spreadsheet listing each water-using fixture and frequency-of-use data. Frequency-of-use data includes the number of female and male daily uses, the duration of use, and the water volume per use. There are no set criteria for determining daily use or duration of use. Applicants can estimate both of these items based on the project's program requirements. With these values, calculate the total potable water used for each fixture type and gender (see **Equation 1**).

2. Sum all of the water volumes used for each fixture type to obtain male and female total daily potable water use.

3. Multiply male and female potable water volumes by the number of male and female building occupants and sum these volumes to obtain the daily total potable water use volume (see **Equation 2**).

4. Multiply total daily potable water volume by the number of workdays in a typical year to obtain the total annual potable water volume use for the building. If rainwater harvest or graywater reuse strategies are employed in the building, subtract these annual volumes from the total potable water use (see **Equation 3**).

Repeat the above calculation methodology for the **baseline case**. Use EPAct fixture flow rates for the baseline case. Do not change the number of building occupants, the number of workdays or the frequency data. Do not include graywater or rainwater harvest volumes. Sample flush and flow fixture flow rates are provided in **Table 2** and **Table 3**.

An **example** potable water use calculation is included for a two-story office building with a capacity of 300 persons. Occupant fixtures that use potable water include water closets, urinals, lavatories, kitchen sinks and showers. Calculations are based on a typical 8-hour workday and 260 workdays per year.

It is assumed that building occupants are 50% male and 50% female. Male occupants are assumed to use water closets once

Equation 1:

$$\text{Potable Water Use}\ [\text{gal}] = \text{Uses} \times \text{Duration [mins or flushes]} \times \frac{\text{Water Volume [gal]}}{\text{Use [min or flush]}}$$

Equation 2:

$$\text{Daily Potable Water Volume}\ [\text{gal}] = \text{Male Occupants} \times \text{Male Sewage Generation}\ [\text{gal}] + \text{Female Occupants} \times \text{Female Sewage Generation}\ [\text{gal}]$$

Equation 3:

$$\text{Total Potable Water Use}\ [\text{gal}] = \frac{\text{Water Use}}{\text{Occupant} \cdot \text{Day}}\left[\frac{\text{gal}}{\text{day}}\right] \times \text{Occupants} \times \frac{\text{Workdays}}{\text{Year}} - \text{Annual Graywater or Rainwater Harvest}\ [\text{gal}]$$

and urinals twice in a typical work day.

Female occupants are assumed to use water closets three times. All occupants in this example are assumed to use lavatories for each restroom use for 15 seconds and kitchen sinks once for 15 seconds. An estimated 10% of the building occupants use showering facilities on a typical day.

Water closets use graywater volumes captured from showers, sinks and lavatories in the building. Waterless urinals are used in male restrooms and these fixtures use no water. Showers, lavatories and kitchen

Table 2: Sample Flush Fixture Types

Flush Fixture Type	Water Use [GPF]
Conventional Water Closet	1.6
Low-Flow Water Closet	1.1
Ultra Low-Flow Water Closet	0.8
Composting Toilet	0.0
Conventional Urinal	1.0
Waterless Urinal	0.0

Table 3: Sample Flow Fixture Types

Flow Fixture Type	Water Use [GPM]
Conventional Lavatory	2.5
Low-Flow Lavatory	1.8
Kitchen Sink	2.5
Low-Flow Kitchen Sink	1.8
Shower	2.5
Low-Flow Shower	1.8
Janitor Sink	2.5
Hand Wash Fountain	0.5

Table 4: Design Case

Flush Fixture	Daily Uses	Flowrate [GPF]	Duration [flush]	Occupants	Water Use [gal]
Ultra Low-Flow Water Closet (Male)	0	0.8	1	150	0
Ultra Low-Flow Water Closet (Female)	3	0.8	1	150	360
Composting Toilet (Male)	1	0.0	1	150	0
Composting Toilet (Female)	0	0.0	1	150	0
Waterless Urinal (Male)	2	0.0	1	150	0
Waterless Urinal (Female)	0	0.0	1	150	0
Flow Fixture	**Daily Uses**	**Flowrate [GPM]**	**Duration [sec]**	**Occupants**	**Water Use [gal]**
Conventional Lavatory	3	2.5	12	300	450
Kitchen Sink	1	2.5	12	300	150
Shower	0.1	2.5	300	300	375
				Total Daily Volume [gal]	1,335
				Annual Work Days	260
				Annual Volume [gal]	347,100
				Graywater Reuse Volume [gal]	(36,000)
				TOTAL ANNUAL VOLUME [gal]	**311,100**

sinks are conventional fixtures and use 2.5 GPM. Motion sensors and electronic controls are used on lavatories, sinks and water closets. These devices are estimated to reduce lavatory and sink use duration by 20% but do not reduce the flow of water closets. These fixtures' duration data have been correspondingly adjusted from 15 seconds to 12 seconds. All of the above data is specific to the design case.

Table 4 provides a summary of the design case. The calculations indicate annual potable water use of 311,100 gallons.

The baseline case is calculated in the same manner as the design case except that ALL fixtures are assumed to be standard fixtures that comply with the Energy Policy Act of 1992. Also, automatic sensors are not used on any fixtures and there is no graywater reuse. Usage rates, occupancy and annual workdays are identical for the baseline and the designed building. **Table 5** provides a summary of the baseline case. The calculations estimate an annual potable water use of 620,100 gallons.

Comparison of the design case to the baseline case indicates that a potable water savings of 309,000 gallons is realized by using low-flow water closets, waterless urinals, auto controls on lavatories and sinks, and graywater reuse. This equates to a savings of 50% over the baseline case.

Other building equipment that uses potable water can also be considered for water efficiency. For instance, water-efficient cooling towers can be specified instead of conventional cooling towers. Fire suppression systems and irrigation systems are not applicable to this credit. Building equipment should be included in the design case calculations as well as in the baseline calculations.

When reusing graywater volumes from the building, it is necessary to model the system on an annual basis to determine graywater volumes generated, storage capacity of the system and any necessary treatment processes before reusing the water volumes. Graywater volumes may

Table 5: Baseline Case

Flush Fixture	Daily Uses	Flowrate [GPF]	Duration [flush]	Auto Controls N/A	Occupants	Water Use [gal]
Conventional Water Closet (Male)	1	1.6	1		150	240
Conventional Water Closet (Female)	3	1.6	1		150	720
Conventional Urinal (Male)	2	1.0	1		150	300
Conventional Urinal (Female)	0	1.0	1		150	0
Flow Fixture	**Daily Uses**	**Flowrate** [GPM]	**Duration** [second]	**Auto Controls** N/A	**Occupants**	**Water Use** [gal]
Conventional Lavatory	3	2.5	15		300	563
Kitchen Sink	1	2.5	15		300	188
Shower	0.1	2.5	300		300	375
					Total Daily Volume [gal]	2,385
					Annual Work Days	260
					TOTAL ANNUAL VOLUME [gal]	**620,100**

SS	WE	EA	MR	EQ	ID
Credit 3					

or may not be consistently available throughout the year because these volumes are dependent on building occupant activities.

For instance, in a typical office building, graywater volumes will change slightly due to vacation schedules and holidays but should be relatively consistent over the year. In contrast, graywater volumes in a school building will substantially decrease in summer months due to the school calendar, and, therefore, graywater volumes may not be available for non-potable applications.

If the project uses rainwater volume for non-potable uses, it is necessary to calculate water savings over a time period of one year. Rain harvest volume depends on the amount of precipitation that the project site experiences and the rainwater collection surface's area and efficiency. See **Equation 4** and consult a rainwater harvesting guide for more detailed instruction. Rainfall data is available from the local weather service (see the Resources section). Rainwater volume depends on variations in precipitation, and, thus, it is necessary to model the reuse strategy on an annual basis. A model of rainwater capture based on daily or monthly precipitation and occupant demand is helpful to determine the rainwater volumes captured and storage tank size. Subtract annual rainwater use as budgeted for flush and flow fixtures in the design case calculations.

Resources

Web Sites

American Rainwater Catchment Systems Association

www.arcsa-usa.org

Includes a compilation of publications, such as the *Texas Guide to Rainwater Harvesting*.

Composting Toilet Reviews

www.buildinggreen.com/features/mr/waste.html, (802) 257-7300

An *Environmental Building News* article on commercial composting toilets.

National Climatic Data Center

www.ncdc.noaa.gov/oa/climate/stateclimatologists.html

Useful for researching local climate data, such as rainfall data for rainwater harvesting calculations. Includes links to state climate offices.

Terry Love's Consumer Toilet Reports

www.terrylove.com/crtoilet.htm

This Web site offers a plumber's perspective on many of the major toilets used in commercial and residential applications.

Water Efficiency Article

home.earthlink.net/~wliebold

An opinion survey addressing various brands of water-efficient toilets and showerheads.

WaterWiser: The Water Efficiency Clearinghouse

www.waterwiser.org, (800) 926-7337

The American Water Works Association's clearinghouse includes articles, reference materials and papers on all forms of water efficiency.

Print Media

Water, Sanitary and Waste Services for Buildings, Fourth Edition, by A. Wise and J. Swaffield, Longman Scientific & Technical, 1995.

Equation 4:

Rainwater Volume [gal] = collection area [SF] x collection efficiency [%] x average rainfall [in] x 0.6233 gal/in

Definitions

A **Composting Toilet** is a dry plumbing fixture that contains and treats human waste via microbiological processes.

Fixture Sensors are applied to lavatories, sinks, water closets and urinals to sense fixture use and automatically turn on and off.

A **Waterless Urinal** is a dry plumbing fixture that uses advanced hydraulic design and a buoyant fluid instead of water to maintain sanitary conditions.

Also see WE Credit 1 definitions.

Case Study

King Street Center
Seattle, Washington

Courtesy of King County

Owner
King County

The King Street Center is an office building that houses several departments of the King County government. To reduce potable water use and harvest site resources, the building was designed to collect rainwater from 44,000 square feet of roof area and store it in three 5,400-gallon tanks in the basement. The water is pumped from the tanks through a filtration system and into a graywater piping system that services water closets on each floor of the eight-story building. Rainwater provides 1.4 million gallons of graywater or about two-thirds of the total water closet demand, the remainder of which is made up by potable water volumes. As a result, stormwater volumes leaving the site are reduced by about two-thirds.

Energy & Atmosphere

Buildings consume approximately 37% of the energy and 68% of the electricity produced in the United States annually, according to the U.S. Department of Energy. Combustion of fossil fuels produces about 75% of our energy. Production of electricity through the use of fossil fuels such as oil and coal requires extraction, transportation, refining, power generation and distribution. These processes significantly impact the environment in a myriad of adverse ways. For example, conventional fossil-based generation of electricity releases carbon dioxide, which contributes to global climate change. The potential consequences of climate change (rising sea levels leading to coastal floods, severe droughts, heat waves, disease migration) affect communities worldwide.

Coal-fired electric utilities emit almost one-third of the country's anthropogenic nitrogen oxide, the key element in smog, and two-thirds the sulfur dioxide, a key element in acid rain. Coal extraction and mining disrupts habitat and can devastate landscapes. Acidic water runoff (acid mine drainage) from coal extraction activities further degrades regional ecosystems. Coal is rinsed with water, which results in billions of gallons of sludge stored in ponds. There are some instances of sludge pond failure which have unleashed several hundred million gallons, wreaking havoc on communities and potable water supplies.

Coal-fired electric generation plants emit more fine particulate material than any other activity in the United States. The human body is incapable of clearing these fine particles from the lungs. Consequently, particulate materials penetrate deep into the lungs and are contributing factors in tens of thousands of cancer and respiratory illness-related deaths annually. In addition, mining is a dangerous occupation in which accidents and long-term effects of breathing coal dust result in shortened life spans of coal miners.

Other energy production technologies include natural gas, nuclear fission and hydroelectric generators. Although its emissions are not as damaging as coal and oil, natural gas is a major source of nitrogen oxides and greenhouse gas emissions. Nuclear power increases the potential for catastrophic accidents and raises significant waste transportation and disposal issues. Hydroelectric generating plants disrupt natural water flows, resulting in disturbance of habitat and depletion of fish populations.

Energy consumption can be dramatically reduced through practices that are economical and readily achievable. Improving the energy performance of buildings lowers operations costs, reduces pollution generated by power plants and other energy-producing equipment, and enhances comfort. Most energy-efficiency measures present an excellent rate of return.

It is essential to consider a building's energy load as a whole and to integrate synergistic energy-efficiency measures in order to maximize savings. For example, reduction of energy loads through improved glazing, insulation, daylighting and use of passive solar features may allow the design team to downsize or even eliminate mechanical HVAC systems. LEED recognizes the importance of integrated energy strategies. As a result, most of the prerequisites and credits under this topic are performance-based rather than prescriptive.

Overview of LEED™ Prerequisites and Credits

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Prerequisite 3
CFC Reduction in HVAC&R Equipment

EA Credit 1
Optimize Energy Performance

EA Credit 2
Renewable Energy

EA Credit 3
Additional Commissioning

EA Credit 4
Ozone Depletion

EA Credit 5
Measurement & Verification

EA Credit 6
Green Power

There are 17 points available in the Energy & Atmosphere category.

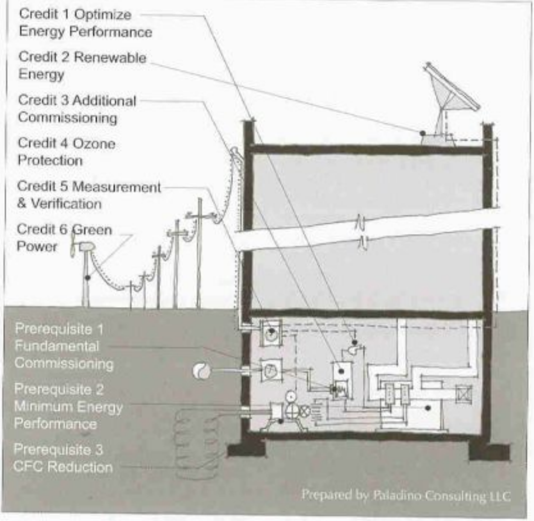


Figure 1: Overview of LEED Prerequisites & Credits

Fundamental Building Systems Commissioning

SS	WE	EA	MR	EQ	ID
Prerequisite 1					

Required

Intent

Verify and ensure that fundamental building elements and systems are designed, installed and calibrated to operate as intended.

Requirements

Implement or have a contract in place to implement the following fundamental best practice commissioning procedures.

- Engage a commissioning team that does not include individuals directly responsible for project design or construction management.
- Review the design intent and the basis of design documentation.
- Incorporate commissioning requirements into the construction documents.
- Develop and utilize a commissioning plan.
- Verify installation, functional performance, training and operation and maintenance documentation.
- Complete a commissioning report.

Submittals

❑ Provide the LEED Letter Template, signed by the owner or commissioning agent(s), confirming that the fundamental commissioning requirements have been successfully executed or will be provided under existing contract(s).

Summary of Referenced Standard

There is no standard referenced for this credit.

Credit Synergies

SS Credit 4
Alternative Transportation

SS Credit 8
Light Pollution Reduction

WE Credit 1
Water Efficient Landscaping

WE Credit 2
Innovative Wastewater Treatment

WE Credit 3
Water Use Reduction

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 2
Renewable Energy

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

EQ Prerequisite 1
Minimum IAQ Performance

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

EQ Credit 7
Thermal Comfort

EQ Credit 8
Daylight & Views

Green Building Concerns

The commissioning process is a quality-based method that is adopted by an owner to consistently achieve successful construction projects. It is not an additional layer of construction or project management—it is the owner's means of verifying that the planning, design, construction and operational processes are achieving their goals, and ensures the delivery of a high quality building with maximum asset value. A commissioned building provides optimized energy efficiency, indoor air quality, and occupant comfort, and sets the stage for minimal operation and maintenance costs.

The commissioning process activities commence at project inception (the start of the pre-design phase) to document the owner's project requirements. The commissioning process activities continue through the design and construction phases, including performance testing, and conclude at one year of occupancy with a warranty review and lessons-learned meeting. A key commissioning process activity typically completed is the development and verification of a cohesive training program of the building staff so they can properly operate and maintain the building to achieve the owner's long-term sustainability goals.

Environmental Issues

Implementation of the commissioning process maintains the focus on high performance building principles from project inception through operation. This typically results in optimized mechanical, electrical and architectural systems—maximizing energy efficiency and thereby minimizing environmental impacts associated with energy production and consumption. Energy conservation reduces the need for natural resource extraction, improves air quality and reduces greenhouse gas emissions.

Economic Issues

A properly designed and executed commissioning plan generates substantial operational cost savings. Successful implementation of the commissioning process often increases energy efficiency by 5% to 10%. The State of Oregon Office of Energy studied direct energy savings for two buildings after completion of a commissioning plan. In a 110,000-square-foot office building, energy savings of $12,276 per year (equivalent to $0.12 per square foot) were realized through completion of the commissioning process activities. In a 22,000-square-foot office building, energy savings equal to $7,630 per year ($0.35 per square foot) were achieved.

In addition to energy performance, occupant productivity is another operational cost impacted by subpar building performance. The Oregon study estimated indirect costs associated with lost productivity due to occupant complaints about the indoor environment. It estimated that if 20% of building occupants expended 30 minutes per month complaining about lighting or temperature conditions, the employer would lose $0.10 per square foot in annual productivity. For a 100,000-square-foot building, this equates to $10,000 per year. This loss does not factor in actual productivity reductions resulting from the suboptimal conditions, but only addresses complaint time.

Other potential costs of poor building performance cited by the Oregon Office of Energy include employee illness, tenant turnover and vacant office space, liability related to indoor air quality, and premature equipment replacement.

The cost of Commissioning Authority services changes with project size. **Table 1** provides estimates of third-party commissioning costs based on historical data.

Evaluation of projects involved in the data in **Table 1** has shown that implementation of the commissioning process activities will pay for itself by late design or early construction, and has a minimum three-to-one payback by the end of construction and through the first year of operation. Savings from implementing the commissioning process are due to improved construction documents (reduced requests for information and change orders), identification and resolution of issues on paper, comprehensive ongoing review construction to maintain focus on the owner's project requirements, and minimizing contractor call-backs during the first year of operation.

On their first projects in which the owner is implementing the commissioning process, architects and engineers may charge higher than normal fees to support the process. These fees are included to cover the additional expense of integrating the commissioning process activities into the project specifications as provided by the Commissioning Authority and documenting the basis of design in a format suitable for the owner. Once they have been through the process, architects and engineers typically charge the same or less for involvement in the commissioning process due to savings during construction and operations from reduced requests for information and change orders. In addition, some design professionals may be eligible for lower professional liability insurance rates through involvement of the commissioning process.

Implementing the commissioning process may provide owners the opportunity to receive state-funded assistance and utility rebates or reduced utility rates.

Community Issues

The commissioning process provides a consistent means for the owner's procurement of a high-quality building that operates in accordance with the owner's project requirements, including the occupants' needs. Ultimately, the entire project team and community benefits when the building is operational the first day of use through reducing occupant complaints and allowing users and occupants to enjoy a healthier and more productive indoor environment that meets their success criteria.

Design Approach

The commissioning process begins at project inception when the owner chooses to adopt the process as the internal means to verify that the design professionals, contractors, and operations and maintenance staff achieve the owner's project require-

Table 1: Estimated Cost of Independent Third-Party Commissioning Services

Construction Cost	Total Cost for Commissioning	Fundamental Activities	Additional Activities
< $5 million	1.5%–3.0%	1.2%–2.5%	0.3%–0.5%
< $10 million	0.7%–2.0%	0.5%–1.7%	0.2%–0.3%
< $50 million	0.6%–1.5%	0.5%–1.3%	0.1%–0.2%
> $50 million	0.4%–1.5%	0.4%–1.3%	0.2%
Complex projects	Add 0.2%–0.8%	0.2%–0.7%	0.1%

Source: Cox, Dorgan and Dorgan. "*The Value of the Commissioning: Costs and Benefits.*" The Austin Papers: The Best of the 2002 USGBC International Green Building Conference. BuildingGreen, Inc, 2002.

Notes:
These costs include moderate travel expenses. Complexity, timing (number of site visits), and team cooperation greatly affect cost. Obtain hourly estimates by task to understand the Commissioning Authority's role and involvement.
These costs are for acquiring the services of an independent third-party Commissioning Authority. If the owner utilizes internal resources with the proper training and skill sets, the cost is often reduced by 20%-50%.

ments from planning through continual operations. The intent of the commissioning process is to minimize costly changes through early identification and continual focus on the achievement of the owner's project requirements. The commissioning process for a LEED project typically focuses on systems and assemblies having to do with the project's operational performance, particularly those relating to LEED prerequisites and credits. Examples include HVAC systems and their controls, duct work and piping; building envelope technologies; renewable and alternative energy technologies; lighting controls and daylighting systems; potable water efficiency technologies; rainwater harvesting systems; water treatment systems; and other advanced performance technologies. Verification of the contractor's achievement of the owner's project requirements includes such items as verification of the traditional testing, adjusting and balancing (TAB) work through sampling of the TAB report.

Strategies

The commissioning process is a planned, systematic quality-based process that involves the owner, users, occupants, operations and maintenance staff, design professionals and contractors. It begins at project inception; has ongoing verification of achievement of the owner's project requirements; requires integration of contractor-completed commissioning process activities into the construction documents; aids in the coordination of static and dynamic testing that acceptance is based on; verifies staff training; and completes with warranty verification and lessons-learned documentation and implementation. An explanation of the steps satisfying this LEED prerequisite is summarized in the following sections:

Engage a Commissioning Authority. Designate a Commissioning Authority as early as possible in the project time line, ideally at project inception. The Commissioning Authority serves as an objective advocate of the owner, directs the commissioning process, and presents final recommendations to the owner regarding the performance of commissioned systems and assemblies. The Commissioning Authority introduces standards and strategies early in the planning process and then verifies implementation of the commissioning process activities by clearly specifying the requirements in construction documents.

Ideally, a person on the owner's staff would be the Commissioning Authority. If this is not possible, a third-party firm is preferable, but for the purposes of this LEED prerequisite the Commissioning Authority can be from a design team firm, as long as that person is not responsible for project design, construction management or supervision. In all scenarios, the reporting of all conditions and findings must be immediate and direct from the Commissioning Authority to the owner. If a third-party Commissioning Authority is retained, it should be utilized for both implementing the fundamental LEED prerequisite and Additional Commissioning credit (EA Credit 3) activities.

Form the Commissioning Team. The Commissioning Team is led by the Commissioning Authority and is composed of the owner, users, occupants, operations and maintenance staff, design professionals and contractors. The Commissioning Team is responsible for accomplishing the commissioning process activities and provides leadership for identifying and resolving all commissioning process issues.

Document the Owner's Requirements. The Commissioning Team shall clearly document the owner's project requirements. The owner's project requirements are utilized throughout the Commissioning Process to provide focus on the key success criteria. These requirements typically address HVAC, lighting, indoor environment, energy efficiency, siting, water and environmental responsiveness of the facility. The document also addresses the ideas, objectives and criteria that the owner considers important. Any criteria listed in the owner's project requirements needs to be measurable, documentable and verifiable. Ideally, the owner's project requirements are developed upon project inception in tandem with LEED goals. However, if the commissioning process is not started until later in the project, the owner's project requirements must still be documented by the Commissioning Team.

Review the Basis of Design. The basis of design is developed by the design professionals as part of their normal design duties, but not often provided to the owner in a cohesive document. The basis of design includes how each of the owner's project requirements has been met; primary design assumptions such as occupancy, space and process requirements; applicable codes, policies and standards; and load and climatic assumptions that influence design decisions. An updated basis of design and design narrative should accompany each design phase submission.

Create a Commissioning Plan. The Commissioning Authority develops a commissioning plan at the start of the commissioning process, preferably at project inception. The commissioning plan evolves with results added as the project progresses. In circumstances when the decision to pursue a LEED rating is made after the design phase, the commissioning plan, including the owner's project requirements and basis of design, should be completed prior to the installation of any commissioned elements. **Table 2** lists the components that are required in the commissioning plan to satisfy this LEED prerequisite.

Include the Commissioning Requirements in Bid Documents. The contractor's commissioning process responsibilities must be integrated in the contract documents and must clearly describe the components listed in **Table 3**.

An area requiring careful coordination is the creation of operation and maintenance manuals. Depending on the owner's needs and relationship with the Commissioning Team members, the responsibility for this deliverable can reside with the Commissioning Authority, the

Table 2: Required Commissioning Plan Components

Required Commissioning Plan Components
Brief overview of the commissioning process
List of all systems and assemblies included in the Commissioning Authority's scope of work
Identification of the Commissioning Team and its responsibilities
Description of the management, communication and reporting of the commissioning process
Overview of the commissioning process activities for the pre-design, design, construction, and occupancy and operations phases, including development of the owner's project requirements, review of the basis of design, schematic design, construction documents and submittals, construction phase verification, functional performance test development and implementation, and 10-month warranty review.
List of the expected work products
List of key commissioning process milestones

Table 3: Commissioning Components in Construction Documents

Commissioning Components in Construction Documents
Commissioning Team involvement
Submittal review procedures
Operations and maintenance documentation requirements
Training plan development
Construction verification procedures
Start-up plan development and implementation
Functional performance testing
Milestones
Training
Warranty review site visit

design professional or the contractor. This decision needs to be made consciously with an aim towards maximizing the long-term usefulness of the documentation. If the owner has a high confidence level in the ability of the design professionals or contractor to prepare these documents, then they can be assigned the responsibility through the construction documents. If the Commissioning Authority is regarded as providing the best deliverable for the owner's needs, then the contractor can provide the basic information and the Commissioning Authority's scope of work can include creation of the manual. Either process satisfies the LEED prerequisite.

The following shall be completed on each commissioned component, equipment, system or feature:

Installation Verification: The Commissioning Authority must accomplish ongoing site visits to verify that each commissioned system and assembly is being installed to achieve the owner's project requirements as detailed in the contract documents and manufacturer's instructions, and to verify that other building systems or assemblies are not compromising the performance of the feature. The Commissioning Authority should accomplish this through verification of the contractor's completed construction checklists.

Start-up and Checkout: The contractor completes the start-up and initial checkout of all items listed in the contract documents. The start-up and checkout results must be clearly documented according to the manufacturer's written instructions and the contract documents, typically the last section of the construction checklists.

Sampling: As the commissioning process is quality-based, the Commissioning Authority applies appropriate sampling techniques to verify that construction, start-up and initial checkout of all commissioned systems and assemblies is successfully completed. For example, instead of checking 100% of the controls system, which is the contractor's responsibility, the Commissioning Authority utilizes sampling techniques to complete an in-depth periodic review of the control system installation, verifying that the components are calibrated; point-to-point checkouts are successful; and each control point is commanding, reporting and controlling according to the intended purpose. This ongoing sampling verification enables the Commissioning Authority to identify systemic issues early so they can be fixed and avoid rework at complete system checkout.

Functional Testing: The Commissioning Authority prepares written, repeatable test procedures, specifically for each project, which are used to functionally test systems and assemblies. These tests must be documented to clearly describe the individual systematic test procedures, the expected system response or acceptance criteria for each procedure, the actual response or findings, and any pertinent discussion. The test procedures are reviewed and accepted by the contractor's test entity, who may choose to implement the tests under the direction of the Commissioning Authority.

After acceptance of the installation, start-up and initial checkout (using the construction checklists), the modes described in the following paragraphs must be tested.

Test each sequence in the sequence of operations and other significant modes. Sequences and control strategies include start-up, shutdown, unoccupied and manual modes, modulation up and down the unit's range of capacity, power failure, alarms, component staging and backup upon failure (unit and pump), interlocks with other equipment, and sensor and actuator calibrations.

Test all larger equipment individually. Similar units that are numerous (e.g., many smaller rooftop packaged units, air terminal units and exhaust fans) may require a specific sampling strategy. Heating equipment must be tested during the winter and air-conditioning equipment must be tested during summer, as appropriate to demonstrate performance under near-design conditions.

Training: The Commissioning Authority must assemble written verification that training was conducted for all commissioned features and systems. The training may be performed by the contractor or the Commissioning Authority utilizing qualified individuals for a sufficient duration to ensure that facility staff has all the information needed to optimally operate, maintain and replace the com-

Table 4: Training Issues to be Addressed by the Commissioning Authority

Training Issues
General purpose of the system (design intent)
Use of the O&M manuals
Review of control drawings and schematics
Start-up, normal operation, shutdown, unoccupied operation, seasonal changeover, manual operation, controls set-up and programming, troubleshooting, and alarms
Interactions with other systems, adjustments and optimizing methods for energy conservation, relevant health and safety issues
Adjustments and optimizing methods for energy conservation
Relevant health and safety issues
Special maintenance and replacement sources
Tenant interaction issues
Discussion of how the feature or system is environmentally responsive

Table 5: Commissioning Report Components

Commissioning Report Components
Description of the owner's project requirements
Description of the project specifications
Verification of installation (construction checklist disposition)
Functional performance testing results and forms
O&M documentation evaluation
Training program evaluation
Value of the commissioning process
Outstanding issues

missioned features and systems. Training must address the issues in **Table 4**.

O&M Manuals: The Commissioning Authority must review the operations and maintenance (O&M) manuals for all commissioned systems and assemblies for completeness and applicability. The O&M data must be bound in labeled binders liberally divided with tabs, or provided electronically, to provide efficient access. Manuals should include: name, address and telephone number of the manufacturer or vendor and installing contractor; submittal data; and operations and maintenance instructions with the model and features for this site clearly marked. The manual should only include data for equipment that is actually installed.

Data requirements include: instructions for installation, maintenance, replacement, start-up, special maintenance and replacement sources, a parts list, a list of special tools, performance data, and warranty information.

The manual should also include a documentation package on as-built controls that includes a narrative for normal operation, shutdown, unoccupied operation, seasonal changeover, manual operation, controls setup and programming, troubleshooting, alarms, control drawings and schematics and final sequences of operation.

Commissioning Report: A commissioning report must be presented to the owner within a reasonable time after occupancy. The report must include a list of each commissioned system and assembly, as well as the disposition of the Commissioning Authority regarding the system's or assembly's compliance with the owner's project requirements. Required components of the commissioning report are listed in **Table 5**.

The written list of all outstanding commissioning issues and any testing that is scheduled for a later date, justified by seasonal conditions, must be included. A list of any compromises in the environmentally responsive features must be provided. All outstanding environmentally responsive feature deficiencies must be corrected or listed in the commissioning report. All completed functional tests should be listed in an appendix to the commissioning report.

Technologies

Commissioning is a process, not a technology that can be purchased. Use the USGBC membership listing (sort by Professional Firms: Commissioning Providers), professional contacts and the Internet to find experts who understand the governing energy codes and the equipment that contractors are likely to furnish and install. Several professional training and accreditation programs have been developed for the commissioning process. While not required for LEED project certification, owners may benefit from engaging a credentialed Commissioning Authority. See the Resources Section.

Synergies and Trade-Offs

The commissioning process affects all systems and assemblies, both static and dynamic. Site features on the project that require commissioning attention include alternative fueling stations and exterior lighting fixtures and systems. Water commissioning includes irrigation systems, plumbing fixtures and plumbing infrastructure. Energy commissioning covers HVAC systems, lighting and energy-generation equipment. Commissioning activities that affect indoor environmental quality include temperature and humidity controls, ventilation systems, monitoring equipment, occupant controls, envelope integrity and daylighting systems.

Resources

Web Sites

American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE)

www.ashrae.org, (800) 527-4723

Provides a two-day introductory course on the commissioning process. ASHRAE Guideline *0P, The Commissioning Process*, is being developed.

Building Commissioning Association

www.bcxa.org, (425) 774-6909

Promotes building commissioning practices that maintain high professional standards and fulfill building owners' expectations. The association offers a five-day intensive course focusing on how to implement the commissioning process, intended for Commissioning Authorities with at least two years' experience.

Federal Energy Management Program *Building Commissioning Guide*

www.eren.doe.gov/femp/techassist/bldgcomgd.html

The Energy Policy Act of 1992 requires each federal agency to adopt procedures necessary to ensure that new federal buildings meet or exceed the federal building energy standards established by the U.S. Department of Energy (DOE). DOE's Federal Energy Management Program, in cooperation with the General Services Administration, developed the *Building Commissioning Guide*.

Oregon Office of Energy, *Commissioning for Better Buildings in Oregon*

www.energy.state.or.us/bus/comm/bldgcx, (503) 378-5697

This document (and Web site of the same name) contains a comprehensive introduction to the commissioning process, including research, financial benefits and case studies.

Portland Energy Conservation Inc. (PECI)

PECI Model Building Commissioning Plan and Guide Specifications

www.peci.org, (503) 248-4636

Details the commissioning process for new equipment during design and construction phases for larger projects. In addition to commissioning guidelines, the document provides boilerplate language, content, format and forms for specifying and executing commissioning. The document builds upon the HVAC Commissioning Process, ASHRAE Guideline 1–1996, with significant additional detail, clarification and interpretation. The document contains four parts, totaling over 500 pages:

Part I. Commissioning Requirements—Design Phase: Commissioning requirements of the design team, including a full solicitation for commissioning services.

Part II. Model Commissioning Plan—Design Phase: Detailed commissioning boilerplate plan for commissioning during design, including design intent and basis of design format for 15 system types.

Part III. Commissioning Guide Specifications: A comprehensive guide organized by specification sections covering protocols, procedures and responsibilities of all parties. Includes complete specification language for Divisions 1, 15, and 16. This part includes testing requirements for 15 system types. Also included are detailed construction checklists for 20 types of equipment and example functional test procedures for 30 system types.

Part IV. Model Commissioning Plan—Construction Phase: Modular commissioning plans with 30 representative forms to facilitate the commissioning process.

University of Wisconsin, Madison, Department of Engineering Professional Development

epdwww.engr.wisc.edu, (800) 462-0876

Offers commissioning process training courses for building owners, architects, engineers, operations and maintenance staff, and other interested parties. The program also offers accreditation of commissioning process providers and managers.

Print Media

ASHRAE Guideline 1–1996: The HVAC Commissioning Process, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1996.

www.ashrae.org, (800) 527-4723

The purpose of this guideline is to describe the commissioning process to ensure that heating, ventilating and air-conditioning (HVAC) systems perform in conformity with design intent. The procedures, methods and documentation requirements in this guideline cover each phase of the commissioning process for all types and sizes of HVAC systems, from pre-design through final acceptance and post-occupancy, including changes in building and occupancy requirements after initial occupancy.

ASHRAE Guideline 4–1993: Preparation of Operations & Maintenance Documentation for Building Systems, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1993.

The purpose of this guideline is to guide individuals responsible for the design, construction and commissioning of HVAC building systems in preparing and delivering O&M documentation. The guideline addresses format, contents, delivery and maintenance of HVAC building systems O&M documentation normally provided by the building design and construction team members.

Sustainable Building Technical Manual, Public Technology, Inc., 1996 (www.pti.org).

SS	WE	EA	MR	EQ	ID

Prerequisite 2

Required

Minimum Energy Performance

Intent

Establish the minimum level of energy efficiency for the base building and systems.

Requirements

Design the building to comply with ASHRAE/IESNA Standard 90.1-1999 (without amendments) or the local energy code, whichever is more stringent.

Submittals

- ❑ Provide a LEED Letter Template, signed by a licensed professional engineer or architect, stating that the building complies with ASHRAE/IESNA 90.1-1999 or local energy codes. If local energy codes were applied, demonstrate that the local code is equivalent to, or more stringent than, ASHRAE/IESNA 90.1-1999 (without amendments).

Summary of Referenced Standard

ASHRAE/IESNA 90.1–1999: Energy Standard for Buildings Except Low-Rise Residential

American Society of Heating, Refrigerating and Air-Conditioning Engineers

www.ashrae.org, (800) 527-4723

Standard 90.1–1999 was formulated by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), under an American National Standards Institute (ANSI) consensus process. The project committee consisted of more than 50 individuals and organizations interested in commercial building energy codes for non-residential projects (commercial, institutional, and some portions of industrial buildings) as well as for high-rise residential buildings. The Illuminating Engineering Society of North America (IESNA) is a joint sponsor of the standard. The standard is also the basis of Chapter 7 of the International Code Council's 2001 International Energy Conservation Code, and forms the basis for many of the commercial requirements in codes that states consider for adoption. U.S. state energy codes that are equivalent or more stringent than the referenced standard are identified on the U.S. Department of Energy's Building Energy Codes Web site (see the Resources section for more details).

Standard 90.1 establishes minimum requirements for the energy-efficient design of buildings, except low-rise residential buildings. The provisions of this standard do not apply to single-family houses, multifamily structures of three habitable stories or fewer above grade, manufactured houses (mobile and modular homes), buildings that do not use either electricity or fossil fuel, or equipment and portions of building systems that use energy primarily for industrial, manufacturing or commercial processes. Building envelope requirements are provided for semi-heated spaces, such as warehouses.

The standard provides criteria in the following general categories: building envelope (section 5); heating, ventilating and air-conditioning (section 6); service water heating (section 7); power (section 8); lighting (section 9); and other equipment (section 10). Within each section, there are mandatory provisions that must always be complied with, as well as additional prescriptive requirements. Some sections also contain a performance alternate. The Energy Cost Budget option (section 11) allows the user to exceed some of the prescriptive requirements provided energy cost savings are made in other prescribed areas. However, in all cases, the mandatory provisions must still be met. See Design Strategies below for a more detailed summary of the requirements included in each section.

Table 1: Scope of Requirements Addressed by ASHRAE 90.1-1999

Components
Building Envelope
Heating, Ventilating, Air Conditioning
Service Water Heating
Electric Power Distribution
Electric Motors and Drives
Lighting

Green Building Concerns

Traditional development paradigms that have dominated building design for the past 50 years assume off-site generation, transmission and delivery of energy. While a case can be made that off-site generation has enabled developers to utilize space more productively, the benefits gained have come at a high environmental cost.

The evidence demonstrating that combustion of fossil fuels (CO_2 and NO_x) is linked to global warming continues to mount even as we continue to extract and burn these fuels at an increasing rate. Deregulated energy markets have enabled hydroelectric generation activities to market their electricity in regions unaffected by the regional impacts that dams can have on endangered species. Habitat protection is becoming a critical element of power planning and allocation efforts. Nuclear power continues to be controversial due to security and environmental issues related to waste reprocessing, transportation and storage. As the side effects associated with energy use become better understood, the demand for energy efficiency and renewable energy continues to grow.

Environmental Issues

Natural resource extraction, air pollution and water pollution can be greatly reduced by minimizing consumption of non-renewable energy resources. Refer to the introduction of the Energy & Atmosphere section for more information.

Economic Issues

Complying with the requirements as stated in the ASHRAE/IESNA 90.1–1999 standard decreases operating costs by reducing total energy consumption as well as "time of day" or "time of season" demand charges. The reduced total energy demand for a building also may translate into reduced first costs. For example, integrated design features may allow for smaller HVAC equipment. Local utility rebate programs and incentives from the state energy office are sometimes available for energy-efficient design and equipment.

Community Issues

Reduced dependence on fossil fuels for heating and cooling reduces air pollutant levels in urban areas. The EPA reports that about one out of every three people in the United States is at a high risk of experiencing adverse health effects from ground-level ozone (smog).

Design Approach

This prerequisite requires that the building comply with ASHRAE/IESNA 90.1-1999 or the local code, whichever is more stringent. For a general sense of how Standard 90.1-1999 compares with an individual state energy code, see the U.S. Department of Energy's Building Energy Codes Web site (see the Resources section). LEED compliance and credits, however, are determined for a specific building. Consequently, it is necessary to go beyond simple or general comparisons. It is necessary to look at the requirements applicable to the proposed design, such as the specific building envelope systems, mechanical systems and lighting uses.

Where both Standard 90.1 and the local code contain a provision that addresses the same topic (e.g., lighting power allowances for office space), it is usually easy to identify which document has the more stringent provision. Sometimes, however, Standard 90.1 and the local code will subdivide areas in different ways (e.g., Standard 90.1 contains four categories of insulation requirements for walls above grade, while a local code may only have one or two categories), and Standard 90.1 might have the more stringent provisions

Credit Synergies

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 3
CFC Reduction in HVAC&R Equipment

EA Credit 1
Optimize Energy Performance

EA Credit 2
Renewable Energy

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 6
Controllability of Systems

EQ Credit 7
Thermal Comfort

EQ Credit 8
Daylight & Views

in some of the subcategories, while the local code will have the more stringent provisions in other categories.

Strategies

Each section of Standard 90.1-1999 describes the applicability of the provisions (e.g., definitions and the building elements of interest), lists the mandatory provisions, and offers a prescriptive path or a performance path to demonstrate compliance.

Building Envelope is addressed in Section 5 of the referenced standard and includes three parts that must be satisfied to earn this prerequisite: 5.1, 5.2, and 5.3; OR 5.1, 5.2, and 5.4; OR 5.1, 5.2, and 11. The building envelope measures apply to enclosed spaces heated by a heating system whose output capacity is equal to or greater than 3.4 Btu/hour-square foot or cooled by a cooling system whose sensible output capacity is equal to or greater than 5 Btu/hour-square foot. Part 5.1 differentiates between the exterior envelope components and semi-exterior envelope components (5.1.1), as well as indicating how semi-heated spaces are to be treated (5.1.4). These definitions are helpful in determining the correct values to use in subsequent charts. Part 5.2 describes mandatory provisions for insulation installation (5.2.1), window, skylight and door ratings (5.2.2), and air leakage (5.2.3). Part 5.3 contains the prescriptive provisions for insulation for opaque assemblies (5.3.1) and U-factor and SHGC for fenestration (5.3.2).

These prescriptive provisions are customized for the location and climate of the project. The format is shown in an instructive example table (Table 5.3). Locations are listed alphabetically by state in Appendix D, with a cross-reference to the appropriate building envelope table. The prescriptive building envelope tables for the various climates are located in Appendix B. To use the prescriptive provisions, the window area must be less than 50% of the gross wall area and the skylight area must be less than 5% of the gross roof area. In some instances, this prescriptive approach may not be preferred because the designer may wish to use certain envelope assemblies that do not comply or the designer may wish to use larger fenestration areas. In these cases, the alternate path in Section 5.4 explains the Building Envelope Trade-off Option that can be followed for compliance. If the designer does not wish to demonstrate compliance using Sections 5.3 or 5.4, the last option is to analyze the entire building using the Energy Cost Budget method in Section 11. The Building Envelope section does not address moisture control or provide design guidelines to prevent moisture migration.

Heating Ventilation and Air Conditioning is addressed in Section 6 and includes three paths to demonstrate compliance with the standard: 6.1.3; OR 6.2 and 6.3; OR 6.2 and 11. Part 6.1.3 describes an approach that may be used for buildings that: 1) are two stories or less and 2) are 25,000 square feet or less. This is the simplest path to compliance for small buildings.

Part 6.2 contains the mandatory provisions. Tables include mandatory performance levels based on equipment size (6.2.1). The tables also provide efficiency levels that took effect in 2001. Minimum control schemes are listed for thermostats, off-hours including setback and optimum start, stair and elevator vents, outdoor air supply and exhaust vents, heat pump auxiliary heat, enclosed parking garage ventilation, humidification and dehumidification, freeze protection and snow/ice melting systems, and ventilation for high occupancy areas(6.2.3); as well as minimum duct construction and duct and pipe insulation criteria (6.2.4).

Part 6.3 provides a prescriptive compliance option. Prescriptive provisions are included for air and water economizers (6.3.1); simultaneous heating and cooling limitations (6.3.2); air system design and control including fan power limitation and variable speed drive (6.3.3); hydronic system design and control including variable flow pumping (6.3.4); heat rejection equipment (6.3.5); energy recovery from exhaust air and condenser water (6.3.6); kitchen and fume exhaust hoods (6.3.7); radiant heating systems (6.3.8); and hot gas bypass limitations (6.3.9). Here again, the alternate is Section 11, the Energy Cost Budget Method.

Service Water Heating is addressed in Section 7. This section follows a similar pattern of mandatory minimum provisions (7.2) and then a choice of prescriptive (7.3) or performance based compliance (11). There are mandatory provisions for efficiency (7.2.2), piping insulation (7.2.3), controls 7.2.4), pool heaters and pool covers (7.2.5), and heat traps for storage tanks (7.2.6). If the system is a combination space heating and water heating system and meets certain prescriptive thresholds (7.3.1), no further demonstration of service water heating compliance is required. If the thresholds are not met, the Energy Cost Budget Method must be followed to demonstrate compliance.

Power provisions are addressed in Section 8. This section only contains mandatory provisions (8.2). There are no prescriptive provisions. Voltage drop is limited (8.2.1) and a set of manuals and as-built drawings must be provided to the owner to document the power distribution system and all major pieces of equipment (8.2.2).

Lighting is addressed in Section 9. There is a mandatory provision subsection (9.2) that describes minimum requirements for controls (9.2.1), tandem wiring (9.2.2), luminaire source efficacy for exit signs (9.2.3), interior lighting power definitions (9.2.5), and luminaire source efficacy for exterior lighting fixture (9.2.6). A prescriptive path (9.3) with two calculation methods for interior lighting (9.3.1) and one calculation method for exterior lighting (9.3.2) can be employed to show final compliance.

For interior lighting, Building Area Method calculations (9.3.1.1) can only be used in cases where the project involves the entire building, or a single independent occupancy within a multi-occupancy building. Selecting the allowable lighting power density from a building type table and multiplying by the project area calculates the lighting budget allowance. If the total proposed lighting power density is lower than the interior lighting power allowance, the project complies. It is the simplest calculation methodology for lighting.

The Space-by-Space Method calculations (9.3.1.2) are applied to mixed-use projects. The method essentially aggregates multiple instances of building area method calculations for different occupancies. Trade-offs between different spaces are allowed as long as the total proposed lighting power density is less than the sum of the lighting power budget allowances for all individual occupancies. If the Energy Budget Cost Method is used for the overall building compliance, the proposed lighting design in the Energy Budget Cost Method model must be based on the lighting power density requirements of the prescriptive methods to demonstrate compliance.

Other Equipment including electric motors is addressed in Section 10. This section only contains mandatory provisions (10.2). There are no prescriptive provisions. All motors must comply with the requirements of the U.S. Energy Policy Act (EPAct) of 1992 (10.2).

The **Energy Cost Budget Method** is presented in Section 11 and describes the process to setup and execute a building simulation to demonstrate compliance. This is the alternate to following the prescriptive provisions of this standard. It may be applied to all proposed designs to demonstrate compliance with the standard EXCEPT those designs that include no mechanical system. Note that this method must be used to claim EA Credit 1: Optimize Energy Performance. Therefore, it is desirable to begin work on the simulation as soon as possible so that the energy efficiency benefits of various strategies can be evaluated early in the design process when there is the most flexibility. EA Credit 1 includes more detailed discussion of the Energy Cost Budget Method.

Synergies and Trade-Offs

The ASHRAE 90.1 standard is designed to afford significant trade-offs in energy efficiency measures while holding the total energy budget of a building constant or reducing it. Even for the basic compliance path, there are options to trade off within each of the Envelope, HVAC, Water Heating, Power and Lighting sections. Appropriate ventilation must be included in energy efficiency efforts to ensure optimal indoor air quality.

Calculations

Follow the calculation and documentation methodology as prescribed in the referenced standard. Record all calculations on the appropriate ASHRAE forms. Provide these forms to USGBC if the credit is audited during the LEED certification review. EA Credit 1 includes detailed discussion of the Energy Cost Budget Method and the LEED Energy Modeling Protocol.

Resources

Web Sites

Advanced Buildings

www.advancedbuildings.org

Hosted by a Canadian public/private consortium, this site provides explanations, costs, and information sources for 90 technologies and practices that improve the energy and resource efficiency of commercial and multi-unit residential buildings.

American Council for an Energy Efficient Economy

www.aceee.org, (202) 429-8873

ACEEE is a nonprofit organization dedicated to advancing energy efficiency as a means of promoting both economic prosperity and environmental protection.

Energy Star® Buildings Upgrade Manual

www.energystar.gov (Tools & Resources section), (888) 782-7937

This document from the EPA is a guide for Energy Star Buildings Partners to use in planning and implementing profitable energy-efficiency upgrades in their facilities and can be used as a comprehensive framework for an energy strategy.

New Buildings Institute

www.newbuildings.org, (509) 493-4468

The New Buildings Institute is a nonprofit, public-benefits corporation dedicated to making buildings better for people and the environment. Its mission is to promote energy efficiency in buildings through technology research, guidelines and codes.

U.S. Department of Energy's Building Energy Codes Program

www.energycodes.gov

The Building Energy Codes program provides comprehensive resources for states and code users, including news, compliance software, code comparisons and the Status of State Energy Codes database. The database includes state energy contacts, code status, code history, DOE grants awarded and construction data.

U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy

www.eere.energy.gov, (800) DIAL-DOE

A comprehensive resource for Department of Energy information on energy efficiency and renewable energy, including access to energy links and downloadable documents.

Print Media

ASHRAE Standard 90.1–1999 User's Manual, ASHRAE, 1999.

The new 90.1–1999 User's Manual was developed as a companion document to the ASHRAE/IESNA Standard 90.1–1999 (Energy Standard for Buildings Except Low-Rise Residential Buildings). The User's Manual explains the new standard and includes sample calculations, useful reference material, and information on the intent and application of the standard. The manual is abundantly illustrated and contains numerous examples and tables of reference data. The manual also includes a complete set of compliance forms and worksheets that can be used to document compliance with the standard.

The User's Manual is helpful to architects and engineers applying the standard to the design of buildings; plan examiners and field inspectors who must enforce the standard in areas where it is adopted as code; and contractors who must construct buildings in compliance with the standard. A compact disc accompanies the User's Manual and contains the EnvStd 4.0 Computer Program for performing building envelope trade-offs, plus electronic versions of the compliance forms found in the User's Manual.

Commercial Lighting Efficiency Resource Book, EPRI, 1991.

Sustainable Building Technical Manual, Public Technology, Inc., 1996.

CFC Reduction in HVAC&R Equipment

SS | WE | EA | MR | EQ | ID

Prerequisite 3

Required

Intent

Reduce ozone depletion.

Requirements

Zero use of CFC-based refrigerants in new base building HVAC&R systems. When reusing existing base building HVAC equipment, complete a comprehensive CFC phase-out conversion.

Submittals

- ❑ Provide a LEED Letter Template, signed by a licensed professional engineer or architect, declaring that the building's HVAC&R systems do not use CFC-based refrigerants.

Summary of Referenced Standard

There is no standard referenced for this credit.

Credit Synergies

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 4
Ozone Depletion

MR Credit 1
Building Reuse

Green Building Concerns

Older refrigeration equipment uses chlorofluorocarbons (CFCs) in refrigerants. CFCs are the root cause of serious environmental and health problems. The reaction between a CFC and an ozone molecule in the earth's stratosphere destroys the ozone and reduces the stratosphere's ability to absorb a portion of the sun's ultraviolet (UV) radiation. Overexposure to UV rays can lead to skin cancer, cataracts and weakened immune systems. Increased UV can also lead to reduced crop yield and disruptions in the marine food chain.

CFCs fall into a larger category of ozone-depleting substances (ODSs). The United States is one of the world's largest emitters of ODSs. As such, actions taken in the United States to limit the release of ODSs have a significant impact on global ODS release. Recognizing the profound human health risks associated with ozone depletion, 160 countries have agreed to follow the Montreal Protocol on Substances that Deplete the Ozone Layer since the late 1980s. This treaty includes a timetable for the phase-out of production and use of ODSs. In compliance with the Montreal Protocol, CFC production in the United States ended in 1995.

As part of the U.S. commitment to implementing the Montreal Protocol, Congress added new provisions to the Clean Air Act designed to help preserve and protect the stratospheric ozone layer. These amendments require the U.S. Environmental Protection Agency (EPA) to develop and implement regulations for the responsible management of ozone-depleting substances in the United States. EPA regulations include programs that ended the domestic production of ODSs, identified safe and effective alternatives to ODSs, and require manufacturers to label products either containing or made with chemicals that have a significant ozone-depleting potential.

Environmental Issues

Leaks in refrigeration circuits result in CFC releases into the atmosphere. CFCs destroy stratospheric ozone molecules through a catalytic reaction that splits the molecule. The reaction renders the ozone incapable of shielding the earth against incoming ultraviolet radiation. CFCs in the stratosphere also absorb infrared radiation and function as potent greenhouse gases.

Banning the use of CFCs in refrigerants slows the depletion of the ozone layer and reduces the accumulation of greenhouse gases and the potential for global climate change. Thoughtfully choosing equipment can also result in greater energy efficiency.

Economic Issues

CFC production in the United States was completely phased out by the end of 1995. Although it is possible to obtain CFC refrigerants from existing stocks (both virgin and recycled), competition for these materials will increase dramatically in the future. Shrinking supplies combined with continued demand has increased the cost of the remaining CFC stockpile higher, thus altering the economics of refrigerant and fire suppression system conversion.

Specification of non-CFC building equipment is now standard as no new systems utilizing CFCs are being manufactured. Existing building renovations will require additional first costs to convert or replace systems currently using CFCs. Most new non-CFC HVAC systems and refrigerants are cost-competitive with CFC equipment. Replacement rather than conversion of HVAC systems may increase equipment efficiencies and enable projects to reap energy savings over the life of the building.

Community Issues

Ozone depletion negatively affects the Earth and its inhabitants. Human beings overexposed to UV rays are at a higher risk of developing skin cancer, cataracts and weakened immune systems. Increased UV contributes to reduced crop yield and disruptions in the marine food chain. Elimination of CFCs in building equipment reduces ozone depletion and in turn minimizes the health and environmental risks as well as their associated economic impacts.

Design Approach

Specify only non-CFC-based refrigerants in all base building HVAC&R and fire suppression systems. In existing structures, check HVAC, refrigerant equipment and fire suppression systems before beginning design work. If equipment uses CFCs, the owner must complete a refrigerant change-out prior to completion of the project. These requirements also apply to central or district cooling facilities.

Strategies

Consider the characteristics of various CFC substitutes. Refrigerants have varying applications, lifetimes, ozone-depleting potentials (ODPs) and global-warming potentials (GWPs). **Table 1** provides examples of environmental lifetimes, ODP values and GWP values for a variety of refrigerants. Refrigerants should be chosen that have short environmental lifetimes, small ODP values and small GWP values. The phase-out period of CFC substitutes should also be taken into account when specifying equipment. Some of these refrigerants are acceptable alternatives today but have relatively short phase-out deadlines.

Technologies

No "ideal" alternative for CFCs has been developed. See the EPA's List of Substitutes for Ozone-Depleting Substances (www.epa.gov/ozone/snap) for a current listing of alternatives to CFC refrigerants. Note that some alternatives are not suitable for retrofits.

Synergies and Trade-Offs

This prerequisite is the first step in a two-step process to reduce a building's contribution to the ozone depletion problem. Also see EA Credit 4. If the project does not contain mechanical refrigeration equipment, then the project meets the requirements of the prerequisite. Refrigeration equipment and refrigerant choices will impact on the energy performance of the building. Thus, it is important to balance energy efficiency with refrigera-

Table 1: Refrigerant Environmental Data

Refrigerant	Lifetime [years]	ODP	GWP
CFC-11	45	1	4,000
CFC-12	100	1	8,500
CFC-13	640	1	11,700
CFC113	85	1	5,000
CFC 114	300	1	9,300
CFC -115	1,700	1	9,500
Halon 1211	11	3	n/a
Halon 1301	65	10	5,600
Halon 2402	n/a	6	n/a
HCFC-22	12	0.06	1,700
HCFC-123	1	0.02	93
HCFC-124	6	0.02	480
HCFC-141b	9	0.11	630
HCFC-142b	19	0.07	2,000
HFC-32	5.6	0	650
HFC-125	32.6	0	2,800
HFC-134a	14.6	0	1,300
HFC-143a	48.3	0	3,800
HFC-152a	1.5	0	140
HFC-236fa	209	0	6,300

Source: EPA's Ozone Depletion Web Site

tion choices. In building reuse projects, it may be costly or difficult to upgrade building equipment that currently uses CFCs.

Resources

Web Sites

Benefits of CFC Phase-out

www.epa.gov/ozone/geninfo/benefits.html

An EPA document on the benefits of CFC phase-out, including brief case studies.

U.S. Environmental Protection Agency's Ozone Depletion Web site

www.epa.gov/ozone, (800) 296-1996

Provides information about the science of ozone depletion, the regulatory approach to protecting the ozone layer (including phase-out schedules) and alternatives to ozone-depleting substances.

U.S. Environmental Protection Agency's Significant New Alternatives Policy (SNAP)

www.epa.gov/ozone/snap, (800) 296-1996

An EPA program to identify alternatives to ozone-depleting substances, the SNAP Program maintains up-to-date lists of environmentally friendlier substitutes for refrigeration and air conditioning equipment, solvents, fire suppression systems, adhesives, coatings and other substances.

Print Materials

Building Systems Analysis & Retrofit Manual, SMACNA, 1995.

CFCs, HCFC and Halons: Professional and Practical Guidance on Substances that Deplete the Ozone Layer, ASHRAE, 2000.

The Refrigerant Manual: Managing The Phase-Out of CFCs, BOMA International, 1993.

Definitions

Chlorofluorocarbons (CFCs) are hydrocarbons that deplete the stratospheric ozone layer.

Hydrochlorofluorocarbons (HCFCs) are refrigerants that cause significantly less depletion of the stratospheric ozone layer compared to CFCs.

Refrigerants are the working fluids of refrigeration cycles. They absorb heat from a reservoir at low temperatures and reject heat at higher temperatures.

Optimize Energy Performance

SS	WE	EA	MR	EQ	ID
Credit 1					

1–10 points

Intent

Achieve increasing levels of energy performance above the prerequisite standard to reduce environmental impacts associated with excessive energy use.

Requirements

Reduce design energy cost compared to the energy cost budget for energy systems regulated by ASHRAE/IESNA Standard 90.1-1999 (without amendments), as demonstrated by a whole building simulation using the Energy Cost Budget Method described in Section 11 of the Standard.

New Bldgs.	Existing Bldgs.	Points
15%	5%	1
20%	10%	2
25%	15%	3
30%	20%	4
35%	25%	5
40%	30%	6
45%	35%	7
50%	40%	8
55%	45%	9
60%	50%	10

Regulated energy systems include HVAC (heating, cooling, fans and pumps), service hot water and interior lighting. Non-regulated systems include plug loads, exterior lighting, garage ventilation and elevators (vertical transportation). Two methods may be used to separate energy consumption for regulated systems. The energy consumption for each fuel may be prorated according to the fraction of energy used by regulated and non-regulated energy. Alternatively, separate meters (accounting) may be created in the energy simulation program for regulated and non-regulated energy uses.

If an analysis has been made comparing the proposed design to local energy standards and a defensible equivalency (at minimum) to ASHRAE/IESNA Standard 90.1-1999 has been established, then the comparison against the local code may be used in lieu of the ASHRAE Standard.

Project teams are encouraged to apply for innovation credits if the energy consumption of non-regulated systems is also reduced.

Submittals

- ❑ Complete the LEED Letter Template incorporating a quantitative summary table showing the energy saving strategies incorporated in the building design.

- ❑ Demonstrate via summary printout from energy simulation software that the design energy cost is less than the energy cost budget as defined in ASHRAE/IESNA 90.1-1999, Section 11.

Summary of Referenced Standard

ASHRAE/IESNA 90.1–1999: Energy Standard for Buildings Except Low-Rise Residential

American Society of Heating, Refrigerating and Air-Conditioning Engineers

www.ashrae.org, (800) 527-4723

Standard 90.1–1999 was formulated by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), under an American National Standards Institute (ANSI) consensus process. The project committee consisted of more than 50 individuals and organizations interested in commercial building energy codes for non-residential projects (commercial, institutional, and some portions of industrial buildings) as well as for high-rise residential buildings. The Illuminating Engineering Society of North America (IESNA) is a joint sponsor of the standard. The standard is also the basis of Chapter 7 of the International Code Council's 2001 International Energy Conservation Code, and forms the basis for many of the commercial requirements in codes that states consider for adoption. U.S. state energy codes that are equivalent or more stringent than the referenced standard are identified on the U.S. Department of Energy's Building Energy Codes Web site (see the Resources section for more details).

Standard 90.1 establishes minimum requirements for the energy-efficient design of buildings, except low-rise residential buildings. The provisions of this standard do not apply to single-family houses, multifamily structures of three habitable stories or fewer above grade, manufactured houses (mobile and modular homes), buildings that do not use either electricity or fossil fuel, or equipment and portions of building systems that use energy primarily for industrial, manufacturing or commercial processes. Building envelope requirements are provided for semi-heated spaces, such as warehouses.

Table 1: Scope of Requirements Addressed by ASHRAE/IESNA 90.1-1999

ASHRAE/IESNA 90.1-1999 Components
Section 5: Building Envelope (including semi-heated spaces such as warehouses)
Section 6: Heating, Ventilating and Air-Conditioning (including parking garage ventilation, freeze protection, exhaust air energy recovery, and condenser heat recovery for service water heating)
Section 7: Service Water Heating (including swimming pools)
Section 8: Power (including all building power distribution systems)
Section 9: Lighting (including lighting for exit signs, building exterior, grounds, and parking garage)
Section 10: Other Equipment (including all permanently wired electrical motors)

For EA Credit 1, LEED relies extensively on the performance compliance path of the standard, the Energy Cost Budget Method (ECB Method). The method provides performance criteria for the components listed in **Table 1**.

The ECB method is intended to demonstrate compliance with ASHRAE/IESNA 90.1-1999 through an interactive model that allows comparison of the total energy cost for the Proposed Design and a baseline design (Budget Building). To accomplish this efficiently, a number of restrictions on the modeling process are imposed by the standard. Examples include simplified climate data, the fact that both buildings must have a mechanical system, and that process loads are to be included in both designs. Important restrictions that must be addressed to achieve compliance with the credit are highlighted in the Calculations section.

Credit Synergies

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Prerequisite 3
CFC Reduction in HVAC&R Equipment

EA Credit 3
Additional Commissioning

EA Credit 4
Ozone Depletion

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 6
Controllability of Systems

EQ Credit 7
Thermal Comfort

EQ Credit 8
Daylight & Views

Green Building Concerns

Energy efficiency reduces the harmful environmental side effects of energy production and use. Institution of energy-efficiency measures can be done at no cost to occupant comfort or building services. Many energy-efficiency measures result in a more comfortable indoor environment while reducing operating and first costs. Even small energy savings have incremental effects on the environment and cost savings.

Environmental Issues

Conventional forms of energy production have devastating environmental effects. Production of electricity from fossil fuels creates air and water pollution; hydroelectric generation plants can make waterways uninhabitable for indigenous fish; and nuclear power has safety concerns as well as problems with disposal of spent fuel. Refer to the Introduction of the Energy & Atmosphere section for more information.

Economic Issues

Many energy-efficiency measures do not require additional first costs. Those measures that do result in higher first costs often create savings realized from lower energy use over the building lifetime, downsized equipment, reduced mechanical space needs, and utility rebates. These savings can dwarf the increased first costs. Payback periods for many off-the-shelf energy efficiency measures are generally short. With more sophisticated integrated design, some systems can even be eliminated.

The importance of even small energy-efficiency measures is significant. For instance, by replacing one incandescent lamp with a fluorescent lamp, production of three-quarters of a ton of carbon dioxide and 15 pounds of sulfur dioxide are avoided over the lifetime of the lamp. This substitution also saves $30-$50 in energy costs over the operating lifetime of the lamp.

Community Issues

Energy-efficiency measures result in a more pleasant indoor environment and can increase worker productivity. Forward-thinking businesses are now actively leveraging their facilities as a strategic tool to attract and retain employees. Energy-efficiency measures result in lower and more stable energy prices. Reduced energy use also results in less global-warming potential, limits the impact of natural resource extraction activities, and prevents water and pollution, benefiting everyone.

Design Approach

The ASHRAE/IESNA 90.1–1999 interactive calculation method is a powerful and versatile tool for comparing the relative costs and benefits of different energy efficiency strategies. The design case is modeled first, and then mandatory and prescriptive provisions of the standard are applied to devise the baseline case. For instance, if the design case has a passive solar design with daylighting, then the baseline case is based on the same building geometry. The terminology used by 90.1–1999 is used in this LEED credit. The term "Design Energy Cost" refers to the design case of the project. The term "Energy Cost Budget" refers to the baseline case of the project as defined by the standard.

The modeling methodology addressed in Section 11 of the ASHRAE/IESNA 90.1–1999 User's Manual describes procedures for establishing the proposed Design Energy Cost and the baseline Energy Cost Budget. Standard ASHRAE forms are provided in the User's Manual. Use these forms to track progress during parametric studies and as support documents for this credit.

It is recommended to start modeling early in the design process. Note that the ECB method starts with the Proposed Design and then backs out the Budget Building. Consequently, as the design progresses from schematics through final drawings, it will be necessary to revise the Budget Building in response to the evolution of the Proposed Design.

Starting the modeling early can provide insights for design decisions and can provide an early indication of what it will take to achieve certain levels of energy cost reductions for a particular project. Many energy efficiency measures (such as better windows, more insulation, more efficient lighting) have impacts on both heating and cooling, sometimes in a complex manner. The modeling methodology shows the interactive effects of energy efficiency measures across all the building systems. For example, when the lighting wattage is changed, this affects both the heating and cooling energy consumption. When more energy efficient lighting (lower wattage) is installed in a building in a hot climate with little or no heating, the model will indicate how much additional energy savings there are in space cooling (due to lower internal loads) and how much the peak cooling equipment can be downsized (for first cost savings). For a cold climate, the model will show a somewhat lower cooling savings, but also some increase in heating (due to a lower internal load). In almost all cases, there will be savings beyond that of the lighting alone, with the most savings in the hottest climates and the least in the coldest climates.

The unit of measure for energy performance required for this credit is the annual energy cost expressed in dollars. Annual energy costs are determined using rates for purchased energy such as electricity, gas, oil, propane, steam and chilled water that are approved by the adopting authority (e.g., state or local government).

In the absence of an adopted rate structure, the applicant may propose use of the local utility rate structure applicable to the project. There may be uncertainty as to what rate schedule will apply to the project due to a long planning horizon, or due to deregulation of the power industry in some states. In this case, use default purchased energy costs as listed in **Table 4**. To earn this credit, the Design Energy Cost must be less than the Energy Cost Budget.

Strategies

Three fundamental strategies can increase energy performance: reduce demand, harvest free energy, and increase efficiency. Accomplish demand reduction by challenging initial use assumptions, by increasing plug load efficiencies, and by reducing internal loads and gains through shell and lighting improvements. Harvesting site energy includes using free resources such as daylight, ventilation cooling and solar heating to satisfy needs for space conditioning. Finally, the efficiency of the building HVAC system should be maximized to meet the other building conditioning requirements.

This three-step approach to optimize energy performance is the most effective method to exceed performance requirements of the referenced standard. When applying this approach, it is important to establish and document energy goals and expectations, and apply modeling techniques to reach these goals.

Demand reduction is the first step to optimize building energy performance. Reduce demand through design strategies such as reducing the overall building footprint to decrease the total space that will require conditioning, relaxing temperature design criteria to allow for a wider acceptable range of indoor temperatures, and utilizing occupancy sensors to automatically turn off equipment when building occupants are not present.

Lighting comprises a major fraction of a commercial building's energy budget. For interior lighting, reference the guidelines of the Illuminating Engineering Society of North America (IESNA) and follow the recommended illumination levels. Lighting should be designed for specific needs such as task lighting to reduce ambient lighting requirements.

Harvesting free energy is the second step in increasing building energy performance and involves meeting as much of the energy load as possible with free sources available on-site. Strategies such as turning off lights when daylight is available, using cool nighttime air for ventilation cooling, and extracting thermal value from the ground through geothermal exchange are all forms of site energy harvesting.

Building orientation is a crucial element to harvesting site energy. Rules of thumb for passive solar orientation and optimal building sections are well developed and can be found in references. Appropriate envelope design and material choices should reflect the local climate. Considerations include use of the building's thermal mass to mitigate diurnal temperature variations, strategic placement of windows to employ natural ventilation, use of appropriate insulation and glazing, and use of appropriate colors to reflect or absorb heat from the sun while avoiding possible glare problems.

To realize simple solar control, the building should be aligned on an east-to-west axis. Sun, wind and light should all be considered when designing the building. Solar gain through the building's roof, walls and windows can be beneficial or detrimental to the building's energy performance. For example, exterior overhang elements can be employed to shade windows in summer months and allow for heat penetration in winter months. In some climates, radiation or evaporative cooling schemes are appropriate.

Once an advantageous building orientation on the site is established, the size and position of doors, windows and vents can be determined based on heating, lighting, cooling and ventilating considerations. For example, the building fenestration can be designed to optimize natural daylighting, heating and cooling. A solar path analysis for the site, as well as aperture optimization studies, can be applied to determine optimal size, location and orientation for windows, floors and skylights. Glare and direct sunlight on task areas should be minimized, and it may be desirable to filter incoming daylight with plants, draperies, screens, translucent shades or light-scattering glazing. Interior finishes should be specified to enhance daylighting based on reflectance.

To maximize daylight penetration, locate windows high on walls or use clerestories and light shelves. Light pipes or fiber-optic devices can be used to introduce daylight in less accessible spaces. Locate storage areas, restrooms and low-occupancy areas in the building's central core while locating regularly occupied spaces in perimeter areas. Skylights and roof monitors can use baffles to diffuse light and reduce glare. Glazing should be selected to balance the need for light transmission with desired insulating and shading performance. Daylighting schemes can incorporate automatic lighting controls to respond to available daylight.

Holes and cracks in sills, studs, joists and other building elements should be plugged, caulked or sealed to reduce or eliminate infiltration. Other air barriers include weather-stripping on doors and sealing gaskets on operable windows. Thermal bridging should be avoided when using materials such as metal framing that conduct heat or cold through walls or cantilevered decks.

Increased efficiency is the final step toward optimizing energy performance and is best realized through application of state-of-the-art equipment to meet the minimized building energy load. This step is applied after the first two steps (described above) are fully implemented.

New, high-performance lighting continues to evolve and become standard in the marketplace. Recent developments include the T-5 fluorescent light and ultra-high efficiency sulfur lamp. Fluorescent lamps should be selected over incandescent bulbs due to their markedly better light output per kilowatt ratio. Compact fluorescent lamps typically use 75% less energy and last 10 times longer than incandescent bulbs. When using linear fluorescents, use a combination of T-5 or T-8 lamps and electronic ballasts that are housed in fixtures with a high coefficient of utilization (CU).

For exterior lighting, use metal halide lamps, low-temperature fluorescents and/or solar powered fixtures. For emergency lighting, use highly efficient LED (light-emitting diode) Energy Star-rated exit signs. A typical long-life incandescent exit sign consumes 40 watts and its lamps must be replaced every eight months. A typical compact fluorescent exit sign consumes 10 watts and the lamps must be replaced every 1.7 years, on average. A typical LED exit sign consumes less than 5 watts and has a life expectancy of over 80 years. Also consider electroluminescent signs that only use 0.5 watts.

Optimize HVAC system efficiency by not oversizing plant equipment. All components should be sized appropriately and take into account other energy performance measures incorporated in the building. Variable-air-volume (VAV) systems can be used to reduce energy use during part-load conditions. In certain climates, economizer cycles can take advantage of free cooling using outside air within appropriate temperature ranges.

Size duct work appropriately and install balancing dampers to reduce velocity losses. Ducts with larger cross-sectional areas have much lower air resistance and can reduce fan energy significantly. Duct cross-section shapes such as round or oval duct work can further reduce ventilation losses. Lower air speeds in ducts reduce energy needs and noise. Duct work should be insulated and sealed. Indoor air quality issues should also be considered when selecting and installing duct insulation.

Specify high-performance chillers and multiple chillers of various sizes to be step-engaged in order to efficiently meet partial load demands. Specify high-efficiency motors for all applications and variable speed drives for fans, chillers and pumps.

Use tank insulation, anti-convection valves, heat traps and smaller heaters with high recovery rates to reduce energy requirements for service water heating, pumping and purification. Time-of-day controls can further optimize energy performance.

Consider installing an effective energy management and control system or a direct digital control (DDC) electronic system. A good energy management system will facilitate smooth building start-ups and shutdowns as well as optimize efficiency and occupant comfort. Control of the management system should include zone-level controls. Occupancy sensors can be used to light spaces only when people are present, resulting in lighting energy savings of up to 60%.

Distributed Generation (DG) and Cogeneration (Cogen) can be used to increase delivered energy efficiency and reutilize waste energy from existing process loads. Cogeneration, also known as Combined Heat and Power (CHP), is the simultaneous production of electricity and useful heat from the same fuel or energy. Distributed Generation is the use of small-scale power generation technologies located at or close to the load being served. Because no long-range transmission of electricity generated on-site is required and waste heat from the generation process is utilized, the delivered efficiency of DG and Cogen facilities can be far superior to electric grid power.

Synergies and Trade-Offs

The opportunity to employ energy-efficiency measures depends in part on the chosen project site and site design. Sites with greater opportunity for solar and wind opportunities should be given preference. Reducing heat island effects can reduce ambient temperature conditions and thus space-cooling requirements. Landscaping can be used to protect the building from wind and to provide shade. Design of site lighting can have a significant effect on energy use.

Water systems can also affect energy use. Automated irrigation and plumbing fixtures require energy for operation. Conversely, low-flow plumbing can save energy required for water pumps and hot water heating. Commissioning and measurement & verification activities have a significant effect on energy use and can ensure that predicted energy savings are realized. Reuse of an existing building may limit energy performance efforts, but there are environmental benefits with regard to materials and construction waste.

Building designers may experience trade-offs between energy efficiency and indoor environmental quality. The provisions for energy efficiency should be balanced with the preferred levels of thermal comfort and ventilation effectiveness. For example, thermal comfort criteria will interact with the HVAC design modeled in the simulation.

Calculations

LEED relies extensively on the performance compliance path of the referenced standard, which is called the Energy Cost Budget method (ECB Method). ECB section 11.4 requires that all building systems and equipment be modeled identically in the Budget Building and Proposed Design, except as specifically instructed in 11.4. While the ECB Method makes sense for a code compliance tool, it is less useful in determining how far green building performance may go beyond conventional practice. To provide guidance to LEED users, and to reward energy efficiency measures that are otherwise not recognized by the referenced standard, the LEED Energy Modeling Protocol (EMP) was created.

The **LEED Energy Modeling Protocol** (EMP) has some major differences from the ECB Method, which are listed below to assist the user with the challenges of modeling a green building. The ECB Method is followed unless the LEED EMP makes exceptions or clarifications to the ECB Method. The basic method of demonstrating compliance is to first model the proposed design, and then set the model parameters back to default prescriptive values, thus establishing a Budget Building (baseline) for comparison.

Schedules of operation must be the same for the proposed and budget building models. Equipment-use profiles may not be estimated using schedule changes. For example, daylighting controls cannot be approximated by turning off the lighting in the model for a portion of the day. The proposed design model must simulate performance of the daylighting control in response to daylight availability. See Section 11.3.11 of the 90.1–1999 User's Manual for an explanation.

Table 2: Bounding Comfort Parameters

Temperature Range	Hours allowed
85° +	<20
80-85°	<50
75-80°	<150
60-65°	<50
55-60°	<20
<55°	not allowed

Design criteria, both climate data and interior set points, must be the same for the proposed and budget building models. For example, if the ASHRAE 2.5% climate data is used for the proposed design, it must also be used for the baseline or budget case.

Buildings that elect to follow thermal comfort indoor design criteria that meet ASHRAE Standard 55–1992 should also pursue Environmental Quality Credit 7. The EMP recognizes that the design criteria for a green building are often different than those used for a conventional building, and less stringent indoor design criteria than Standard 55–1992 may be followed. In an effort to keep energy use comparisons consistent and related to a common definition of comfort conditions, LEED defines some bounding parameters for a minimum level of comfort during occupied hours. The bounding parameters are listed in **Table 2**.

To assure compliance, the applicant must determine if the project is within the bounding parameters by inspection of values shown on the "Building Energy Performance Summary (BEPU)" report generated by most energy-simulation software.

This report typically provides a message that describes "percent of hours any system zone outside of throttling range" and/or "percent of hours any plant load not satisfied." If a building falls outside of these parameters because it uses non-temperature-based comfort parameters, a demonstration of minimum comfort using the ASHRAE comfort zone depicted on a psychrometric chart is required.

HVAC systems are generally the same basic type in the proposed and the budget cases. It is assumed that any trade-offs are made between more or less efficient versions of the chosen system. In efforts to reduce gaming and to simplify the determination of code compliance, the standard has a restricted set of HVAC systems that must be used in the Budget Building (baseline) model. Use the ECB Method to determine the Budget HVAC system type. Tables are provided in the 90.1 User's Manual for selecting the terminal system and plant configuration.

The LEED EMP makes one exception to this rule. For proposed equipment with less than 150 tons of cooling capacity, the baseline (budget building) condenser cooling source can be defined as air regardless of the proposed design. The purpose of this exception is to encourage designers to specify more efficient water-based cooling systems over air-based cooling systems in smaller equipment sizes.

HVAC systems in green buildings are sometimes hybrid or experimental in nature. It may be necessary to approximate some or all of the functional aspects of experimental systems. To conduct the simulation, an analog mechanical system must be created. The simulation must be a thermodynamically similar model that can be used to simulate passive conditioning schemes.

For example, there are few energy simulation computer programs that can model an under-floor ventilation system. To create a modeling analog of this system, a conventional VAV system could be modeled with 63°F supply air, extended economizer hours, and a taller return air plenum modeled to capture all of the heat from lights and some fraction of the interior gains such as plug loads. Energy modeling judgment is required to create this representation, and should be completed by an experienced energy analyst. Use the LEED Credit Interpretation process to have special modeling approaches approved.

Both the ECB Method and the LEED EMP assume that even if a heating or cooling system is not installed at the time of construction, future occupants might elect to use energy-consuming temporary measures for conditioning needs. Special cases of absent heating or cooling systems require the modeling of a default system to establish the ECB.

For example, in a building cooled *only* by passive ventilation, occupants may resort to personal space fans in large numbers, eliminating the expected energy savings. Buildings that do not have one of these systems must have the ECB modeled with an HVAC system that meets the minimum Prescriptive Requirements of the referenced standard.

The approach described above may create problems when a green, non-conventional system is proposed. If no clear HVAC System Map (Table 11.4.3) choice is apparent, then no clear set of prescriptive values for the default green system exists. In other cases, the HVAC System Map would lead the modeler to conclude that a baseline system quite different than the proposed design should be selected. This decision conflicts with the ASHRAE Section 11 approach of holding the baseline and design systems constant to determine energy savings. When in doubt, use the Credit Interpretation process to have system modeling choices approved.

Fan energy is separated from the cooling system in the ECB Method. Thus, if the HVAC manufacturer provides an overall efficiency rating, such as an energy efficiency ratio (EER), it must be separated into the component energy using the coefficient of performance (COP) or other conversion factors. See Section 11.4.3 of the User's Manual for more information.

Outdoor air ventilation can be a major energy consumer but it is not considered an opportunity for energy savings using the referenced standard. Ventilation rates must be the same in both the proposed and budget building designs. If heat recovery is required (see Section 6.3.6.1), then it must be modeled in both cases. See Section 11.4.3d of the User's Manual for more information.

Envelope criteria of special significance include roof and shading devices. Reflective roofs that have lower heat absorption can be modeled differently and are given credit for reduced heat gains. If the reflective roof is rated at a minimum reflectance of 0.70 and a minimum emittance of 0.75, the project is not required to use the default 0.30 value. Qualifying roofs can use a modeled value of 0.45 which accounts for age degradation of the roof over time.

Overhangs and other **shading projections** in the proposed design can receive credit against fenestration flush to the exterior wall of the Budget Building if these features reduce the solar gains on the glazing. The modeler should include the differences between the budget and proposed cases as appropriate. Interior shading devices such a mini-blinds and curtains that are not permanent cannot be used in the ECB Method to reduce energy costs of the proposed case below the budget. Interior shading devices must be modeled identically for the proposed and budget cases. See Section 11.4.2 of the 90.1-1999 User's Manual for an explanation.

Lighting is to be modeled the same except as identified in 11.4.5. For lighting, credit can be taken for lower installed lighting wattage. Lighting controls (primarily automatic shutoff) are modeled using lighting schedules. Daylighting controls are not modeled in the budget building, but may be modeled in the proposed building design. If modeled, the controls must be based on the response to daylight levels, not a change in the lighting schedule. See 90.1 Section 11.4.5 for more information.

Other systems regulated by Standard 90.1-1999 include: parking garage ventilation (6.2.3.5), freeze protection and snow/ice melting systems (6.2.3.8), exhaust air energy recovery which applies to laboratory systems unless they comply with 6.3.7.2 (6.3.6.1), condenser heat recovery for service water heating which applies primarily to laundries in hospitals (6.3.6.2), kitchen hoods (6.3.7.1), laboratory fume hoods (6.3.7.2), swimming pools (7.2.2 & 7.2.5), "all building power distribution systems" (8.1), exit signs (9.2.3), exterior building grounds lighting (9.2.6), parking garage lighting (9.3.1, Tables 9.3.1.1 & 9.3.1.2), building exterior lighting including entrance, exit, and façade lighting (9.3.2), and "all permanently wired electrical motors" (10.1). Credit can be taken in the proposed building for improvements over the minimum requirements listed above for the budget building.

Process energy or other energy-related systems that generate internal heat gains or interact with other energy systems need to be carefully assessed and must be modeled in both the proposed and budget designs. ASHRAE provides only limited guidance on the definition of process loads, stating that it is "the energy consumed in support of manufacturing, industrial or commercial processes not related to the comfort and amenities of the building's occupants."

In the absence of direction in the 1999 version of the standard, LEED users are directed to use the minimum receptacle loads recommended in the 1989 version of ASHRAE as listed in **Table 3**. If there are substantially larger plug loads, they must be modeled identically in the proposed and baseline cases. For example, many technology companies have large plug loads associated with multiple computers per user. Be aware, though, that most equipment now has an energy saver mode, so the nameplate load is rarely experienced. ASHRAE has done much research in this area. Before using name-

Table 3: Minimum Receptacle Loads

Use	Receptacle Power Density [W/SF]
Assembly	0.25
Office	0.75
Retail	0.25
Warehouse	0.10
School	0.50
Hotel/Motel	0.25
Restaurant	0.10
Health	1.00
Multi-family	See ASHRAE 90.1 (Table 13-5)

plate ratings for load calculations, refer to Chapter 29 of the 2001 ASHRAE Handbook of Fundamentals for recommended heat gain from typical computer equipment (Table 8) and other equipment (Tables 5-10). These loads should be modeled using reasonable assumptions and must be modeled identically in both the budget and proposed cases.

Energy Rates are an important part of the ECB Method. Rates from the local utility schedules are the default option to compute energy costs. The intent is to encourage simulations that provide owners value and help them minimize their energy costs. The modeler needs to use the same rates for both the budget and proposed building designs.

In the absence of a local utility rate schedule, or of energy rate schedules approved by the local ASHRAE/IESNA 90.1–1999 adopting authority, the applicant may use the energy rates listed in **Table 4**. This table is based on Table 11-K from the 90.1 User's Guide, and the data published periodically in the document DOE/EIA-0380 (2000/03). Regardless of the source of the rate schedule used, the same rate

Table 4: Commercial Sector Average Energy Costs by State

State	Electricity [$/kWh]	Natural Gas [$/mcf]	No. 2 Fuel Oil [$/MMBtu]	No. 6 Fuel Oil [$/MMBtu]
Alabama	$0.066	$6.98	$4.07	$2.40
Alaska	$0.094	$2.44	$5.92	n/a
Arizona	$0.076	$5.31	$5.06	n/a
Arkansas	$0.057	$5.23	$4.09	n/a
California	$0.091	$6.41	$5.11	$2.70
Colorado	$0.057	$4.06	$4.70	n/a
Connecticut	$0.101	$7.23	$4.94	$3.38
Delaware	$0.069	$6.70	$4.06	$2.62
District of Columbia	$0.071	$7.37	$4.60	$3.16
Florida	$0.065	$6.85	$4.36	$2.71
Georgia	$0.071	$6.43	$4.27	$2.76
Hawaii	$0.126	$15.77	$5.01	$2.93
Idaho	$0.043	$4.49	$5.25	$2.31
Illinois	$0.078	$5.43	$4.55	$2.78
Indiana	$0.062	$5.44	$4.20	$2.49
Iowa	$0.066	$5.18	$4.30	n/a
Kansas	$0.063	$5.38	$4.30	$2.51
Kentucky	$0.052	$5.79	$4.34	n/a
Louisiana	$0.066	$6.22	$4.07	n/a
Maine	$0.110	$7.70	$5.15	$2.75
Maryland	$0.065	$6.52	$4.39	$2.74
Massachusetts	$0.092	$7.34	$4.90	$2.86
Michigan	$0.080	$5.00	$4.48	$2.57
Minnesota	$0.061	$4.80	$4.39	$2.41
Mississippi	$0.067	$5.26	$4.19	n/a
Missouri	$0.058	$5.88	$4.27	$2.36
Montana	$0.061	$4.83	$4.56	$2.20
Nebraska	$0.053	$4.88	$4.30	$2.38
Nevada	$0.066	$5.08	$5.13	n/a
New Hampshire	$0.115	$7.63	$4.68	$2.55
New Jersey	$0.099	$5.88	$4.40	$2.92
New Mexico	$0.080	$4.01	$4.11	n/a
New York	$0.115	$6.49	$5.06	$3.34
North Carolina	$0.063	$7.00	$4.27	$2.81
North Dakota	$0.059	$4.35	$4.30	$2.38
Ohio	$0.076	$6.23	$4.30	$2.69
Oklahoma	$0.053	$5.34	$4.28	$2.37
Oregon	$0.051	$4.63	$4.54	$2.74
Pennsylvania	$0.082	$7.35	$4.62	$2.80
Rhode Island	$0.099	$8.21	$5.49	$3.00
South Carolina	$0.063	$6.74	$4.32	$2.72
South Dakota	$0.065	$4.71	$4.26	$2.36
Tennessee	$0.064	$6.11	$4.34	$2.40
Texas	$0.067	$4.91	$4.16	$2.46
Utah	$0.057	$3.92	$4.79	$1.86
Vermont	$0.104	$5.18	$5.22	$2.90
Virginia	$0.057	$6.45	$4.48	$2.68
Washington	$0.048	$4.73	$4.91	$2.75
West Virginia	$0.056	$6.34	$4.43	n/a
Wisconsin	$0.059	$5.35	$4.59	$2.38
Wyoming	$0.053	$3.93	$4.75	$2.29
U.S. Average	**$0.074**	**$5.79**	**$4.69**	**$3.14**

Source: ASHRAE/IESNA Standard 90.1-1999 User's Manual schedule must be used in both the baseline and proposed simulations.

Calculating LEED energy performance is straightforward, but requires several steps to accomplish. Only energy regulated by ASHRAE/IESNA Standard 90.1–1999 is considered in determining the percent energy savings. The "regulated energy components" include the commonly thought-of systems for heating, cooling, auxiliaries (pumps, fans, etc.), water heating and interior lighting as well as those items listed "other systems."

Non-regulated components are limited but include plug loads, process energy (including special filtering requirements for clean rooms, etc.), garage ventilation, exterior lighting, elevators and any other miscellaneous energy uses in the building for which the standard does not contain requirements. The exclusion of non-regulated loads requires that the results of most whole-building simulation reports need additional processing in order to determine the percent energy savings for LEED.

The percent savings should be calculated as in **Equation 1**, where ECB' is the energy cost budget for the regulated energy components, and DEC' is the design energy cost for the regulated components.

Determining ECB' and DEC' requires a small amount of manipulation. First, the whole-building simulation is used to produce economic reports that show the total cost for electricity, gas and possibly other energy sources such as steam and chilled water. These reports provide ECB and DEC (no primes).

The next simulation report to be examined splits energy use by the regulated and non-regulated energy uses. In DOE2, for example, this report is called the building energy performance summary or BEPU report. Data from this report would be used to determine ECB' and DEC' as described by **Equation 2**. This is the approach specified by Standard 90.1–1999 so that process energy, plug loads, elevators and all other non-regulated energy components are identical for both the ECB and the DEC.

The following example shows how the ECB method works for a 100,000-square-foot project. The design case uses a high performance envelope, a VAV air system with high-efficiency, ground-coupled heat pumps, and direct/indirect ambient lighting with task lamps. Using the ASHRAE system map, the budget HVAC system type is modeled as a water source heat pump

Equation 1: Energy Savings Calculation

$$\% \text{ Savings} = 100 \times \frac{ECB' - DEC''}{ECB'}$$

Equation 2: Energy Cost Budget Calculation

$$ECB' = \text{Baseline } \frac{\text{Regulated kWh}}{\text{Total kWh}} \times \frac{\text{kWh}}{\text{Cost}} [\$] + \text{Baseline } \frac{\text{Regulated Therms}}{\text{Total Therms}} \times \frac{\text{Gas}}{\text{Cost}} [\$] + \text{Baseline } \frac{\text{Other}}{\text{Energy}} [\$]$$

Equation 3: Design Energy Cost Calculation

$$DEC' = \text{Proposed } \frac{\text{Regulated kWh}}{\text{Total kWh}} \times \frac{\text{kWh}}{\text{Cost}} [\$] + \text{Proposed } \frac{\text{Regulated Therms}}{\text{Total Therms}} \times \frac{\text{Gas}}{\text{Cost}} [\$] + \text{Proposed } \frac{\text{Other}}{\text{Energy}} [\$]$$

Equation 4: Design Energy Cost with Renewable Contribution Calculation

$$DEC'' = DEC' - REC'$$

system type, constant volume fan control, direct expansion cooling, and electric heat pump and boiler heating type.

To determine the **Design Energy Cost**, create a design building energy simulation model using DOE2, TRANE Trace, Carrier E20II or another hourly load and energy-modeling tool. The model parameters for all loads, including plug and process loads and the expected building occupancy profile and schedule, are adjusted to determine central system capacities and energy use by system. Through parametric manipulation, the designer increases component efficiencies to exceed the referenced standard.

Using a summary report of the modeled building energy load per system (e.g, the BEPU Report for DOE2), separate regulated loads from non-regulated loads as defined by ASHRAE. Non-regulated loads are plug and direct process loads. Regulated loads are HVAC, lighting and service hot water loads.

Determine the design energy cost for individual fuels by then processing the regulated loads' fuel quantities and the unit cost per fuel. The individual fuel DECs are then totaled to establish the design building regulated load energy cost. As there is no on-site renewable energy in

Table 5: Design Case Data

End Use	Energy Type	Electric [kWh]	Gas [CCF]	Energy Use [10^3 Btu]	Cost [$]
Regulated					
Lighting	Electric	160,200		546,602	$11,200
Space Heating	Natural gas		4,550	455,000	$3,223
Space Cooling	Electric	240,300		819,904	$16,800
Fans/Pumps	Electric	120,150		409,952	$8,400
Hot Water (1)	Natural gas		1,750	175,000	$1,240
Hot Water (2)	Natural gas		700	70,000	$496
Subtotal Regulated (DEC')		520,650	7,000	2,476,458	$41,358
Nonregulated					
Lighting	Electric	80,100		273,301	$5,600
Space Heating	Natural gas		4,000	400,000	$2,833
Space Cooling	Electric	40,050		136,651	$2,800
Fans/Pumps	Electric	80,100		273,301	$5,600
Hot Water	Natural gas		1,000	100,000	$708
Subtotal Non-Regulated		200,250	5,000	1,183,253	$17,542
Total Building		**720,900**	**12,000**	**3,659,711**	**$58,900**
Subtotal Regulated (DEC')		520,650	7,000	2,476,458	$41,358
Subtotal Renewable (REC')		(65,641)		(223,968)	-$4,589
DEC"				2,252,489	**$36,769**

this example, this establishes the DEC" for the design case. In cases where on-site renewable energy is generated, subtract the equivalent cost from DEC' as shown in **Equation 4**. The simulation reports for the example are utilized to create **Table 5**.

The **Energy Cost Budget** is then calculated by modeling the baseline system that the reference standard system map prescribes into the simulation model. Include the exact same loads (including plug and process loads) and an identical building occupancy profile and schedule to accurately determine central system capacities and energy use by system.

Minimum or prescriptive system component efficiencies are entered to satisfy the referenced standard and to meet EA Prerequisite 2. This simulation is performed to establish the baseline minimum energy performance, or ECB.

Using a summary of the modeled building energy load per system (e.g., BEPU Report for DOE2), separate regulated loads from non-regulated loads as defined by ASHRAE. Non-regulated loads are plug and direct process loads. Regulated loads are HVAC, lighting, and service hot water loads.

Table 6: Budget Case Data

End Use	Energy Type	Electric [kWh]	Gas [CCF]	Energy Use [10^6 Btu]	Cost [$]
Regulated					
Lighting	Electric	350,000		1,194,200	$35,000
Space Heating	Natural gas		9,000	900,000	$5,850
Space Cooling	Electric	250,000		853,000	$25,000
Fans/Pumps	Electric	150,000		511,800	$15,000
Hot Water (1)	Natural gas		4,500	450,000	$2,925
Hot Water (2)	Natural gas		1,500	150,000	$975
Subtotal Regulated (ECB')		750,000	15,000	4,059,000	$84,750
Nonregulated					
Lighting	Electric	80,100	-	273,301	$8,010
Space Heating	Natural gas		4,000	400,000	$2,600
Space Cooling	Electric	40,050	-	136,651	$4,005
Fans/Pumps	Electric	80,100	-	273,301	$8,010
Hot Water	Natural gas		1,000	100,000	$650
Subtotal Non-Regulated		200,250	5,000	1,183,253	$23,275
Total Building		**950,250**	**20,000**	**5,242,253**	**$108,025**
Subtotal Regulated (ECB')		750,000	15,000	4,059,000	$84,750
ECB'				**4,059,000**	**$84,750**

The ECB for individual fuels is then determined by processing the regulated loads' fuel quantities and the unit cost per fuel. The individual fuel ECBs are then added together to establish the ECB' for the baseline case. The results are shown in **Table 6**.

Finally, compare the two simulation results using **Equation 2**. In the example, the results are summarized in **Table 7**, which is the format required for LEED documentation submittal. If an existing building renovation includes a new building addition, point achievement will be prorated (based on percentage of new versus existing square footage) during the LEED certification review.

Resources

Web Sites

DOE2

doe2.com

A comprehensive energy analysis program used to predict hourly performance of a building's energy use and utility costs.

ENERGY STAR®

www.energystar.gov, (888) 782-7937

ENERGY STAR is a government/industry partnership managed by the U.S. Environmental Protection Agency and the U.S. Department of Energy. The program's Web site offers energy management strategies, benchmarking software tools for buildings, product procurement

Table 7: LEED Energy Cost Budget Compliance Table

Regulated Energy Summary by End Use	Energy Type	Proposed Building Energy [10³ Btu]	Proposed Building Peak [10³ Btu]	Budget Building Energy [10³ Btu]	Budget Building Peak [10³ Btu]	Proposed/ Budget Energy [%]
Lighting - Conditioned	Electricity	491,942	163,981	1,074,780	346,703	46%
Lighting - Unconditioned	Electricity	54,660	5,466	119,420	12,571	46%
Space Heating	Gas	455,000	1,365,000	900,000	4,320,000	51%
Space Cooling	Electricity	819,904	273,301	853,000	304,643	96%
Pumps	Electricity	40,995	7,884	51,180	10,236	80%
Fans - Interior Ventilation	Electricity	360,758	649,364	450,384	150,128	80%
Fans - Interior Exhaust	Electricity	8,199	8,199	10,236	10,236	80%
Service Water Heating	Gas	245,000	81,667	600,000	214,286	41%

Energy & Cost Summary by Fuel	DEC" Use [10³ Btu]	DEC" Cost [$]	ECB' Use [10³ Btu]	ECB' Cost [$]	DEC" / ECB' Energy %	DEC" / ECB' Cost %
Electricity	1,776,458	$36,400	2,559,000	$75,000	69%	49%
Natural Gas	700,000	$4,958	1,500,000	$9,750	47%	51%
Other Fossil Fuel	-	$0	-	$0	-	-
Subtotal Non-Renewable (DEC')	2,476,458	$41,358	4,059,000	$84,750		
Subtotal Renewable (REC')	(223,968)	-$4,589	-	$0	-	-
Total	2,252,489	$36,769	4,059,000	$84,750		
		Percent Savings = 100 x (ECB' $ -DEC" $)/ECB' $ =				56.6%
			Credit 1 Points Awarded =			9

guidelines and lists of ENERGY STAR-labeled products and buildings.

National Renewable Energy Program (NREL) Energy-10

www.nrel.gov/buildings/energy10, (303) 275-3000

ENERGY-10 is an award-winning software tool for designing low-energy buildings. *ENERGY-10* integrates daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient shell design and mechanical equipment. The program is applicable to commercial and residential buildings of 10,000 square feet or less. Note, however, that while useful for design, Energy-10 does not satisfy the requirements of Section 11 of ASHRAE/IESNA 90.1-1999, and can not be used for compliance with EA Credit 1.

U.S. Department of Energy's Building Energy Codes Program

www.energycodes.gov

The Building Energy Codes program provides comprehensive resources for states and code users, including code comparisons, compliance software, news and the *Status of State Energy Codes* database. The database includes state energy contacts, code status, code history, DOE grants awarded and construction data.

U.S. Department of Energy Office of Energy Efficiency and Renewable Energy

www.eren.doe.gov/EE/buildings.html, (800) DOE-EREC

This extensive Web site for energy efficiency is linked to a number of DOE-funded sites that address buildings and energy. Of particular interest is the tools directory that includes the Commercial Buildings Energy Consumption Tool for estimating end-use consumption in commercial buildings. The tool allows the user to define a set of buildings by principal activity, size, vintage, region, climate zone and fuels (main heat, secondary heat, cooling and water heating), and to view the resulting energy consumption and expenditure estimates in tabular format.

Print Media

ASHRAE Standard 90.1–1999 User's Manual, ASHRAE, 1999.

The new 90.1–1999 User's Manual was developed as a companion document to the ASHRAE/IESNA Standard 90.1–1999 (Energy Standard for Buildings Except Low-Rise Residential Buildings). The User's Manual explains the new standard and includes sample calculations, useful reference material, and information on the intent and application of the standard.

The manual is abundantly illustrated and contains numerous examples and tables of reference data. The manual also includes a complete set of compliance forms and worksheets that can be used to document compliance with the standard. The User's Manual is helpful to architects and engineers who must apply the standard to the design of the buildings, plan examiners and field inspectors who must enforce the standard in areas where it is adopted as code, and contractors who must construct buildings in compliance with the standard. A compact disc accompanies the User's Manual and contains the EnvStd 4.0 Computer Program for performing building envelope trade-offs plus electronic versions of the compliance forms found in the User's Manual.

IESNA Lighting Handbook (Ninth Edition), IESNA, 2000.

Mechanical and Electrical Systems for Buildings, 4th Edition, by Benjamin Stein and John S. Reynolds, John Wiley & Sons, 1992.

Sustainable Building Technical Manual, Public Technology, Inc., 1996 (www.pti.org).

Case Study

Donald Bren School of Environmental Science and Management
Santa Barbara, California

The University of California at Santa Barbara's Donald Bren School of Environmental Science and Management is a LEED™ Platinum Pilot Project and houses campus facilities including research and teaching laboratories, and offices. To optimize energy performance, the building was designed to harvest natural light and natural ventilation. High-efficiency building systems that include pumps, chillers, boilers, a high-efficiency laboratory ventilation system, and a chilled water loop were incorporated into the building design. The building envelope was designed to reduce high heat loads. Energy modeling of the building indicates that these measures result in energy savings of 23% when compared with a Title 24 baseline case.

Courtesy of Zimmer Gunsul Frasca Partnership

Owner
University of California at Santa Barbara

Renewable Energy

5%

1 point

Intent

Encourage and recognize increasing levels of on-site renewable energy self-supply in order to reduce environmental impacts associated with fossil fuel energy use.

Requirements

Supply at least 5% of the building's total energy use (as expressed as a fraction of annual energy cost) through the use of on-site renewable energy systems.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or responsible party, declaring that at least 5% of the building's energy is provided by on-site renewable energy. Include a narrative describing on-site renewable energy systems installed in the building and calculations demonstrating that at least 5% of total energy costs are supplied by the renewable energy system(s).

SS WE EA MR EQ ID

Credit 2.2

1 point
in addition to
EA 2.1

Renewable Energy

10%

Intent

Encourage and recognize increasing levels of self-supply through renewable technologies to reduce environmental impacts associated with fossil fuel energy use.

Requirements

Supply at least 10% of the building's total energy use (as expressed as a fraction of annual energy cost) through the use of on-site renewable energy systems.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or responsible party, declaring that at least 10% of the building's energy is provided by on-site renewable energy. Include a narrative describing on-site renewable energy systems installed in the building and calculations demonstrating that at least 10% of total energy costs are supplied by the renewable energy system(s).

SS	WE	EA	MR	EQ	ID

Credit 2.3

1 point
in addition to
EA 2.1 and 2.2

Renewable Energy

20%

Intent

Encourage and recognize increasing levels of self-supply through renewable technologies to reduce environmental impacts associated with fossil fuel energy use.

Requirements

Supply at least 20% of the building's total energy use (as expressed as a fraction of annual energy cost) through the use of on-site renewable energy systems.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or responsible party, declaring that at least 20% of the building's energy is provided by on-site renewable energy. Include a narrative describing on-site renewable energy systems installed in the building and calculations demonstrating that at least 20% of total energy costs are supplied by the renewable energy system(s).

Summary of Referenced Standard

ASHRAE/IESNA 90.1 – 1999: Energy Standard For Buildings Except Low-Rise Residential

American Society of Heating, Refrigerating and Air-Conditioning Engineers

www.ashrae.org, (800) 527-4723

On-site renewable or site-recovered energy that might be used to capture EA Credit 2 is handled as a special case in the modeling process. If either renewable or recovered energy is produced at the site, the ECB Method considers it free energy and it is not included in the Design Energy Cost. See the Calculation section for details.

Credit Synergies

SS Credit 1
Site Selection

SS Credit 5
Reduced Site Disturbance

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Credit 1
Optimize Energy Performance

EA Prerequisite 2
Minimum Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

EQ Credit 8
Daylight & Views

Green Building Concerns

Renewable energy can be generated on a building site by using technologies that convert energy from the sun, wind and biomass into usable energy. On-site renewable energy is superior to conventional energy sources such as coal, nuclear, oil, natural gas and hydropower generation, because of its negligible transportation costs and impacts. In addition to preventing environmental degradation, on-site use of renewable power can improve power reliability and reduce reliance on the local power distribution grid. In the 1990s, renewable energy applications were the fastest growing new sources of energy. Opportunities for renewable energy vary by location and climate.

In 2000, the photovoltaic (PV) panel market's annual growth rate was 20%. PV module production for terrestrial use has increased 500-fold in the past 20 years. Worldwide PV module shipments in 2002 exceeded 400 megawatts (MW). The United States now owns more than one-third of the global PV market.

The United States is one of the top five wind power markets in the world, according to the American Wind Energy Association. The construction of large wind farms in many states to satisfy regional electricity requirements and the installation of micro-turbines for specific applications continue to increase the U.S. market share of wind power. The U.S. wind energy industry currently has a 4,685 MW capacity and generates about 10 billion kilowatt-hours of electricity annually, equivalent to the annual electricity needs for one million average American homes, but less than 1% of U.S. electricity generation.

The market for small wind systems (< 100 kW) had an estimated growth of 35% in 1999. These small wind systems power homes and small businesses such as farms and ranches. The United States is also a leading producer of small wind systems. Four primary companies sell products both nationally and internationally.

Biomass power is derived from organic matter such as waste wood and grasses. The U.S. Department of Energy (DOE) estimates that biomass power is the largest source of non-hydroelectric renewable energy in the world, with an estimated 14,000 MW of annual worldwide installed generation capacity. With more than 7,000 MW of installed capacity, the United States is the largest single "biopower" generator, representing a $15 billion investment and 66,000 jobs. The 37 billion kWh of electricity produced each year from biomass is more than the entire state of Colorado uses annually. Generating this amount of electricity requires around 60 million tons of biomass per year. The Electric Power Research Institute (EPRI) has estimated that biomass combustion facilities could satisfy 5% of the total U.S. power market for electricity while increasing overall farm income by $12 billion annually.

Continued need for on-site industrial power, waste reduction, more stringent environmental regulations, and rising consumer demand for renewable energy will provide the main impetus for the industry's growth.

Environmental Issues

Use of renewable energy reduces environmental impacts associated with utility energy production and use. These impacts include natural resource destruction, air pollution and water pollution. Utilization of biomass can divert an estimated 350 million tons of woody construction, demolition, and land-clearing waste from landfills each year. Conversely, air pollution will occur due to incomplete combustion if these wastes are not processed properly.

Economic Issues

Use of on-site renewable energy technologies can result in energy cost savings, particularly if peak hour demand charges are high. Utility rebates are often available to reduce first costs of renewable energy equipment. In some states, first costs can be offset by net metering, where excess electricity is sold back to the utility.

The combined efforts of industry and the DOE reduced PV system costs by more than 75% from 1982 to 2000. The cost of PV systems with capacities greater than 1 kW is measured in "levelized" costs per kWh. In other words, the costs are spread out over the system lifetime and divided by kWh output. The levelized cost for these systems is currently estimated at $0.25 to $0.50 per kWh. Systems that do not require storage batteries can have significantly lower costs. PV systems are usually cost-effective for customers located farther than one-quarter mile from the nearest utility line. With Building-Integrated Photovoltaics (BIPVs), the costs should also include the marginal savings on the replaced elements of the building such as roofing or cladding. The reliability and lifetime of PV systems are also improving. Manufacturers typically guarantee their PV systems for up to 20 years.

According to the American Wind Energy Association, the levelized cost for commercial wind energy generation is $0.04 to $0.06 per kWh, or $0.033 to $0.053 if the federal production tax credit is factored in.

Community Issues

Renewable energy has a dramatic impact on outdoor environmental quality. Reductions in air and water pollution are beneficial to all community members. Renewable energy has a positive impact on rural communities. Economic development in these communities can be enhanced by siting and operating wind farms and biomass conversion facilities. Wind Powering America is an initiative by the DOE to dramatically increase the use of wind energy in the United States. Rural wind generation is providing new sources of income for American farmers, Native Americans, and other rural landowners while meeting the growing demand for clean sources of electricity. However, care must be taken to minimize undesirable noise from wind farms and suboptimal combustion at biomass conversion facilities.

Design Approach

Strategies

Design and specify the use of on-site nonpolluting renewable technologies to contribute to the total energy requirements of the project. Consider and employ high-temperature solar, geothermal, wind, biomass (other than unsustainably harvested wood) and bio-gas technologies. See **Table 1** for system trends. Note that passive solar, solar hot water heating, ground-source heat pumps and daylighting do not qualify for points under this credit because they do not gener-

Table 1: Renewable System Trends

Power Option	Current Size Range [kW]	Current Cost [$/kW]	Mass Production Cost [$/kW]
Wind Turbine	up to 3,000	$900 to $1000	$500
Solar Cell	up to 1,000	$5,000 to $10,000	$1,000 to $3,000
Biomass	up to 5,000	$2,000 to $2,500	$1,000

Sources: State of the World 2000 (WorldWatch Institute) and the BioEnergy Information Network (bioenergy.ornl.gov).

ate power. These strategies are recognized under EA Credit 1.

Make use of net metering by contacting local utilities or electric service providers (ESPs). Net metering is a metering and billing arrangement that allows on-site generators to send excess electricity flows to the regional power grid. These electricity flows offset a portion of the electricity flows drawn from the grid. For more information on net metering in individual states, visit the DOE's Green Power Network Web site at www.eere.energy.gov/greenpower/netmetering.

Technologies

Biomass is plant material such as trees, grasses and crops. To generate electricity, biomass is converted to heat energy in a boiler or gasifier. The heat is converted to mechanical energy in a steam turbine, gas turbine or an internal combustion engine, and the mechanical device drives a generator that produces electricity. Current biomass technology produces heat in a direct-fired configuration. Biomass gasifiers are also under development and are being introduced to the marketplace.

The most economical and sustainable biomasses are residue materials from regional industrial processes. Example materials include organic by-products of food, fiber and forest production such as sawdust, rice husks and bark. In urban areas, pallets and clean woody yard waste may be available. There also may be a steady supply of wood fiber from local waste collection of construction, demolition and land-clearing (CDL) debris. The cost to generate electricity from biomass varies depending on the type of technology used, the size of the power plant, and the cost of the biomass fuel supply.

The DOE's Small Modular Bioenergy Initiative is developing small, efficient and clean bio-power systems. Feasibility studies and prototype demonstrations will lead to full system integration based on a business strategy for commercialization.

Photovoltaics (PVs) are composite materials that convert sunlight directly into electrical power. In the past, these materials were assembled into PV panels that required a structure to orient them to the sun. In recent years, the efficiency of the cells has increased and the cost has dropped. As a result, Building-Integrated Photovoltaics (BIPVs) are now in production. BIPVs are increasingly incorporated into building elements such as the roof, cladding or window systems.

PVs generate direct current (DC) electricity, which generally must be converted to alternating current (AC) before it can be used in mainstream building systems. The conversion process requires electronic devices between the PV module and electrically powered appliances. Both dispersed and central converter schemes are possible. The conversion process also affords net metering, where power is put back into the utility grid when the local demand is less than the capacity of the PV array. As shown in **Table 2**, PV systems are rapidly becoming cost-effective. Spot electricity costs in the summer months of 2000 exceeded the cost of PV power by a factor of four at some locations in the United States.

Wind Energy systems convert wind into electricity. Wind energy installations are becoming increasingly popular as corporate power users and utilities realize the electricity supply, peak shaving, and net metering benefits of clean, low-cost, reliable wind energy.

Recent innovations include a larger rotor diameter using advanced airfoils and trailing-edge flaps for over-speed control. In the future, more advanced wind turbines incorporating the latest materials and mechanical technologies will be introduced to the marketplace. One example of advances in the wind turbine industry

Table 2: Photovoltaic Economic Trends

Photovoltaic Data	1991	1995	2000	2010 - 2030
Electricity Price [¢/kWh]	40 - 75	25 - 50	12 - 20	<6
Module Efficiency [%]	5 - 14	7 - 17	10 - 20	15 - 25
System Cost [$/W]	10 - 20	7 - 15	3 - 7	1 - 1.50
System Lifetime [years]	5 - 10	10 - 20	>20	>30
U.S. Cumulative Sales [MW]	75	175	400 - 600	>10,000

Source: U.S. Department of Energy Photovoltaics Program

is the development of a vertical-axis wind turbine which relies on simplicity of design and advanced blade configuration to create a potentially low-cost, efficient power system.

Synergies and Trade-Offs

Renewable energy equipment typically impacts the project site. Some project sites are more compatible with renewable strategies than others. The magnitude of the impact of renewable energy generation equipment is usually small. Renewable energy equipment will impact energy performance of the building and requires commissioning and measurement & verification attention. Building-integrated PV systems should be integrated with daylighting strategies.

Geothermal energy is electricity generated from steam or hot water that is released from the Earth, and is captured by sizable power plants rather than small on-site systems. This is not to be confused with geothermal heat exchange, which is an energy-efficient heating and cooling strategy, the benefits of which are applicable to EA Credit 1 (Optimize Energy Performance). Electricity generated from geothermal sources is applicable to EA Credit 6 (Green Power).

Calculations

The following calculation methodology supports the submittals as listed on the first page of this credit. The fraction of energy cost supplied by the renewable energy features is calculated against the DEC' determined in EA Credit 1. An energy simulation of the base project is required to capture the Renewable Energy Credit. The quantity of energy generated on-site may be estimated outside of the simulation tool.

The following example illustrates how to calculate the renewable energy credit achievement levels. Performance of the renewable source may be predicted using a bin type calculation. This requires the applicant to account for the contribution of variables associated with the renewable source. For example, a BIPV design would include the effects of sunny, cloudy and overcast conditions, the orientation and attitude of the array, and system losses. **Table 3** shows the calculation for

Table 3: Renewable Energy Calculation

BIPV system design	
Number of stories	5
Length of south facade	525 LF
Depth of awning	2 LF
Gross area of awning	5,250 SF
Shading effects	85%
Net area of awning =	4,463 SF
PV capacity	5.5 w/SF
Awning peak capacity	25 kW
Average daily output	4.03 kWh/100 SF
Average annual output	65,641 kWh

Equation 1: Renewable Energy Calculation

$$\% \text{ Renewable Energy} = 100 \times \frac{REC'}{DEC''}$$

a BIPV array installed on the same building used in the example calculations for EA Credit 1.

Once the amount of energy generated by the renewable system is calculated, an energy cost must be computed to establish the LEED level of achievement. The dollar value of the renewable energy must be derived from the simulation results of the energy model by determining a "virtual" energy rate for the renewable system.

As in the Calculations section of EA Credit 1, there are three options to compute the project energy costs, from which the "virtual" rate is derived. First, the LEED Energy Modeling Protocol (EMP) allows the use of a rate schedule available for the project location from local utility companies. The second option is to compute the energy cost using a proposed energy rate schedule, preferably approved by the local ASHRAE/IESNA 90.1–1999 adopting authority. In the absence of these approved rates, a third option is to follow the rates as shown in **Table 4**. This table is based on Table 11-K from ASHRAE/IESNA 90.1–1999 User's Manual, and the data published periodically in the document DOE/EIA-0380 (2000/03).

The value of the on-site production of energy is a simplified calculation. To assign a dollar value to the on-site energy, determine the "virtual" energy rate by dividing the total energy cost (regulated and unregulated) by the total energy use. Multiply the predicted on-site energy produced by the "virtual rate" for the value of this type of energy. **Table 5** shows the calculation for the renewable energy "virtual" rate of electricity and gas used by the sample building described in Credit 1.

When calculating the total energy cost using the LEED EMP, the contribution of any on-site renewable or recovered energy is accounted for by deducting the "virtual" utility costs. In other words, the Renewable Energy Cost (REC') is deducted from the DEC', as the ECB method is based on energy that crosses the property line. This net regulated energy cost is designated as the DEC" in the calculation method. The DEC" is used as the denominator of the achievement calculation, which in turn increases the percent improvement over the reference standard (see **Equation 1**).

In the example, the project described in EA Credit 1 is modified to include BIPVs as part of the design. The energy-modeling simulation is not changed for this credit. A bin analysis is used to predict that ~65,000 kWh are generated and fed into the grid through net metering. To calculate the value of this energy, a virtual rate is established from the existing simulation and then used to determine the dollar value used in the LEED savings calculation. **Table 6** shows how to incorporate the renewable energy cost into the calculations.

The example also shows how the renewable energy can change the overall energy savings calculation used to determine the points achieved in Credit 1 (Optimize Energy Performance). Compare **Table 7** with Table 6 of Credit 1. Note that the Energy Cost Budget (ECB) is the same in both examples. There are no default values for renewable energy, so there is no change to the ECB.

The total percent reduction in energy use changes, however. This is because Credit 1 is based on grid energy that crosses the

Table 4: Commercial Sector Average Energy Costs by State

State	Electricity [$/kWh]	Natural Gas [$/mcf]	No. 2 Fuel Oil [$/MMBtu]	No. 6 Fuel Oil [$/MMBtu]
Alabama	$0.066	$6.98	$4.07	$2.40
Alaska	$0.094	$2.44	$5.92	n/a
Arizona	$0.076	$5.31	$5.06	n/a
Arkansas	$0.057	$5.23	$4.09	n/a
California	$0.091	$6.41	$5.11	$2.70
Colorado	$0.057	$4.06	$4.70	n/a
Connecticut	$0.101	$7.23	$4.94	$3.38
Delaware	$0.069	$6.70	$4.06	$2.62
District of Columbia	$0.071	$7.37	$4.60	$3.16
Florida	$0.065	$6.85	$4.36	$2.71
Georgia	$0.071	$6.43	$4.27	$2.76
Hawaii	$0.126	$15.77	$5.01	$2.93
Idaho	$0.043	$4.49	$5.25	$2.31
Illinois	$0.078	$5.43	$4.55	$2.78
Indiana	$0.062	$5.44	$4.20	$2.49
Iowa	$0.066	$5.18	$4.30	n/a
Kansas	$0.063	$5.38	$4.30	$2.51
Kentucky	$0.052	$5.79	$4.34	n/a
Louisiana	$0.066	$6.22	$4.07	n/a
Maine	$0.110	$7.70	$5.15	$2.75
Maryland	$0.065	$6.52	$4.39	$2.74
Massachusetts	$0.092	$7.34	$4.90	$2.86
Michigan	$0.080	$5.00	$4.48	$2.57
Minnesota	$0.061	$4.80	$4.39	$2.41
Mississippi	$0.067	$5.26	$4.19	n/a
Missouri	$0.058	$5.88	$4.27	$2.36
Montana	$0.061	$4.83	$4.56	$2.20
Nebraska	$0.053	$4.88	$4.30	$2.38
Nevada	$0.066	$5.08	$5.13	n/a
New Hampshire	$0.115	$7.63	$4.68	$2.55
New Jersey	$0.099	$5.88	$4.40	$2.92
New Mexico	$0.080	$4.01	$4.11	n/a
New York	$0.115	$6.49	$5.06	$3.34
North Carolina	$0.063	$7.00	$4.27	$2.81
North Dakota	$0.059	$4.35	$4.30	$2.38
Ohio	$0.076	$6.23	$4.30	$2.69
Oklahoma	$0.053	$5.34	$4.28	$2.37
Oregon	$0.051	$4.63	$4.54	$2.74
Pennsylvania	$0.082	$7.35	$4.62	$2.80
Rhode Island	$0.099	$8.21	$5.49	$3.00
South Carolina	$0.063	$6.74	$4.32	$2.72
South Dakota	$0.065	$4.71	$4.26	$2.36
Tennessee	$0.064	$6.11	$4.34	$2.40
Texas	$0.067	$4.91	$4.16	$2.46
Utah	$0.057	$3.92	$4.79	$1.86
Vermont	$0.104	$5.18	$5.22	$2.90
Virginia	$0.057	$6.45	$4.48	$2.68
Washington	$0.048	$4.73	$4.91	$2.75
West Virginia	$0.056	$6.34	$4.43	n/a
Wisconsin	$0.059	$5.35	$4.59	$2.38
Wyoming	$0.053	$3.93	$4.75	$2.29
U.S. Average	**$0.074**	**$5.79**	**$4.69**	**$3.14**

Source: ASHRAE/IESNA Standard 90.1-1999 User's Manual

Table 5: Renewable Energy Rate Calculation

Utility Rate	Resource	Energy Use	Energy Cost
E -19 -Office	Electricity	540,675 kWh	$ 37,800
E -19 -Rtl	Electricity	180,225 kWh	$ 12,600
		720,900 kWh	$ 50,400
		Virtual Electricity Rate	$ 0.07 /kWh
G - NR1- Office	Natural Gas	12,000 CCF	$ 8,500
G - NR1- Rtl	Natural Gas	-	$ -
		12,000 CCF	$ 8,500
		Virtual Natural Gas Rate	$ 0.71 /CCF

Table 6: Proposed Case Post Processed Data

End Use	Energy Type	Electric [kWh]	Gas [CCF]	Energy Use [10^3 Btu]	Cost [$]
Regulated					
Lighting	Electric	160,200		546,602	$11,200
Space Heating	Natural gas		4,550	455,000	$3,223
Space Cooling	Electric	240,300		819,904	$16,800
Fans/Pumps	Electric	120,150		409,952	$8,400
Hot Water (1)	Natural gas		1,750	175,000	$1,240
Hot Water (2)	Natural gas		700	70,000	$496
Subtotal Regulated (DEC')		520,650	7,000	2,476,458	$41,358
Nonregulated/ Process					
Lighting	Electric	80,100		273,301	$5,600
Space Heating	Natural gas		4,000	400,000	$2,833
Space Cooling	Electric	40,050		136,651	$2,800
Fans/Pumps	Electric	80,100		273,301	$5,600
Hot Water	Natural gas		1,000	100,000	$708
Subtotal Non-Regulated		200,250	5,000	1,183,253	$17,542
Total Building		**720,900**	**12,000**	**3,659,711**	**$58,900**
Subtotal Regulated (DEC')		520,650	7,000	2,476,458	$41,358
Subtotal Renewable (REC')		(65,641)		(223,968)	-$4,589
DEC"				2,252,489	**$36,769**

property line. When part of the building energy load is handled from an on-site generation source, it is deducted from the numerator in the calculation. The final LEED point tallies are shown in **Table 7**.

Resources

Web Sites

American Bioenergy Association

www.biomass.org, (202) 467-6540

An industry trade association dedicated to developing the entire breadth of the bioenergy industry from power to fuels to bio-based chemicals.

Table 7: LEED Energy Cost Budget Compliance Table

Regulated Energy Summary by End Use	Energy Type	Proposed Building		Budget Building		Proposed/ Budget Energy
		Energy	Peak	Energy	Peak	
		[10^3 Btu]	[10^3 Btu]	[10^3 Btu]	[10^3 Btu]	[%]
Lighting - Conditioned	Electricity	491,942	163,981	1,074,780	346,703	46%
Lighting - Unconditioned	Electricity	54,660	5,466	119,420	12,571	46%
Space Heating	Gas	455,000	1,365,000	900,000	4,320,000	51%
Space Cooling	Electricity	819,904	273,301	853,000	304,643	96%
Pumps	Electricity	40,995	7,884	51,180	10,236	80%
Fans - Interior Ventilation	Electricity	360,758	649,364	450,384	150,128	80%
Fans - Interior Exhaust	Electricity	8,199	8,199	10,236	10,236	80%
Service Water Heating	Gas	245,000	81,667	600,000	214,286	41%

Energy & Cost Summary by Fuel	DEC" Use [10^3 Btu]	DEC" Cost [$]	ECB' Use [10^3 Btu]	ECB' Cost [$]	DEC" / ECB' Energy %	DEC" / ECB' Cost %
Electricity	1,776,458	$36,400	2,559,000	$75,000	69%	49%
Natural Gas	700,000	$4,958	1,500,000	$9,750	47%	51%
Other Fossil Fuel	-	$0	-	$0	-	-
Subtotal Non-Renewable (DEC')	2,476,458	$41,358	4,059,000	$84,750		
Subtotal Renewable (REC')	(223,968)	-$4,589	-	$0	-	-
Total	2,252,489	$36,769	4,059,000	$84,750		

Percent Savings = 100 x (ECB' $ -DEC" $)/ECB' $ =	**56.6%**
Credit 1 Points Awarded =	**9**
Percent Renewable = 100 x (REC' $)/DEC' $ =	**11.1%**
Credit 2 Points Awarded =	**2**

American Wind Energy Association (AWEA)

www.awea.org, (202) 383-2500

A national trade association representing wind-power plant developers, wind turbine manufacturers, utilities, consultants, insurers, financiers, researchers and others involved in the wind industry.

Database of State Incentives for Renewable Energy (DSIRE)

www.dcs.ncsu.edu/solar/dsire/dsire.cfm

This database was developed by the North Carolina Solar Center to track available information on state financial and regulatory incentives (e.g., tax credits, grants, and special utility rates) that are designed to promote the application of renewable energy technologies. DSIRE also offers additional features such as preparing and printing reports that detail the incentives on a state-by-state basis.

Green Power Network

www.eere.energy.gov/greenpower

Provides news and information on green power markets, utility pricing programs for net metering, and more. The Web site is maintained by the National Renewable Energy Laboratory for the U.S. Department of Energy

U.S. Department of Energy's BioPower Program

www.eere.energy.gov/biopower, (800) DOE-EREC

Includes information on the current state of the biomass industry. Of particular interest is the page describing the Small Modular BioPower Initiative. The initiative is aimed at determining the feasibility of developing systems that are fuel-flexible, efficient, simple to operate, and whose operation will have minimum negative impacts on the environment. The intended power range for these systems is from 5 kilowatts to 5 megawatts.

U.S. Department of Energy's National Center for Photovoltaics (NCPV)

www.nrel.gov/ncpv, (800) DOE-EREC

Provides clearinghouse information on all aspects of PV systems.

U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE)

www.eere.energy.gov, (800) DOE-EREC

The EERE mission is to strengthen America's energy security, environmental quality and economic vitality through public-private partnerships that enhance energy efficiency and productivity; bring clean, reliable and affordable energy technologies to the marketplace; and provide relevant information and tools for businesses and individuals

U.S. Department of Energy's Photovoltaics Program

www.eere.energy.gov/pv, (800) DOE-EREC

A DOE Web site with the mission of making photovoltaics (PV) a significant part of the domestic economy as an industry as well as an energy resource.

U.S. Department of Energy's Wind Energy Program

www.eere.energy.gov/wind

A DOE Web site with the mission of making photovoltaics (PV) a significant part of the domestic economy as an industry as well as an energy resource.

Print Media

Wind and Solar Power Systems, Mukund Patel, CRC Press, 1999.

Wind Energy Comes of Age, Paul Gipe, John Wiley & Sons, 1995.

Case Study

Phillip Merrill Environmental Center Headquarters
Annapolis, Maryland

Courtesy of U S Green Building Council

Owner
Chesapeake Bay Foundation

The Phillip Environmental Center is a LEED Version 1.0 Platinum Pilot Project that houses the Chesapeake Bay Foundation's headquarters. The project is located on 31 acres of diverse habitat on the Chesapeake Bay and functions as an office building and an education and training facility. To harvest site energy resources, thin-film photovoltaic sunshades and crystalline photovoltaic skylights generate electricity and are integrated into the daylighting strategy. The electricity is used to power lighting and office equipment, supplying an estimated 1% of the building's total power requirements. In addition, a solar domestic watMerriller heating system is used to heat all hot water used in the building. The building was also engineered to take advantage of many passive solar and energy saving strategies to reduce the total energy used.

Additional Commissioning

SS | WE | EA | MR | EQ | ID
Credit 3

1 point

Intent

Verify and ensure that the entire building is designed, constructed and calibrated to operate as intended.

Requirements

In addition to the Fundamental Building Commissioning prerequisite, implement or have a contract in place to implement the following additional commissioning tasks:

1. A commissioning authority independent of the design team shall conduct a review of the design prior to the construction documents phase.
2. An independent commissioning authority shall conduct a review of the construction documents near completion of the construction document development and prior to issuing the contract documents for construction.
3. An independent commissioning authority shall review the contractor submittals relative to systems being commissioned.
4. Provide the owner with a single manual that contains the information required for re-commissioning building systems.
5. Have a contract in place to review building operation with O&M staff, including a plan for resolution of outstanding commissioning-related issues within one year after construction completion date.

Submittals

- ❑ Provide the LEED Letter Template, signed by the owner or independent commissioning agent(s) as appropriate, confirming that the required additional commissioning tasks have been successfully executed or will be provided under existing contract(s).

Summary of Referenced Standard

There is no standard referenced for this credit.

SS | WE | EA | MR | EQ | ID

Credit 3

Credit Synergies

SS Credit 4
Alternative Transportation

SS Credit 8
Light Pollution Reduction

WE Credit 1
Water Efficient Landscaping

WE Credit 2
Innovation Wastewater Treatment

WE Credit 3
Water Use Reduction

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 2
Renewable Energy

EA Credit 5
Measurement & Verification

EQ Prerequisite 1
Minimum IAQ Performance

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

EQ Credit 7
Thermal Comfort

EQ Credit 8
Daylight & Views

Green Building Concerns

The LEED commissioning prerequisite (EA Prerequisite 1) establishes the critical activities for verifying achievement of the owner's project requirements. The Additional Commissioning credit enhances integration activities and provides the owner with greater value for limited additional investment. This credit focuses on reviewing the building design and construction documents to identify potential problems and areas for improvement early, providing long-term documentation for optimization, and implementing a continuous improvement program.

Environmental Issues

The additional commissioning activities serve to further increase the building's energy efficiency, thus reducing the environmental effects of energy production and use. Environmental effects include natural resource depletion, air pollution and water pollution.

Economic Issues

Fees for the additional commissioning activities are typically a small investment for high returns. See EA Prerequisite 1 for more discussion.

Community Issues

The commissioning process provides a consistent means for the owner's procurement of high-quality buildings that operate in accordance with the owner's project requirements, including the occupants' needs. Ultimately, the entire project team and community benefits when the building is operational the first day of use through reducing occupant complaints and allowing users and occupants to enjoy a healthier and more productive indoor environment that meets their success criteria.

Design Approach

Strategies

EA Prerequisite 1 establishes the framework of an effective commissioning program. This Additional Commissioning Credit ensures peer review through independent, third-party verification. Tasks 1 through 3 of the credit requirements must be executed by a firm that is not on the design team (an "independent" Commissioning Authority). This requirement acts to avoid conflicts of interests and bias. It is recommended that the same independent Commissioning Authority deliver tasks 4 and 5, although it is not required.

The Commissioning Authority is assigned these additional tasks:

1. Schematic Design Review. To receive the maximum benefits of the commissioning process, the independent Commissioning Authority must review the design at the schematic design phase. This enables the Commissioning Authority to verify that each commissioned feature or system meets the owner's requirements relative to functionality, energy performance, water performance, maintainability, sustainability, system cost, indoor environmental quality, and local environmental impacts. Evidence of this design review must be fully documented in a written report.

2. Construction Documents Review. The independent Commissioning Authority must review the construction documents to ensure that commissioning is adequately specified and to verify that each commissioned system or assembly meets the owner's project requirements relative to functionality, energy performance, water performance, maintainability, sustainability, system cost, indoor environmental quality and local environmental impacts. Evidence of this construction documents review must be fully documented in a written report.

3. Focused Review of Submittals. The Commissioning Authority must review the contractor's standard submittals of commissioned systems and assemblies to verify that the feature being provided will meet the owner's project requirements, particularly as it relates to environmentally responsive characteristics.

4. Systems Manual. In addition to the standard commissioning report, a Commissioning Authority must develop an indexed systems manual to be delivered to the owner with the commissioning report. **Table 1** lists components of the manual that must be organized into one compilation, although some parts may also be in the standard O&M manuals provided by the general contractor. The systems manual is preferably delivered as both electronic and hardcopy documents.

5. Near-Warranty End or Post-Occupancy Review. The Commissioning Authority must be under contract to return to the site 10 months into the 12-month warranty period. The Commissioning Authority must review current building operation with facility staff and address the condition of outstanding issues related to the owner's project requirements. Also, the Commissioning Authority must interview facility staff to identify problems or concerns they have in operating the building as originally intended. The Commissioning Authority must provide suggestions for improvements and record these changes in the systems manual. The Commissioning Authority should identify problems that are covered under warranty or under the original construction contract. Finally, the Commissioning Authority must assist facility staff in developing reports, documents and requests for services to remedy outstanding problems.

Technologies

Commissioning is a process, not a technology that can be purchased. Use professional contacts and referrals to find local experts who understand the governing energy codes and the equipment that local contractors are likely to furnish and install. Several professional training and accreditation programs have been devel-

Table 1: Recommissioning Management Manual Components

Components of the Systems Manual
Final version of the owner's project requirements and basis of design
As-built sequences of operations for all equipment as provided by the design professionals and contractors, including time-of-day schedules and schedule frequency, and detailed point listings with ranges and initial setpoints
Ongoing operating instructions for all energy- and water-saving features and strategies
Functional performance tests results (benchmarks), blank test forms, and recommended schedule for ongoing benchmarking
Seasonal operational guidelines
Recommendations for recalibration frequency of sensors and actuators by type and use
Single line diagrams of each commissioned system
Troubleshooting table for ongoing achievement of the owner's project requirements
Guidelines for continuous maintenance of the owner's project requirements (operational requirements) and basis of design (basis of operation)

oped for the commissioning process. While not required for LEED project certification, owners may benefit from engaging a credentialed Commissioning Authority.

Synergies and Trade-Offs

The commissioning process affects all systems and assemblies, both static and dynamic. Site features on the project that require commissioning attention include alternative fueling stations and exterior lighting fixtures and systems. Water commissioning includes irrigation systems, plumbing fixtures and plumbing infrastructure. Energy commissioning covers HVAC systems, lighting and energy-generation equipment. Commissioning activities that affect indoor environmental quality include ventilation systems, monitoring equipment, occupant controls, envelope integrity, material selection and daylighting systems.

Resources

See EA Prerequisite 1 for Web and print resources.

Case Study

Energy Resource Center
Downey, California

Courtesy of Southern California Gas Company

Owner
Southern California Gas Company

The Energy Resource Center is a LEED™ Certified Pilot Project and serves as a state-of-the-art energy technology showcase and educational center. The ERC incorporates efficient lighting, cooling and architectural technologies to exceed California's Title 24 energy code by 38%. The project team instituted a rigorous commissioning plan to ensure that the completed building operated in accordance with the design intent. The Commissioning Authority was charged with quality assurance and construction management of the mechanical system as well as functional testing of the mechanical system and lighting system. The commissioning process identified 30 major issues that did not conform with the design intent and would have adversely affected the comfort and energy performance of the HVAC system. For example, major reconfiguration of the second floor air distribution system was required after unacceptable losses in ductwork were identified. Finally, the building staff was trained to optimize energy-efficient operation over the lifetime of the building.

SS	WE	EA	MR	EQ	ID

Credit 4

1 point

Ozone Protection

Intent

Reduce ozone depletion and support early compliance with the Montreal Protocol.

Requirements

Install base building level HVAC and refrigeration equipment and fire suppression systems that do not contain HCFCs or Halons.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or engineer, stating that HVAC&R systems as-built are free of HCFCs and Halons.

Summary of Referenced Standard

There is no standard referenced for this credit.

Credit Synergies

EA Prerequisite 2
Minimum Energy Performance

EA Prerequisite 3
CFC Reduction in HVAC&R Equipment

EA Credit 1
Optimize Energy Performance

MR Credit 1
Building Reuse

Green Building Concerns

Hydrochlorofluorocarbons (HCFCs) are one class of chemicals that can be substituted for CFCs in building systems. EA Prerequisite 3 addresses phase-out of CFCs through substitution of HCFCs and other low ozone-depleting refrigerants. While HCFCs are more environmentally friendly than CFCs, HCFCs still have ozone depletion potential (ODP). HCFCs commonly used in building refrigerant systems have ODPs ranging from 0.01 to 0.1. As a result, HCFCs will be phased out in the United States by 2030. HCFCs with the highest ODPs will be phased out first, starting in 2003.

Halons are used in fire suppression systems and fire extinguishers. Halon production has been banned in the United States since 1994 due to their high ODP values. Halons have particularly high ODPs because they contain bromine, which is many times more effective at destroying ozone than chlorine. Halons commonly used in buildings have ODPs ranging from 3 to 10, many times greater than ODPs for CFCs and HCFCs.

While HCFCs and halons are both addressed under this credit, their effects on the environment are significantly different. The environmental impacts of halons are typically an order of magnitude or greater than HCFCs. See **Table 1** for comparisons.

Environmental Issues

Similar to CFCs, elimination of HCFCs and halons in building systems reduces ozone depletion. Release of these substances to the atmosphere destroys stratospheric ozone molecules through a catalytic process. Reduction of stratospheric ozone reduces the Earth's natural shield for incoming ultraviolet radiation. CFCs, HCFCs and halons also contribute to global climate change.

Economic Issues

The phase-out of CFCs over the past decade has enabled the HVAC industry to develop cost-effective alternatives. Many owners are converting to HCFCs as an interim step. HCFCs are scheduled to be phased out by 2030. Therefore, many owners may find it is cost-effective to fully migrate to hydrofluorocarbon (HFC)-based equipment now, rather than utilizing HCFCs as an interim technology. CFC- and HCFC-based equipment are typically more energy-efficient than current HFC-based equipment. Manufacturers are working diligently to close the efficiency gap in HFC-based systems.

Community Issues

HCFC and halon use have a global impact. Continued release of HCFCs, halons and other ozone-depleting substances has already started to cause increased occurrences of certain human illness and mortality as well as widespread damage to ecosystems. Treatment of these illnesses represents liabilities for health insurance companies.

Design Approach

Strategies

Research and specify all building systems with non-ozone-depleting equipment. Building systems to consider include HVAC, refrigeration, insulation, and fire suppression systems. Common substitutes for HCFCs in HVAC and refrigeration systems are hydrofluorocarbons (HFCs). While HFCs have substantially lower ODPs, they have higher global-warming potentials (GWPs). Thus, it is important to study different potential substitutes and choose the most appropriate substitute with the lowest environmental impacts. See **Table 1** for a list of common refrigerants and their associated environmental data.

SS	WE	EA	MR	EQ	ID
Credit 4					

To qualify for this credit, all building equipment must be free of HCFCs and halons before occupancy. For buildings that use a central plant as the base building cooling system (such as university and government buildings with centrally located heating systems), all equipment in the central plant must be HCFC- and halon-free.

Consider the trade-offs among refrigerants across a range of potential impacts including worker safety, impacts on the ozone layer, energy efficiency and climate change. These are addressed in the EPA's Significant New Alternatives Policy (SNAP) Program, which has a mandate to identify alternatives to ozone-depleting substances and to publish lists of acceptable and unacceptable substitutes.

Table 1: Refrigerant Environmental Data

Refrigerant	Lifetime [years]	ODP	GWP
CFC-11	45	1	4,000
CFC-12	100	1	8,500
CFC-13	640	1	11,700
CFC113	85	1	5,000
CFC 114	300	1	9,300
CFC -115	1,700	1	9,500
Halon 1211	11	3	n/a
Halon 1301	65	10	5,600
Halon 2402	n/a	6	n/a
HCFC-22	12	0.06	1,700
HCFC-123	1	0.02	93
HCFC-124	6	0.02	480
HCFC-141b	9	0.11	630
HCFC-142b	19	0.07	2,000
HFC-32	5.6	0	650
HFC-125	32.6	0	2,800
HFC-134a	14.6	0	1,300
HFC-143a	48.3	0	3,800
HFC-152a	1.5	0	140
HFC-236fa	209	0	6,300

Source: EPA's Ozone Depletion Web Site

Synergies and Trade-Offs

This credit is intimately tied with EA Prerequisite 3 and also has impacts on energy performance on the building. If a building is reused, equipment containing HCFCs and halons must be replaced.

Resources

Web Sites

U.S. Department of Energy Halon Phase-Out Information

tis.eh.doe.gov/fire/guidance/halon_phaseout.html, (800) 473-4375

Provides interim criteria on the management of the reduction and potential elimination of halon fire extinguishing systems within the DOE.

Ozone-Depleting Substances

www.epa.gov/ozone/ods.html

A listing of atmospheric lifetimes, ozone-depleting potentials (ODPs), and global-warming potentials (GWPs) for various substances and CFC substitutes under the SNAP program (see below).

U.S. Environmental Protection Agency's Ozone Depletion Web site

www.epa.gov/ozone, (800) 296-1996

Provides information about the science of ozone depletion, the regulatory approach to protecting the ozone layer (including phase-out schedules) and on alternatives to ozone-depleting substances.

U.S. Environmental Protection Agency's Significant New Alternatives Policy (SNAP)

www.epa.gov/ozone/snap, (800) 296-1996

An EPA program to identify alternatives to ozone-depleting substances, SNAP maintains up-to-date lists of environmentally friendly substitutes for refrigeration and air-conditioning equipment, solvents, fire suppression systems, adhesives, coatings and other substances.

Print Media

Strategies for Managing Ozone-Depleting Refrigerants: Confronting the Future by Katharine B. Miller et al., Battelle Press, 1995.

The HVAC/R Professional's Field Guide to Alternative Refrigerants by Richard Jazwin, Bookmasters, 1995.

Definitions

Chlorofluorocarbons (CFCs) are hydrocarbons that deplete the stratospheric ozone layer.

Halons are substances used in fire suppression systems and fire extinguishers in buildings. These substances deplete the stratospheric ozone layer.

Hydrochlorofluorocarbons (HCFCs) are refrigerants used in building equipment that deplete the stratospheric ozone layer, but to a lesser extent than CFCs.

Hydrofluorocarbons (HFCs) are refrigerants that do not deplete the stratospheric ozone layer. However, some HFCs have high global warming potential and, thus, are not environmentally benign.

SS	WE	EA	MR	EQ	ID
Credit 5					

1 point

Measurement & Verification

Intent

Provide for the ongoing accountability and optimization of building energy and water consumption performance over time.

Requirements

Install continuous metering equipment for the following end-uses:

- Lighting systems and controls
- Constant and variable motor loads
- Variable frequency drive (VFD) operation
- Chiller efficiency at variable loads (kW/ton)
- Cooling load
- Air and water economizer and heat recovery cycles
- Air distribution static pressures and ventilation air volumes
- Boiler efficiencies
- Building-related process energy systems and equipment
- Indoor water risers and outdoor irrigation systems

Develop a Measurement and Verification plan that incorporates the monitoring information from the above end-uses and is consistent with Option B, C or D of the 2001 *International Performance Measurement & Verification Protocol (IPMVP) Volume I: Concepts and Options for Determining Energy and Water Savings.*

Submittals

- ❑ Provide the LEED Letter Template, signed by the licensed engineer or other responsible party, indicating that metering equipment has been installed for each end-use and declaring the option to be followed under IPMVP version 2001.
- ❑ Provide a copy of the M&V plan following IPMVP, 2001version, including an executive summary.

Summary of Referenced Standard

International Performance Measurement and Verification Protocol Volume 1, 2001 Version

www.ipmvp.org

The IPMVP presents best practice techniques available for verifying savings produced by energy- and water-efficiency projects. While the emphasis is on a methodology geared toward performance contracting for retrofits, the protocol identifies the required steps for new building design in Section 6.0. Section 3.0 provides a general approach, procedures and issues, while Section 4.0 provides guidance on retrofit projects.

SS	WE	EA	MR	EQ	ID

Credit 5

Credit Synergies

SS Credit 4
Alternative Transportation

SS Credit 8
Light Pollution Reduction

WE Credit 1
Water Efficient Landscaping

WE Credit 2
Innovation Wastewater Treatment

WE Credit 3
Water Use Reduction

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 2
Renewable Energy

EA Credit 3
Additional Commissioning

EQ Prerequisite 1
Minimum IAQ Performance

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

EQ Credit 7
Thermal Comfort

EQ Credit 8
Daylight & Views

Green Building Concerns

The benefits of optimal building operation, especially in terms of energy and water performance, are substantial. The lifetime of many buildings is greater than 50 years. Even minor energy and water savings are significant when considered in aggregate. These long-term benefits often go unrealized due to maintenance personnel changes, aging of building equipment, and changing utility rate structures. Therefore, it is important to institute measurement & verification (M&V) procedures to achieve and maintain optimal performance over the lifetime of the building through continuous monitoring. The goal of M&V activities is to provide building owners with the tools and data necessary to identify systems that are not functioning as expected, and to optimize building system performance.

Environmental Issues

Measurement & verification of a building's ongoing energy and water consumption allows for optimization of related systems over the lifetime of the building. As a result, the cost and environmental impacts associated with energy and water use can be minimized.

Economic Issues

Building retrofits that institute effective M&V practices, such as Options B and C outlined in the referenced standard, experience energy savings that are on average 10% to 20% greater than buildings retrofitted with little or no M&V practices. It should be noted that M&V practices will predict performance improvements achieved through Energy Conservation Measures (ECMs) and commissioning, and contribute to savings.

The added cost to institute a rigorous M&V program for retrofitting buildings with energy and water equipment is typically 1% to 5% of the total retrofit cost. These additional first costs are generally repaid within a few months of operation due to energy and water utility savings as well as reduced operations and maintenance costs. It is important to remember that the goal of this credit is to allow building owners the ability to identify problems and achieve improved system performance. Large amounts of money can be spent on M&V systems that do not accomplish this goal. Careful planning and implementation are always necessary for a truly effective M&V system.

Community Issues

The collateral benefits of energy and water efficiency to the community are often diffuse and difficult to quantify over time. However, a healthy workforce and a healthy ecosystem are both indicators of a long-term pattern of sustainable development. Continuous measurement of resource use at individual projects will facilitate documentation and aggregation of emissions reductions benefits and contribute to providing benefits to the community over several generations, extending the resource base they enjoy and depend upon.

Design Approach

The LEED Commissioning prerequisite and credit provide quality assurance that a project meets the design intent, ensuring that it is functioning as intended at the beginning of occupancy. The LEED Measurement & Verification credit provides an extension of this quality assurance effort by ensuring that the predicted performance of the functioning building is actually producing savings to the owner.

The referenced standard describes a methodology to ensure that the design team consistently addresses the three basic aspects of energy and water conservation performance:

1. Accurate cataloging of baseline conditions.

2. Verification of the complete installation and proper operation of new equipment and systems specified in the contract documents.

3. Confirmation of the quantity of energy and water savings, as well as energy and water cost savings, that occur during the period of analysis.

The four basic M&V options are listed in **Table 1**. Each method provides a greater level of rigor than those previous. The appropriate level for a particular project is dependent on project specifics such as scope, level of owner interest in M&V, and contractual relationships of the design team.

The first technique, Option A, does not satisfy the requirements of the LEED M&V credit. The remaining options (B, C and D) satisfy the LEED requirements when implemented correctly. Compliance with the credit requirements can be demonstrated through engineering calculations, operational estimates, and utility meter-billing analysis, or through more rigorous statistical sampling, metering and monitoring, and computer simulations.

Table 1: Measurement & Verification Options for New and Renovation Construction Projects

M&V Option	LEED Compliant	Option Description	Savings Calculations	Cost
A	No	Focuses on physical assessment of equipment changes to ensure the installation is to specification. Key performance factors such as lighting wattage and chiller efficiency are determined by spot or short-term measurements and operational factors.	Engineering calculations using spot or short-term measurements, computer simulations, and/or historical data.	Typically 1-5% of project construction cost, dependent on number of measurement points.
B	Yes	Savings are determined after project completion by short-term or continuous measurements taken throughout the term of the contract at the device or system level. Both performance and operations factors are monitored.	Engineering calculations using metered data.	Typically 3-10% of project construction cost, dependent on number and type of systems measured and the term of analysis/metering.
C	Yes	After project completion, savings are determined at the "whole- building" or facility level using current year and historical utility meter (gas or electricity) or sub-meter data.	Analysis of utility meter (or submeter) data using techniques from simple comparison to multivariate (hourly or monthy) regression analysis.	Typically 1-10% of project construction cost, dependent on number and complexity of parameters in analysis.
D	Yes	Savings are determined through simulation of facility components and/or the whole facility.	Calibrated energy simulation and modeling; calibrated with hourly or monthly utility billing data and/or end-use metering.	Typically 3-10% of project construction cost, dependent on number and complexity of systems evaluated.

All of the options in the referenced standard require the design team to specify equipment for installation in the building systems to allow for comparison, management and optimization of actual versus estimated energy and water performance. The mechanical engineer in particular should take advantage of the building automation systems to perform M&V functions where applicable. Elements of the M&V Plan that are required to comply with the requirements of this credit are listed in **Table 2**.

Retrofits

Use of Option B in retrofits is appropriate when the end use capacity, demand or power level of the baseline can be measured *and* the energy/water consumption of the equipment or subsystem is to be measured post-installation over time. This option can involve continuous measurement of energy/water both before and after the retrofit for the specific equipment, or it can be measurements for a limited period of time necessary to determine the retrofit savings. Portable monitoring equipment may be installed for a period of time or continuously to measure in-situ, baseline and post-installation periods. Periodic inspection of the equipment is recommended. Energy/water consumption is then calculated by developing statistical models of the end use capacity.

New buildings

M&V strategies for new buildings differ fundamentally from retrofit projects because performance baselines are hypothetical rather than materially existent. Therefore, savings are not physically measurable or verifiable. There are implications to the M&V process related to the complexity of measures and strategies to be monitored and verified. However, the basic steps in new building M&V do not vary significantly in concept from retrofit M&V.

Creating the M&V Plan

The steps to create a Measurement & Verification Plan are as follows:

List all measures to be monitored and verified. Create a summary of any whole-building or system-specific energy or water conservation measures that will be implemented in the project. In most

Table 2: Measurement & Verification Plan Requirements

Requirements
1. IPMVP standard language and terminology should be employed.
2. State which option and method from the document will be used.
3. Indicate who will conduct the M&V.
4. State key assumptions about significant variables or unknowns.
5. Create an accurate baseline using techniques appropriate to the project.
6. Describe the method of ensuring accurate energy savings determination.
7. Define a post installation inspection plan.
8. Specify criteria for equipment metering, calibration, measurement period.
9. Define the level of accuracy to be achieved for all key components.
10. Indicate quality assurance measures.
11. Describe the contents of reports to be prepared, along with a schedule.

cases, these will be presented in other LEED credit documentation and should be referenced here.

Define the Baseline. Defining a new building baseline is a two-part process. First, develop and define a baseline case. This baseline can range from the stipulation of specific baseline equipment to specifying whole-building compliance with energy codes or standards.

Once the baseline case has been established, use computer-aided analytical tools to estimate the associated performance baseline. It is sometimes appropriate to "back-engineer" a baseline by deleting specific ECMs or features from the energy-efficient building. This approach can be particularly useful for whole building M&V by using Option C with computer simulation methods. For retrofits, the baseline is the existing systems in place and this is a straightforward step.

Besides defining the expected resource usage quantity for the baseline case, include additional assumptions relating to energy and water unit costs, weather, utility distribution, system schedule, occupancy or other factors and their anticipated adjustment to the baseline.

Define the Green Building Design and Projected Savings. The green approach is refined through the building design process and is the final outcome of the process. Computer-aided tools are then used to estimate performance of the final green design, which is subtracted from the baseline performance to generate projected savings. Present the resource quantity and associated cost reductions to be achieved on a monthly measure-specific basis. The estimation process should also include the identification and, if possible, quantification of factors that could affect the performance of both the baseline and green design.

Define the General M&V Approach. LEED requires Option B as a minimum level of precision for the process. Option B is directed at end-use measures, and Option C addresses whole-building M&V methods. The relative suitability of each approach is a function of:

- M&V objectives and requirements of any related performance contracts.
- Number of ECMs and the degree of interaction with each other and with other systems.
- Practicality issues associated with M&V of particular ECMs or whole-building ECMs.
- Trends towards holistic building design, which are guiding M&V requirements towards Option C.

Prepare a Project-Specific M&V Plan. Development of an effective and efficient M&V plan for new buildings tends to be more involved than retrofit projects since performance strategies are usually more complex and the technical issues to address are more challenging.

Technical analyses that are performed in support of design decisions concerning performance during the building design process provide a starting point in defining the M&V objectives and approach. The key elements of energy analyses are also usually key factors in M&V. Therefore, the energy analyses and projections should be well documented and organized with this in mind. M&V considerations should influence certain design decisions such as instrumentation and building systems organization. Identify any applicable data sources (e.g., utility bills, control system points and trending periods, and portable metering), the method of data collection (including equipment calibration requirements and other quality assurance practices), and the identity of monitoring personnel.

Verify Installation and Commissioning of ECMs or Energy-Efficient Strategies. Installation and proper operation is verified through site inspections as necessary combined with review of reports such as commissioning reports and fluid/air test and balance reports. Any deviations should be noted and addressed through adjustment of the affected performance projections.

Determine Savings Under Actual Post-Installation Conditions. Virtually all performance projections are predicated upon certain assumptions regarding operational conditions (e.g., occupancy and weather). This affects both the baseline and green design estimations. Deviations from the operational assumptions must be tracked by an appropriate mechanism (e.g., site survey or short and/or long term metering) and the baseline and green projections modified accordingly to determine actual savings.

Describe any engineering calculations and/or software tools that will be used to process the data to demonstrate the savings achieved. This will include identification of any stipulated variables or values to be used in the calculations, as well as baseline adjustment factors, regression analysis (or other) tools to determine significance and weighting of such factors.

Reevaluate at Appropriate Intervals. Ongoing performance of ECMs or green building strategies and the associated savings must be reevaluated and verified at intervals and over a time frame appropriate to M&V and related performance contract requirements. This also allows ongoing management and correction of significant deviations from projected performance.

It is important to link contractor final payments to documented M&V system performance, so require all documentation in the final report. The contractor must also provide an ongoing M&V system maintenance and operating plan in the building operations and maintenance manuals.

Synergies and Trade-Offs

Measurement & verification activities affect all equipment that uses energy and water. Site equipment affected includes alternative refueling stations, exterior light fixtures and systems, irrigation systems, water reuse systems and wastewater treatment facilities. Inside the building, all plumbing fixtures and electrical fixtures as well as HVAC systems are affected. Measurement & verification activities are intimately related to commissioning activities and the two processes should be coordinated.

ENERGY STAR® Portfolio Manager is another tool that can be used to track and recognize ongoing performance of energy systems. While the ENERGY STAR rating itself does not demonstrate compliance with this credit, it can be used as the basis for a comprehensive measurement and verification tool for portfolio building owners. See the ENERGY STAR Web site at www.energystar.gov for information.

Resources

Web Sites

ENERGY STAR®

www.energystar.gov, (888) STAR-YES

ENERGY STAR was introduced by the Environmental Protection Agency in 1992 as a voluntary labeling program designed to identify and promote energy-efficient products and buildings, in order to reduce carbon dioxide emissions. EPA partnered with the Department of Energy in 1996 to promote the ENERGY STAR label, with each agency taking responsibility for particular product categories. ENERGY STAR has expanded to cover most of the buildings sector.

International Performance Measurement and Verification Protocol

www.ipmvp.org

The IPMVP presents internationally developed best practice techniques for verifying results of energy efficiency, water efficiency and renewable energy projects in commercial and industrial facilities.

Measurement & Verification Documents

ateam.lbl.gov/mv, (510) 486-5001

A list of M&V resources provided by Lawrence Berkeley National Laboratory, ranging from implementation guidelines to hands-on checklists.

Definition

Energy Conservation Measures (ECMs) are installations of equipment or systems, or modifications of equipment or systems, for the purpose of reducing energy use and/or costs.

Case Study

Brengel Technology Center
Milwaukee, Wisconsin

The Brengel Technology Center is a LEED™ Silver Pilot Project that showcases advanced building control technologies to maximize energy efficiency and indoor environmental quality. The building is operated with an energy management system to reduce operating costs over the building lifetime. Electricity use is monitored with smart metering that measures occupant and building system electricity use in real time with nine voltage meters. Data is gathered and analyzed to identify energy utilization improvements, to bargain for lower energy prices with the local utility, and to determine future load shaping measures. In addition, two meters monitor steam use for heating, and two water meters monitor occupants' water use and water consumption of the cooling towers.

Courtesy of Zimmerman Design Group

Owner
Johnson Controls, Inc.

SS	WE	EA	MR	EQ	ID
Credit 6					

Green Power

1 point

Intent

Encourage the development and use of grid-source, renewable energy technologies on a net zero pollution basis.

Requirements

Provide at least 50% of the building's electricity from renewable sources by engaging in at least a two-year renewable energy contract. Renewable sources are as defined by the Center for Resource Solutions (CRS) Green-e products certification requirements.

Submittals

- ❑ Provide the LEED Letter Template, signed by the owner or other responsible party, documenting that the supplied renewable power is equal to 50% of the project's energy consumption and the sources meet the Green-e definition of renewable energy.
- ❑ Provide a copy of the two-year electric utility purchase contract for power generated from renewable sources.

Summary of Referenced Standard

Center for Resource Solutions' Green-e Product Certification Requirements

www.green-e.org, (888) 634-7336

The Green-e Program is a voluntary certification and verification program for green electricity products. Those products exhibiting the Green-e logo are greener and cleaner than the average retail electricity product sold in that particular region. To be eligible for the Green-e logo, companies must meet certain threshold criteria for their products. Criteria include qualified sources of renewable energy content such as solar electric, wind, geothermal, biomass and small or certified low-impact hydro facilities; "new" renewable energy content (to support new generation capacity); emissions criteria for the non-renewable portion of the energy product; absence of nuclear power; and other criteria regarding renewable portfolio standards and block products. Criteria are often specific per state or region of the United States. Refer to the standard for more details.

SS	WE	EA	MR	EQ	ID

Credit 6

Credit Synergies

SS Credit 1
Site Selection

Green Building Concerns

Energy production is a significant contributor to air pollution in the United States. Air pollutants released from energy production include sulfur dioxide, nitrogen oxide and carbon dioxide. These pollutants are primary contributors to acid rain, smog and global warming. With other associated pollutants, they have widespread and adverse effects on human health in general, especially on human respiratory systems. The Green-e Program was established by the Center for Resource Solutions to promote green electricity products and provide consumers with a rigorous and nationally recognized method to identify green electricity products. These products reduce the air pollution impacts of electricity generation by relying on renewable energy sources such as solar, water, wind, biomass and geothermal sources.

Environmental Issues

Green electricity products produce less air pollution than conventional electricity products. This reduces acid rain, smog, global-warming potential, and human health problems resulting from air contaminants. In addition, the use of ecologically responsive energy sources avoids reliance on nuclear power and large-scale hydropower. Nuclear power continues to be controversial due to security and environmental issues related to waste reprocessing, transportation and storage. Deregulated energy markets have enabled hydroelectric generation activities to market their electricity in regions unaffected by the regional impacts that dams can have on endangered aquatic species. While green electricity is not entirely environmentally benign, it greatly lessens the environmental impacts of power generation.

Economic Issues

Current costs for green power products are equal to or somewhat greater than conventional energy products. However, green power products are derived, in part, from renewable energy sources with stable energy costs. As the green power market matures and impacts on the environment and human health are factored into power costs, green power products are expected to be less expensive than conventional power products.

Community Issues

Supplying conventional energy adds heavy pressures to local ecosystems and reduces biodiversity. This directly affects the health of our communities. For example, large dams redirect natural water flows, damaging wildlife habitat and sometimes displacing communities.

Biomass projects offer an opportunity to strengthen the power producer's links with the community it serves. This generation strategy productively uses resources such as forestry and agricultural residue that might otherwise require landfilling. Bio-based power can also foster local economic growth and provide jobs for those involved in raising, harvesting, transporting, and processing fuel crops. When making any power decisions, it is prudent to consider local pollution effects.

Design Approach

Strategies

Calculate the electricity needs for the project. Use the electricity components of the DEC" value (net use of grid electricity) from EA Credit 1. Research power providers in the area and select a provider that guarantees that a fraction of its delivered electric power is derived from net nonpolluting renewable technologies. If the project is in an open market state, investigate green power and power marketers licensed to provide power in that state. Grid power that qualifies for this credit originates from solar, wind, geothermal, biomass or low-impact hydro sources.

Green-e electricity is available in a growing number of American states. See the Green-e Web site (www.green-e.org) for up-to-date information on each state. Green power may be procured from a Green-e certified power marketer or accredited utility program, through Green-e certified Tradable Renewable Certificates or from a non-certified supply that is proven to meet the Green-e product requirements.

Synergies and Trade-Offs

The location of a project will determine if green power is available. Where green power is not available, tradable renewable energy certificates (TRCs) can be used.

Calculations

For the purposes of this credit, the building's grid-supplied electricity use is defined as that which is used by the energy components regulated by ASHRAE/IESNA Standard 90.1-1999 (see EA Credit 1), less the amount supplied by on-site renewable energy (see EA Credit 2). To achieve this credit, 50% of the design electricity use (by kilowatt hours) from the electricity grid must be supplied by electricity derived from renewable energy, as defined by the Green-e product requirements. For example, 50% of electricity can come from a 100% renewable-derived power product or 100% of electricity must be derived from a green power source comprised of at least 50% renewable energy. See the referenced standard for complete details.

Resources

Web Sites

Green Power Network

www.eere.energy.gov/greenpower

Provides news on green power markets and utility pricing programs—both domestic and international. It contains up-to-date information on green power providers, product offerings, consumer issues and in-depth analyses of issues and policies affecting green power markets. The Web site is maintained by the National Renewable Energy Laboratory for the Department of Energy.

Green-e Program

www.green-e.org, (888) 634-7336

See the Summary of Referenced Standard for more information.

Union of Concerned Scientists

www.ucsusa.org/clean_energy

UCS is an independent nonprofit that analyzes and advocates energy solutions that are sustainable both environmentally and economically. The site provides news and information on research and public policy.

U.S. Environmental Protection Agency (EPA) Green Power Partnership

www.epa.gov/greenpower

EPA's Green Power Partnership is a new voluntary program designed to reduce the environmental impact of electricity generation by promoting renewable energy. The Partnership will demonstrate the advantages of choosing renewable energy, provide objective and current information about the green power market, and reduce the transaction costs of acquiring green power.

Materials & Resources

Building materials choices are important in sustainable design because of the extensive network of extraction, processing and transportation steps required to process them. Activities to create building materials pollute the air and water, destroy natural habitats and deplete natural resources. Construction and demolition wastes constitute about 40% of the total solid waste stream in the United States.

One of the most effective strategies for minimizing the environmental impacts of material use is to reuse existing buildings. Rehabilitation of existing building shells and non-shell components reduces solid waste volumes and diverts these waste volumes from landfills. It also reduces environmental impacts associated with the production and delivery of new building products. Reuse of an existing building minimizes habitat disturbance and typically requires less infrastructure such as utilities and roads. An effective way to use salvaged non-shell components in new buildings is to specify these materials in construction documents.

When new materials are used in buildings, it is important to consider different sources. Salvaged materials can substitute for new materials, save on material costs and perhaps add character to the building. Recycled content materials reuse waste products that would otherwise be deposited in landfills. The use of local materials supports the local economy and reduces the impacts of transportation. The use of rapidly renewable materials and third-party certified wood minimizes the impact of natural resource consumption to manufacture new building materials.

Over the past decade or so, an increasing number of public and private waste management operations have begun to reduce construction debris volumes by recycling and reusing these materials. Recovery and recycling activities typically involve job site separation into multiple bins or disposal areas. These activities can also take place off-site if space is not available on the project site.

Overview of LEED™ Prerequisites and Credits

MR Prerequisite 1
Storage & Collection of Recyclables

MR Credit 1
Building Reuse

MR Credit 2
Construction Waste Management

MR Credit 3
Resource Reuse

MR Credit 4
Recycled Content

MR Credit 5
Local/Regional Materials

MR Credit 6
Rapidly Renewable Materials

MR Credit 7
Certified Wood

There are 13 points available for the Materials & Resources category.

Storage & Collection of Recyclables

SS | WE | EA | MR | EQ | ID

Prerequisite 1

Required

Intent

Facilitate the reduction of waste generated by building occupants that is hauled to and disposed of in landfills.

Requirements

Provide an easily accessible area that serves the entire building and is dedicated to the separation, collection and storage of materials for recycling including (at a minimum) paper, corrugated cardboard, glass, plastics and metals.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or owner, declaring that the area dedicated to recycling is easily accessible and accommodates the building's recycling needs.
- ❑ Provide a plan showing the area(s) dedicated to recycled material collection and storage.

Summary of Referenced Standard

There is no standard referenced for this prerequisite.

Synergies

SS Credit 2
Urban Redevelopment

SS Credit 5
Reduced Site Disturbance

MR Credit 1
Building Reuse

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 5
Indoor Chemical & Pollutant Source Control

Green Building Concerns

Recycling has become an integral part of U.S. culture in the past two decades. Curbside recycling is now a standard service in many urban communities. Recycling is also becoming the norm in other parts of life. For instance, office workers recycle paper, airlines recycle aluminum cans, and manufacturing facilities recycle scrap materials such as steel, plastic and wood. The majority of U.S. population is inclined to recycle as long as the process is not too inconvenient or costly. **Table 1** provides an estimate of solid waste generation for various building types. Occupant recycling rates vary by building type.

As an example of the potential for occupant recycling, the waste stream of a large federal office building was analyzed before recycling efforts were employed. The average weight of waste per employee was 2.9 pounds per day. Many of the listed materials, if not all, could be recycled instead of landfilled. The results of the study are shown in **Table 2**.

The most effective method for promoting recycling activities is to create convenient opportunities for building occupants to recycle. This includes designating adequate space for recycling activities and storage of recyclable materials.

Environmental Issues

By creating convenient recycling opportunities for building occupants, a significant portion of the solid waste stream can be diverted from landfills. Recycling of paper, metals, cardboard and plastics reduces the need to extract virgin natural resources. For example, recycling one ton of paper prevents the processing of 17 trees and saves three cubic yards of landfill space. Recycled aluminum requires only 5% of the energy required to produce virgin aluminum from bauxite, its raw material. Recycling also reduces environmental impacts of waste in landfills. Land, water and air pollution impacts can all be reduced by minimizing waste volumes sent to landfills.

Economic Issues

Recycling requires minimal initial cost and offers significant savings in reduced landfill disposal costs or tipping fees. However, recycling activities use floor space that could be used otherwise. In larger buildings, processing equipment such as can crushers and cardboard balers are effective at minimizing the space required for recycling activities.

Table 1: Solid Waste Generation Rates

Building Type	Amount of Solid Waste
Warehouses	1.5 lbs / 100 SF /day
Office Buildings	1 lb / 100 SF / day
Department Stores	3 lbs / 100 SF / day
Supermarkets	7 lbs / 100 SF / day
Restaurants	2 lbs / 100 SF / day
Drugstores	3 lbs / 100 SF / day
Cafeterias	0.5 to 0.75 lbs / meal
Clubs	1.5 lbs / meal
Hotels	2 lbs / room / day & 2 lbs / meal
Schools	6 lbs / room & 0.25 lbs / student / day
Hospitals	20 lbs / bed / day & 2 lbs / meal
Nursing Homes	4 lbs / person / day

Source: International Dynetics Corporation

Table 2: Sample Office Waste Characterization

Recyclable Material	Percentage (by volume)
High-grade paper	39.6%
Low-grade paper	20.2%
Glass	11.8%
Miscellaneous paper	7.4%
Newsprint	7.0%
Food waste	2.9%
Cardboard	2.8%
Plastic	2.6%
Metal	1.8%
Other	3.9%

Community Issues

Many communities sponsor recycling programs to encourage building owners and occupants to reduce the amount of waste being deposited in landfills. Recycling efforts return valuable resources to the production process and provide more jobs versus landfilling. Some recyclables provide revenue, although often not enough to offset the cost of collection and processing. The cumulative effects reduce dependence on virgin resources whose extraction may destroy local and distant habitat areas. Higher recycling rates also result in more stable markets for recycled materials.

Design Approach

Strategies

In the design phase, designate well-marked collection and storage areas for recyclables including office paper, newspaper, cardboard, glass, metals and plastics. Locate a central collection and storage area in the basement or on the ground level with easy access for collection vehicles. Size the collection and storage space to accommodate recyclables storage. Research local recycling efforts to find the best method of diverting recyclable materials from the waste stream.

Provide instruction to occupants and maintenance personnel on recycling procedures. Encourage activities to reduce and reuse materials before recycling in order to reduce the amount of recyclable volumes handled. For instance, building occupants can reduce the solid waste stream by using reusable bottles, bags and other containers.

The City of Seattle passed an ordinance to require minimum areas for recycling and storage of recyclables in commercial buildings. The ordinance is based on the total square footage of the building. Minimum areas for residential buildings were also specified. **Table 3** can be used as a guideline to size your recycling area. Note that LEED does not require adherence to these guidelines.

Technologies

In addition to providing sufficient and accessible space for recycling, other devices may further facilitate recycling efforts. These include, but are not limited to, cardboard balers, aluminum can crushers and recycling chutes.

Synergies and Trade-Offs

Dense urban areas typically have recycling infrastructure in place, but additional space for collection and storage may be costly. It is possible that recyclable collection and storage space could increase the building footprint in some instances. It is important to address possible indoor environmental quality (IEQ) impacts on building occupants due to recycling activities. Those activities that create odors, noise and air contaminants should be iso-

Table 3: Recycling Area Guidelines

Commercial Building Square Footage [SF]	Minimum Recycling Area [SF]
0 to 5,000	82
5,001 to 15,000	125
15,001 to 50,000	175
50,001 - 100,000	225
100,001 - 200,000	275
200,001 or more	500

lated or performed during non-occupant hours to maintain optimal IEQ.

Resources

Web Sites

Business Resource Efficiency and Waste Reduction

www.ciwmb.ca.gov/bizwaste, (916) 341-6615

A program from the California Integrated Waste Management Board to assist in office recycling and waste reduction efforts.

Earth's 911

www.1800cleanup.org, (602) 224-5444

Information and education programs on recycling as well as regional links to recyclers.

Recycling at Work

www.usmayors.org/USCM/recycle, (202) 293-7330

A program of the U.S. Conference of Mayors that provides information on workplace recycling efforts.

Waste at Work

www.informinc.org/wasteatwork, (212) 788-7900

An online document from Inform, Inc., and the Council on the Environment of New York City on strategies and case studies to reduce workplace waste generation.

Print Media

Composting and Recycling Municipal Solid Waste by Luis Diaz et al., CRC Press, 1993.

McGraw-Hill Recycling Handbook by Herb Lund, McGraw-Hill, 2000.

Definitions

Recycling is the collection, reprocessing, marketing and use of materials that were diverted or recovered from the solid waste stream.

A **Landfill** is a waste disposal site for the deposit of solid waste from human activities.

SS | WE | EA | MR | EQ | ID

Credit 1.1

Building Reuse

Maintain 75% of Existing Walls, Floors and Roof

1 point

Intent

Extend the life cycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport.

Requirements

Maintain at least 75% of existing building structure and shell (exterior skin and framing, excluding window assemblies and non-structural roofing material).

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or other responsible party, listing the retained elements and declaring that the credit requirements have been met.

SS | WE | EA | MR | EQ | ID

Credit 1.2

1 point
in addition to
MR 1.1

Building Reuse

Maintain 100% of Existing Walls, Floors and Roof

Intent

Extend the life cycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport.

Requirements

Maintain an additional 25% (100% total) of existing building structure and shell (exterior skin and framing, excluding window assemblies and non-structural roofing material).

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or other responsible party, demonstrating the retained elements and declaring that the credit requirements have been met.

SS	WE	EA	MR	EQ	ID
Credit 1.3					

1 point
in addition to
MR 1.1 & 1.2

Building Reuse

Maintain 100% of Shell/Structure and 50% of Non-Shell/Non-Structure

Intent

Extend the life cycle of existing building stock, conserve resources, retain cultural resources, reduce waste and reduce environmental impacts of new buildings as they relate to materials manufacturing and transport.

Requirements

Maintain 100% of existing building structure and shell (exterior skin and framing, excluding window assemblies and non-structural roofing material) AND at least 50% of non-shell areas (interior walls, doors, floor coverings and ceiling systems).

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or other responsible party, demonstrating the retained elements and declaring that the credit requirements have been met.

Summary of Referenced Standard

There is no standard referenced for these credits.

Credit Synergies

SS Credit 4
Alternative Transportation

SS Credit 5
Reduced Site Disturbance

SS Credit 6
Stormwater Management

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

SS Credit 8
Light Pollution Reduction

WE Credit 1
Water Efficient Landscaping

WE Credit 2
Innovative Wastewater Treatment

WE Credit 3
Water Use Reduction

EA Prerequisite 2
Minimum Energy Performance

EA Prerequisite 3
CFC Reduction in HVAC&R Equipment

EA Credit 1
Optimize Energy Performance

EA Credit 4
Ozone Depletion

MR Prerequisite 1
Storage & Collection of Recyclables

MR Credit 2
Construction Waste Management

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

EQ Credit 8
Daylight & Views

Green Building Concerns

Many opportunities exist to rehabilitate existing buildings. Commercial real estate companies often rehabilitate old industrial buildings to take advantage of prime location, lower building costs and desirable building characteristics.

Environmental Issues

Reusing the building shell and non-shell components of an existing building significantly reduces construction waste volumes leaving the project site. Reuse strategies also reduce environmental impacts associated with raw material extraction, manufacture and transportation of new or recycled materials. Building reuse minimizes habitat disturbance associated with developing on a greenfield site and typically requires less new infrastructure development for utilities and roads.

Economic Issues

Reuse of an existing structural shell depends on many factors including structural and material integrity, building code compliance, fire and safety compliance, adaptability to the new building program, possible contamination issues, and energy and environmentally efficient retrofit considerations. A critical review of all these elements is necessary to determine the advantages of reuse versus demolition.

Reuse of an existing building can reduce the first costs of building substantially. For instance, the Southern California Gas Company reused an existing building for its Energy Resource Center and estimated a savings of approximately $3.2 million, based on typical first costs for a 44,000-square-foot building. The largest savings were realized in masonry (87% savings), site work (57% savings), concrete (49% savings) and carpentry (70% savings).

Community Issues

The character of a neighborhood is often defined by existing historic buildings. Building reuse maintains the vital link between neighborhoods of the past and present. Building reuse can often shorten construction periods and reduce noise and traffic disruptions in the neighborhood.

Design Approach

Strategies

Research the potential reuse of an existing building's structural shell in the early design phase of the project and create a list of benefits and drawbacks of such a scheme. Determine if programming and space planning can be accommodated in the existing building structure. If reuse of the structural shell is not possible, consider preserving the facade, particularly in urban areas.

The building envelope has a significant impact on energy performance and operational costs over the lifetime of the building. Evaluate the building's structural integrity and skin, functional suitability, code compliance, historic and cultural significance, and adaptability. In addition, consider the environmental attributes of the building, surrounding site and structural shell. Examples of environmental attributes include solar benefits or drawbacks, transportation access, existing air quality levels, and the possibility for upgrading outdated building components such as insulation and glazing. Identify asbestos, lead-based paint and other contaminants in the building and apply required or appropriate removal or isolation measures.

Technologies

Consider upgrading outdated components with new components that can enhance energy efficiency, water efficiency and indoor environmental quality. Building systems to consider for upgrade include HVAC systems, plumbing systems, insulation and windows.

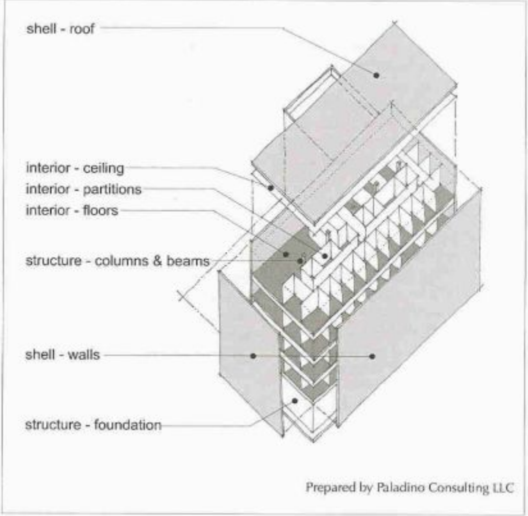


Figure 1: Example Reuse of Building

Synergies and Trade-Offs

The location of the existing building determines the neighborhood density, brownfield status and transportation options. Site amenities may or may not exist for stormwater control and site lighting. Preserved site surfaces such as roofs and parking lots may contribute to urban heat island effects. The existing plumbing and irrigation systems may not have the flexibility to allow for potable water use reduction, wastewater generation reduction, and stormwater reuse.

The energy performance of buildings is highly dependent on the building envelope and HVAC and lighting systems. For instance, an existing building with minimal insulation will tend to exhibit lower energy performance than a new building with state-of-art wall construction. The existing building orientation may preclude the use of passive solar gains or may lack shading devices to prevent unwanted solar gain and glare.

Reusing a building also reduces the amount of solid waste leaving the project site. Thus, building elements qualifying for this credit can also be applied to MR Credit 2: Construction Waste Management. If a portion of a building's structure, shell or non-shell components are reused but this effort does not meet the minimum levels as stated in this credit, apply these reuse activities to MR Credit 2.

Existing buildings may have space constraints and may not be able to provide adequate space for occupant recycling activities and separation of chemical storage areas. Older buildings may contain contaminants such as asbestos and lead-based paint that can affect indoor air quality. Their systems may also contain HCFs and halons that are detrimental to the Earth's atmosphere. Daylighting and occupant control strategies may be difficult to implement in the existing building's layout.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. In order to qualify for this point, the existing building must undergo a substantial renovation. If the project includes an addition that is greater than 50% of the existing building's square footage, it is considered a new building and is thus ineligible for the building reuse credit. In such cases, the reused building materials should be included as part of MR Credit 2.

To calculate the percentage of reused building structure, consider structural elements such as footings, slabs on grade, stem walls, columns, beams, exterior wall sections and diaphragms, as well as shell elements such as brick cladding, roofing and siding (see **Equations** 1 and 2).

Quantify structural elements in terms of cubic feet (CF) and shell elements in terms of square feet (SF). Do not include doors and similar elements. (Apply the environmental benefits of reusing these elements to MR Credit 2: Construction Waste Management.) If an item that cannot be reused for its original function is reprocessed (on or off the site) and installed for a different use, it can be counted toward MR Credit 3: Resource Reuse. Wood beams that are remilled for a similar use, for instance, would be applicable to this credit. Demolished concrete that is crushed on site for use as structural fill would also be applicable to MR Credit 3.

Once the structural and shell reuse percentages have been determined, add these two percentages together and divide by two to obtain the approximate percentage of the total building that is being reused (see **Equation 3**).

To calculate the percentage of reused non-shell building portions, consider all walls, doors, floor coverings and ceiling systems. Quantify the elements in terms of square feet and divide the reused elements by the existing total square footage of walls, doors, floor coverings and ceiling systems to obtain the percentage of reused non-shell building elements (see **Equation 4**).

Tables 1, 2 and 3 summarize an example building reuse project where both structural elements as well as non-shell (i.e., interior) elements were reused. The

Equation 1:

$$\text{Structural Reuse } [\%] = \frac{\text{Reused Elements [CF]}}{\text{Total Elements [CF]}}$$

Equation 2:

$$\text{Shell Reuse } [\%] = \frac{\text{Reused Elements [SF]}}{\text{Total Elements [SF]}}$$

Equation 3:

$$\text{Building Reuse } [\%] = \frac{(\text{Structural Reuse } [\%] + \text{Shell Reuse } [\%])}{2}$$

Equation 4:

$$\text{Non-Shell Reuse } [\%] = \frac{\text{Reused Elements [SF]}}{\text{Total Elements [SF]}}$$

spreadsheet indicates that 100% of the structure and exterior shell was reused and 56% of the non-shell interior components were reused. This qualifies for three points under this credit.

Resources

Web Sites

Sustainable Communities Network Case Studies

www.smartgrowth.org/library/typelist.asp, (202) 328-8160

Several deconstruction and reuse case studies.

Table 1: Structural Elements Reuse Example

Structural Element	Existing [CF]	Reused [CF]	Percentage Reused [%]
Foundation / Slab on Grade	11,520	11,520	100%
Columns	500	500	100%
Beams	250	250	100%
Basement Wall	500	500	100%
Floor Decks	250	250	100%
Diaphragms	1,507	1,507	100%
Roof Deck	1,507	1,507	100%
TOTALS	**16,034**	**16,034**	**100%**

Table 2: Shell Elements Reuse Example

Shell Element	Existing [SF]	Reused [SF]	Percentage Reused [%]
Roofing	1,000	1,000	100%
North Exterior Wall	8,235	8,235	100%
East Exterior Wall	6,950	6,950	100%
South Exterior Wall	8,235	8,235	100%
West Exterior Wall	6,950	6,950	100%
TOTAL	**31,370**	**31,370**	**100%**

Table 3: Interior Elements Reuse Example

Interior Element	Existing [SF]	Reused [SF]	Percentage Reused [%]
Ceilings	40,000	0	0%
Wood Flooring	40,000	40,000	100%
Other Flooring	500	250	50%
Floor Coverings	500	250	50%
Walls	500	250	50%
Wall Panels	29,600	18,800	64%
Other	29,600	18,800	64%
TOTAL	**140,700**	**78,350**	**56%**

SS WE EA MR EQ ID

Credit 1

Print Media

Adaptive Reuse: Issues and Case Studies in Building Preservation by Richard Austin and David Woodstock, Van Nostrand Reinhold Company, 1987.

Case Study

KSBA Architects Office Building
Pittsburgh, Pennsylvania

Courtesy of KSBA Architects

Owner
KSBA Architects

The KSBA Architects office building is a LEED™ Certified Pilot Project located in the Lawrenceville section of Pittsburgh. The entire shell of the 1888 building was reused as well as 90% of interior millwork. New components were installed to update the interior spaces, including a raised access floor with HVAC and modular cabling, indirect lighting and ergonomics. The building now serves as a state-of-the-art information and technology headquarters for an architectural firm.

SS	WE	EA	MR	EQ	ID

Credit 2.1

1 point

Construction Waste Management

Divert 50% from Landfill

Intent

Divert construction, demolition and land clearing debris from landfill disposal. Redirect recyclable recovered resources back to the manufacturing process. Redirect reusable materials to appropriate sites.

Requirements

Develop and implement a waste management plan, quantifying material diversion goals. Recycle and/or salvage at least 50% of construction, demolition and land clearing waste. Calculations can be done by weight or volume, but must be consistent throughout.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or other responsible party, tabulating the total waste material, quantities diverted and the means by which diverted, and declaring that the credit requirements have been met.

SS	WE	EA	MR	EQ	ID
Credit 2.2					

1 point
in addition to
MR 2.1

Construction Waste Management

Divert 75% from Landfill

Intent

Divert construction, demolition and land clearing debris from landfill disposal. Redirect recyclable recovered resources back to the manufacturing process. Redirect reusable materials to appropriate sites.

Requirements

Develop and implement a waste management plan, quantifying material diversion goals. Recycle and/or salvage an additional 25% (75% total) of construction, demolition and land clearing waste. Calculations can be done by weight or volume, but must be consistent throughout.

Submittals

- ❏ Provide the LEED Letter Template, signed by the architect, owner or other responsible party, tabulating the total waste material, quantities diverted and the means by which diverted, and declaring that the credit requirements have been met.

Summary of Referenced Standard

There is no standard referenced for this credit.

SS	WE	EA	MR	EQ	ID

Credit 2

Credit Synergies

SS Credit 2
Urban Redevelopment

SS Credit 3
Brownfield Redevelopment

MR Credit 1
Building Reuse

EQ Credit 3
Construction IAQ Management Plan

Green Building Concerns

Construction and demolition (C&D) activities generate enormous quantities of solid waste. The U.S. EPA estimates that 136 million tons of C&D debris (versus 209.7 million tons of municipal solid waste) was generated in 1996—57% of it from non-residential construction, renovation and demolition activities. This equates to 2.8 pounds per capita per day.

Commercial construction generates between 2 and 2.5 pounds of solid waste per square foot, and the majority of this waste can potentially be recycled. The City of Portland, Oregon, has instituted programs to reduce solid waste generation and promote recyclable material markets. In 1993, the city was successful in diverting 47% of all construction and demolition waste from landfills. In one project, 76% of the waste from the construction of a 5,000-square-foot restaurant was diverted from landfilling (61% was recyclable or reusable wood, 11% was cardboard, and 4% was gypsum wallboard).

Recycling opportunities are expanding rapidly in many communities. Metal, vegetation, concrete and asphalt recycling opportunities have long been available and economical in most communities. Paper, corrugated cardboard, plastics and clean wood markets vary by regional and local recycling infrastructure, but are recycled in most communities. Some materials, such as gypsum wallboard, have recycling opportunities only in communities where reprocessing plants exist. The recyclability of a demolished material is often dependant on the amount of contamination attached to it. Demolished wood, for instance, is often not reusable or recyclable unless it is deconstructed and de-nailed.

A construction and demolition debris study conducted during one week in 1994 in Des Moines, Iowa is presented in **Table 1**. Data include debris from construction, renovation and demolition activities. While this example is a potential scenario, it should be noted that the composition of C&D debris is highly variable and depends on the geographic location and type of activity. Cardboard, for instance, is more prevalent during construction activities.

Environmental Issues

Recycling of construction and demolition debris reduces demand for virgin resources, and, in turn, reduces the environmental impacts associated with resource extraction, processing and, in many cases, transportation. Landfills contaminate groundwater and encroach upon valuable green space. Through effective construction waste management, it is possible to extend the lifetime of existing landfills, avoiding the need for expansion or new landfill sites.

Economic Issues

In the past, when landfill capacity was readily available and disposal fees were low, recycling or reuse of construction waste was not economically feasible. Construction materials were inexpensive compared to the cost of labor and, thus, construction jobsite managers focused on

Table 1: CDL Waste Stream Characterizations

Material	Percentage (by volume)
Concrete	28.8
Wood	20.6
Drywall	14.0
Metal	11.2
Roofing	7.7
Brick	6.2
Cardboard	3.5
Miscellaneous	8.0

Adapted from Brickner, Robert, GB&B Inc., "Identifying C&D Debris Markets." Scrap Processing, March/April 1995.

worker productivity rather than materials conservation. In addition, recycling infrastructure and materials marketplaces to process and resell construction debris did not exist. In recent years, increased materials and disposal costs coupled with more stringent waste disposal regulations and decreasing landfill capacity have changed the waste management equation. Local government agencies and private organizations have partnered with the industry to support construction waste management by publishing guides, directories and other educational materials; presenting recycling information at seminars and workshops; and operating pilot projects to demonstrate the feasibility and cost-effectiveness of these activities.

Waste management plans require time and money to draft and implement but they can guide a project to achieve substantial savings throughout the construction process. Projects that recycle construction and demolition debris benefit from lower tipping fees.

As landfill tipping fees continue to escalate, the option to recycle becomes more economically attractive. As a rule of thumb, when landfill tipping fees exceed $50 per ton, recycling becomes cost-effective. Local governments sometimes inflate tipping fees artificially to encourage greater recycling efforts.

Recyclable materials have differing market values depending on the presence of local recycling facilities, reprocessing costs and the availability of virgin materials on the market. In general, it is economically beneficial to recycle metals, concrete, asphalt and cardboard—to receive revenue as well as to avoid paying a landfill tipping fee. Market values normally fluctuate from month to month. When no revenue is received for materials—often the case for scrap wood and gypsum wallboard—smaller rewards can come from possibly shorter hauling distances and avoiding landfill tipping fees.

Some materials can be reprocessed and reused on site. For instance, grinding demolished concrete for use as structural fill can provide excellent savings versus hauling debris away and purchasing gravel.

Community Issues

The conventional approach to construction waste is to remove all wastes from the site and start with a "clean slate." In recent years, construction waste strategies have dictated more thoughtful planning and scheduling of solid waste streams. Reusing existing structures and deconstructed materials on-site can reduce disruption to the community by minimizing truck traffic. Recycling supports local processing facilities, creates jobs and reduces the need for additional landfill capacity. Salvage may include the donation of materials to charitable organizations such as Habitat for Humanity.

Table 2: Construction Materials Being Recycled

Materials	
Land clearing debris	Asphalt shingles
Clean dimensional wood	Paint
Plywood, OSB, & particle board	Window glass
Concrete	Carpet & carpet pad
Asphaltic concrete	Plastic film
Concrete masonry units (CMUs)	Polystyrene
Bricks	High density polyethylene (HDPE)
Gysum wallboard	Cardboard, paper, & packaging
Rigid foam insulation	

Design Approach

Strategies

Minimize factors that contribute to waste such as over-packaging, improper storage, ordering errors, poor planning, breakage, mishandling, and contamination of construction materials. For waste volumes generated, identify and institute reuse, salvage and recycle opportunities whenever economics and logistics allow. **Table 2** is a list of materials that are being recycled in various places around the United States.

Develop and institute a construction waste management plan that identifies proposed deconstruction and salvage opportunities, on-site reprocessing and reuse opportunities, recommended recycling activities, licensed haulers and processors of recyclables, and potential markets for salvaged materials. The plan should include estimated costs associated with recycling, salvaging and reusing materials and should also address source reduction of materials use.

On the construction site, designate an area specifically for construction and demolition waste recycling. Train site workers on the proper recycling protocol and label recyclable containers effectively. Institute monthly reporting and feedback on the waste management plan to assess progress and address any problems. Post this information for all construction personnel to read. Provide signs in the native language(s) of the workers.

Synergies and Trade-Offs

Project sites in urban areas may have little or no space available for waste separation activities. Recycling areas should be chosen wisely to avoid contaminating stormwater runoff volumes and to protect stockpiled recyclable materials from the elements.

If the project is reusing a building, the materials preserved can be applied to this credit as well as to MR Credit 1. The waste management plan should address construction area housekeeping to avoid the contamination of the building and subsequent impacts on indoor air quality.

Materials included in MR Credits 3, 4, 5, 6 and 7 cannot be applied to this credit.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. Use a spreadsheet to track the weights of construction wastes that are landfilled and the weight of construction, demolition and land clearing (CDL) wastes that are recycled. To calculate the recycling percentage, use **Equation 1**. Calculations can be done by weight or volume, but must be consistent throughout. Do not include hazardous waste and excavation soil in the calculations.

Tables 3 and **4** demonstrate waste calculations for an example project. The project recycled concrete, steel, wood, cardboard, gypsum wallboard, masonry and land clearing debris. An estimated 245.5 tons of waste were recycled while 43.7 tons were sent to the landfill. This results in a recycling rate of 85%, which qualifies for two points under this credit.

Typically, waste containers are sized by volume and these volumes are weighed at the materials recovery facility or landfill. To assist in calculations, **Table 5** provides estimates to convert waste materials from volume to weight.

Equation 1:

$$\text{Recycling Rate } [\%] = \frac{\text{Recycled Waste}}{\text{Recycled Waste} + \text{Garbage}}$$

Table 3: Recycled Materials Example

Recycled and Salvaged Materials	Weight [tons]
Concrete	138.0
Land Clearing Debris	56.2
Wood	19.6
Gypsum Wallboard	9.5
Masonry	9.4
Cardboard	7.2
Steel	3.1
Furniture	2.5
TOTAL	245.5

Table 4: Landfills Materials Example

Garbage	Weight [tons]
Miscellaneous Garbage	43.7
TOTAL	43.7

Table 5: Solid Waste Conversion Factors

Material	Density [lbs/CY]
Cardboard	100
Gypsum Wallboard	500
Mixed Waste	350
Rubble	1,400
Steel	1,000
Wood	300

Resources

Web Sites

Construction and Demolition Waste Recycling Information

www.ciwmb.ca.gov/ConDemo, (916) 341-6499

A program by the California Integrated Waste Management Board including case studies, fact sheets and links.

Construction Materials Recycling Association

www.cdrecycling.org

A nonprofit dedicated to information exchange within the North American construction waste and demolition debris processing and recycling industry.

Construction Waste Management Handbook

www.smartgrowth.org/library/articles.asp?art=15, (202) 328-8160

A report by the NAHB Research Center on residential construction waste management for a housing development in Homestead, Florida.

Contractors' Guide to Preventing Waste and Recycling

www.resourceventure.org/publications.htm, (206) 389-7304

A guidebook on waste prevention in construction from the Business and Industry Resource Venture.

Government Resources

Check with the solid waste and natural resources departments in your city or county. Many local governments provide information about regional recycling opportunities.

Recycling and Waste Management During Construction

www.metrokc.gov/procure/green/wastemgt.htm

Specification language from City of Seattle and Portland Metro projects on construction waste management.

Sustainable Building Sourcebook

www.greenbuilder.com/sourcebook/ConstructionWaste.html

A guide to construction waste management from the *Sustainable Building Sourcebook*.

U.S. EPA – Environmental Specifications for Research Triangle Park

www.epa.gov/rtp/new-bldg/environmental/specs.htm, (919) 541-0249

Waste management and other specifications.

Waste Spec: Model Specifications for Construction Waste Reduction, Reuse and Recycling

www.tjcog.dst.nc.us/cdwaste.htm, (919) 558-9343

Model specifications developed by Triangle J Council of Governments in North Carolina. Ten case studies show results of using the specifications.

Definitions

Construction, demolition and land clearing (CDL) debris includes waste and recyclables generated from construction, land clearing (e.g., vegetation, but not soil), renovation, and demolition or deconstruction of pre-existing structures.

Recycling is the collection, reprocessing, marketing and use of materials that were diverted or recovered from the solid waste stream.

Reuse is a strategy to return materials to active use in the same or a related capacity.

Tipping Fees are fees charged by a landfill for disposal of waste volumes. The fee is typically quoted for one ton of waste.

Case Study

The Aspen Skiing Company Sundeck Restaurant
Aspen, Colorado

Courtesy of The Aspen Skiing Company

Owner
The Aspen Skiing Company

The Aspen Skiing Company Sundeck Restaurant is a LEED™ Bronze Pilot Project that is located atop Aspen Mountain. The project team adopted a construction waste management plan and instituted rigorous "grass roots" construction waste management efforts that resulted in the diversion of 84% of construction waste materials from the landfill. The existing building was deconstructed, and beams, doors, fixtures, appliances, furniture and other valuable items were sold at a yard sale. Steel was segregated from the construction waste stream and recycled. Wood and gypsum wallboard were ground on-site and reused as compost. Finally, the existing foundation was processed on-site and reused as fill material. Overall, these measures significantly reduced hauling trips to the landfill and resulted in project savings of $35,000.

SS | WE | EA | MR | EQ | ID

Credit 3.1

1 point

Resource Reuse

5%

Intent

Reuse building materials and products in order to reduce demand for virgin materials and to reduce waste, thereby reducing impacts associated with the extraction and processing of virgin resources.

Requirements

Use salvaged, refurbished or reused materials, products and furnishings for at least 5% of building materials.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or other responsible party, declaring that the credit requirements have been met and listing each material or product used to meet the credit. Include details demonstrating that the project incorporates the required percentage of reused materials and products and showing their costs and the total cost of materials for the project.

SS	WE	EA	MR	EQ	ID
Credit 3.2					

1 point
in addition to
MR 3.1

Resource Reuse

10%

Intent

Reuse building materials and products in order to reduce demand for virgin materials and to reduce waste, thereby reducing impacts associated with the extraction and processing of virgin resources.

Requirements

Use salvaged, refurbished or reused materials, products and furnishings for at least 10% of building materials.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or other responsible party, declaring that the credit requirements have been met and listing each material or product used to meet the credit. Include details demonstrating that the project incorporates the required percentage of reused materials and products and showing their costs and the total cost of all materials for the project.

Summary of Referenced Standard

There is no standard referenced for this credit.

Green Building Concerns

Use of salvaged and refurbished materials in new building projects extends the life of materials and can reduce overall first costs of construction materials. Use of salvaged materials can also add character to the building and can be used effectively as architectural details. Some areas of the United States, such as New England, the Pacific Northwest, and California, have well-developed markets for salvaged materials while other regions are just beginning to develop these markets.

Environmental Issues

Reuse strategies divert material from the construction waste stream, reducing the need for landfill space and the associated water and air contamination issues. Use of salvaged materials eliminates environmental impacts of producing new construction and product materials. These impacts are significant since buildings account for a large portion of our use of natural resources, including 40% of raw stone, gravel and sand, and 25% of virgin wood.

Economic Issues

Some salvaged materials are more costly than new materials due to the high cost of labor involved in recovering and refurbishing processes. However, salvaged materials are often of higher quality and more durable than available new materials. Local demolition companies may be willing to sell materials recovered from existing buildings to avoid landfill tipping fees and to generate income. In some areas, municipalities and waste management companies have established facilities to sell salvaged building material sales at landfill sites.

Sometimes salvaged materials are offered at prices that appear to be cost-effective but may include hidden costs such as the need for reprocessing, exorbitant transportation costs or liabilities associated with toxic contamination.

Conversely, certain salvaged materials may be impossible to duplicate (such as turn-of-the century lumber and casework) and may well be worth the higher cost compared to new but inferior materials.

Community Issues

By reusing locally obtained salvaged materials, local salvage businesses are supported. Also, saving landfill capacity benefits the community through lower tipping fees and fewer landfill sites overall.

Design Approach

Strategies

Develop a reuse strategy early in the schematic design phase to incorporate salvaged and refurbished building materials and set salvaged materials goals. For instance, state that a minimum of 50% of all floor surfaces will be salvaged. Identify local sources for salvaged or refurbished building materials and products. It may be helpful to create and maintain a current list of the salvage material suppliers to use on other projects.

Commonly salvaged or refurbished building materials and products include structural elements such as beams and posts, wood flooring, wood paneling, doors and frames, cabinetry and furniture, brick and other masonry products, and decorative items such as mantels, ironwork and antique light fixtures. Research all salvaged and refurbished materials for durability, performance, code compliance and environmental considerations. Do not consider items that generally should not be salvaged and reused, such as toilets (older models consume more water) and windows (older styles are less energy efficient).

When considering salvaged structural materials such as heavy timbers, it is imperative to check for structural integrity, code compliance and engineered rating to comply with building codes for structural re-

SS | WE | EA | MR | EQ | ID

Credit 3

Credit Synergies

SS Credit 2
Urban Redevelopment

SS Credit 3
Brownfield Redevelopment

MR Credit 1
Building Reuse

MR Credit 5
Local/Regional Materials

quirements. Also investigate salvaged materials for possible contamination by lead paint, asbestos, pesticides and rot.

Synergies and Trade-Offs

The availability of salvaged materials will depend on the location of the project site. Building projects in urban areas often have many opportunities to use salvaged materials. These materials can be applied to MR Credit 5 if the materials comply with the requirements of the credit. Salvaged materials cannot be applied to MR Credits 1, 2, 4, 6 and 7.

A material salvaged during a building renovation can be applied to this credit only if it can no longer serve its original function and has been reprocessed and installed for a different use. Materials that will be reinstalled to serve in their original function must be applied to MR Credit 1.3, Building Reuse. On a project site where an existing building is being demolished or deconstructed, the material that is salvaged on-site and installed in the new building can be used to comply with this credit.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. To calculate the percentage of salvaged materials used on a project, use the LEED Letter Template's spreadsheet to list all materials and products used on the project and their associated costs. Identify those building materials that are salvaged and use **Equation 1** to determine the salvage percentage for the project.

The salvaged or refurbished status of each material must be validated by a statement from the provider of that material, in case this credit is audited. If major mechanical, plumbing and/or electrical components are part of the salvaged materials contributing to credit compliance, then add mechanical, plumbing and/or electrical material costs in the calculation (numerator and denominator). If the cost of the salvaged or refurbished material is below market value, use replacement cost to estimate the material value. For example, if reclaimed plywood is used in the project at a cost of $15 per sheet and new plywood costs $25 per sheet, use the new cost in salvage and reuse calculations.

A sample calculation for salvaged building materials is presented in **Table 1**. Salvaged materials in this example include brick and reclaimed wood. The material costs of these items are totaled and divided by the total material cost for the project. The total materials cost figure may be derived from a default calculation (45% of total construction cost) or a tally of actual material costs. The sample project has chosen the latter. The resulting percentage of 5.68% qualifies for one point under this credit.

Resources

Web Sites

California Materials Exchange

www.ciwmb.ca.gov/CalMAX, (877) 520-9703

A program of the California Integrated Waste Management Board, this exchange allows users to exchange waste items online.

Government Resources

Check with the solid waste and natural resources departments in your city or county. Many local governments provide information about regional materials exchanges and other sources.

Equation 1:

$$\text{Salvage Rate } [\%] = \frac{\text{Salvaged Materials Cost [\$]}}{\text{Total Materials Cost [\$]}}$$

Guide to Resource-Efficient Building Elements

www.crbt.org, (406) 549-7678

The Center for Resourceful Building Technology's directory of environmentally responsible building products. This resource provides introductory discussions per topic and contact information for specific products, including salvaged materials.

Materials Exchanges on the Web

www.metrokc.gov/hazwaste/imex/exchanges.html, (206) 296-4899

A listing of materials exchanges on the Web.

Reuse Development Organization (ReDO)

www.redo.org, (317) 631-5395

A national nonprofit located in Indianapolis, Indiana, that promotes reuse as an environmentally sound, socially beneficial and economical means of managing surplus and discarded materials. See the List of ReDO Subscribers for contacts around the United States.

Salvaged Building Materials Exchange

www.greenguide.com/exchange/search.html

A searchable database of salvaged building materials.

Used Building Materials Association

www.ubma.org, (877) 221-UBMA

UBMA is a nonprofit, membership-based organization that represents companies and organizations involved in the acquisition and/or redistribution of used building materials.

Used Building Materials Exchange

www.build.recycle.net, (519) 767-2913

A free marketplace for buying and selling recyclables and salvaged materials.

Definitions

Chain-of-Custody is a tracking procedure to document the status of a product from the point of harvest or extraction to the ultimate consumer end use.

Salvaged Materials are construction materials recovered from existing buildings or construction sites and reused in other buildings. Common salvaged materials include structural beams and posts, flooring, doors, cabinetry, brick and decorative items. See the Synergies section for more LEED-related details.

Table 1: Letter Template Spreadsheet Example for Resource Reuse

Provide total construction cost for 45% default total materials value; OR Provide total materials cost (exclude labor, equipment)	$ 2,879,744	
Product Name	**Company Name**	**Product Cost**
Brick (salvaged)	Salvage Company	$ 33,700
Reclaimed Wood	Salvage Company	$ 130,000
	Sub-total salvaged or reused	**$ 163,700**
	Salvaged and reused materials as a percentage of total materials cost	**5.68%**

Case Study

Philips Eco-Enterprise Center
Minneapolis, Minnesota

The Phillips Eco-Enterprise Center is a mixed-use building that houses environmental and energy efficiency organizations, consultants and manufacturers. The building incorporates many reused building materials such as bricks, sinks, fire extinguisher cabinets, furniture, doors and windows. In addition, the structural members of the building consist of 189 reused steel joists from a demolished warehouse. Reuse of these joists saved an estimated 50 tons of steel and 110 million BTUs of energy that would have been needed for the building design. Finally, the building was designed for disassembly in the future. For example, the fire exit stair tower was designed to be disassembled, moved and reassembled. Also, the high-bay manufacturing space was designed for conversion to two floors of office space if needed by future tenants.

Owner
The Green Institute

SS	WE	EA	MR	EQ	ID

Credit 4.1

1 point

Recycled Content

5% (post-consumer + 1/2 post-industrial)

Intent

Increase demand for building products that incorporate recycled content materials, therefore reducing impacts resulting from extraction and processing of new virgin materials.

Requirements

Use materials with recycled content such that the sum of post-consumer recycled content plus one-half of the post-industrial content constitutes at least 5% of the total value of the materials in the project.

The value of the recycled content portion of a material or furnishing shall be determined by dividing the weight of recycled content in the item by the total weight of all material in the item, then multiplying the resulting percentage by the total value of the item.

Mechanical and electrical components shall not be included in this calculation. Recycled content materials shall be defined in accordance with the Federal Trade Commission document, *Guides for the Use of Environmental Marketing Claims, 16 CFR 260.7 (e)*, available at www.ftc.gov/bcp/grnrule/guides980427.htm.

Potential Technologies & Strategies

Establish a project goal for recycled content materials and identify material suppliers that can achieve this goal. During construction, ensure that the specified recycled content materials are installed and quantify the total percentage of recycled content materials installed.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or other responsible party, declaring that the credit requirements have been met and listing the recycled content products used. Include details demonstrating that the project incorporates the required percentage of recycled content materials and products and showing their cost and percentage(s) of post-consumer and/or post-industrial content, and the total cost of all materials for the project.

SS	WE	EA	MR	EQ	ID

Credit 4.2

1 point
in addition to
MR 4.1

Recycled Content

10% (post-consumer + 1/2 post-industrial)

Intent

Increase demand for building products that incorporate/have incorporated recycled content materials, therefore reducing the impacts resulting from extraction and processing of new virgin materials.

Requirements

Use materials with recycled content such that the sum of post-consumer recycled content plus one-half of the post-industrial content constitutes at least 10% of the total value of the materials in the project.

The value of the recycled content portion of a material or furnishing shall be determined by dividing the weight of recycled content in the item by the total weight of all material in the item, then multiplying the resulting percentage by the total value of the item.

Mechanical and electrical components shall not be included in this calculation. Recycled content materials shall be defined in accordance with the Federal Trade Commission document, *Guides for the Use of Environmental Marketing Claims, 16 CFR 260.7 (e)*, available at www.ftc.gov/bcp/grnrule/guides980427.htm.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or other responsible party, declaring that the credit requirements have been met and listing the recycled content products used. Include details demonstrating that the project incorporates the required percentage of recycled content materials and products and showing their cost and percentage(s) of post-consumer and/or post-industrial content, and the total cost of all materials for the project.

Summary of Referenced Standard

FTC Guides for the Use of Environmental Marketing Claims, 16 CFR 260.7 (e)

www.ftc.gov/bcp/grnrule/guides980427.htm

According to the guide: "A recycled content claim may be made only for materials that have been recovered or otherwise diverted from the solid waste stream, either during the manufacturing process (pre-consumer), or after consumer use (post-consumer). To the extent the source of recycled content includes pre-consumer material, the manufacturer or advertiser must have substantiation for concluding that the pre-consumer material would otherwise have entered the solid waste stream. In asserting a recycled content claim, distinctions may be made between pre-consumer and post-consumer materials. Where such distinctions are asserted, any express or implied claim about the specific pre-consumer or post-consumer content of a product or package must be substantiated.

"It is deceptive to misrepresent, directly or by implication, that a product or package is made of recycled material, which includes recycled raw material, as well as used, reconditioned and remanufactured components. Unqualified claims of recycled content may be made if the entire product or package, excluding minor, incidental components, is made from recycled material. For products or packages that are only partially made of recycled material, a recycled claim should be adequately qualified to avoid consumer deception about the amount, by weight, of recycled content in the finished product or package. Additionally, for products that contain used, reconditioned or remanufactured components, a recycled claim should be adequately qualified to avoid consumer deception about the nature of such components. No such qualification would be necessary in cases where it would be clear to consumers from the context that a product's recycled content consists of used, reconditioned or remanufactured components."

See the FTC document for illustrative examples.

SS	WE	EA	MR	EQ	ID

Credit 4

Credit Synergies

MR Credit 5
Local/Regional Materials

EQ Credit 4
Low-Emitting Materials

Green Building Concerns

Recycled content building products contain feedstock materials recovered from consumers or industrial waste streams. These products are beneficial to the environment because they reduce virgin material use and solid waste volumes. The number of building products containing recycled content feedstocks continues to grow every year as recycling efforts increase and the marketplace for recycled materials develops. Many commonly used products are now available with recycled content. These products include metals, concrete, masonry, acoustic tile, carpet, ceramic tile and insulation. Most recycled content products exhibit performance similar to products containing virgin materials and can be incorporated into building projects with ease.

Environmental Issues

By selecting materials with recycled content, environmental impacts associated with extracting, harvesting and manufacturing virgin materials are often reduced. The solid waste stream is also reduced by diverting recyclable materials that would otherwise be deposited in a landfill, with associated impacts to land, water and air also lessened. The total environmental benefits of material recycling are generally less than that of material reuse because of the environmental burdens associated with recyclable materials collection, transport and processing into new products. Therefore, reuse of building materials (MR Credits 1 and 3) is preferred over recycling when possible.

Economic Issues

Some recycled content products cost more than equivalent virgin products due to the expenses of research and design, innovative manufacturing equipment and new plants to produce the products, as well as the actual costs of the recycling process. As demand for recycled products in the building market continues to grow, the costs for these items will become competitive with standard products. This LEED credit favors post-consumer recycled content because there is greater need and value in stimulating the post-consumer recycling market. Some recycled products may not be as widely available as conventional products.

Design Approach

Strategies

Consider the incorporation of recycled content building materials in the early stages of project design and identify recycled content materials goals. Identify the types of materials for which recycled alternatives exist and then identify specific products.

Recycled content materials are building products that include components that have recycled content and are processed off-site. Materials from the site that are processed for reuse on the site, such as crushed brick, asphalt and concrete, are not defined as recycled content materials in this context. Instead, these materials should be applied to MR Credit 3: Resource Reuse.

Ensure that recycled content materials perform equally or better than virgin materials in terms of strength, maintenance and lifetime. Maintain or refer to lists of manufacturers and suppliers of recycled content materials, and support regionally produced recycled content products when possible to reduce the added costs of transportation.

Incorporate products into the building design that not only have recycled content but are also recyclable. Remember to research all recycled content materials for durability, performance and environmental considerations. For instance, if the recycled content product is not as durable, the benefits to the environment may be compromised. Also check recycled content materials for problematic air emissions, especially with synthetic products such as plastic, rubber and polyester.

During construction, ensure that the actual materials installed are those that were specified in the contract documents. Record the percentage of post-consumer and post-industrial recycled content for the LEED Letter Template calculations.

Synergies and Trade-Offs

Recycled content products should be evaluated in terms of their potential impacts on IAQ. In some cases, chemical binders used in recycled content products or processes contain off-gassing ingredients that can have a negative impact on IAQ. These off-gassing building products could affect construction workers as well as building occupants over the lifetime of the building.

It is often possible to specify recycled content building products that are also manufactured and recovered locally. If this is the case, recycled content materials can also be applied to MR Credit 5. Recycled content materials cannot be included in calculations for MR Credits 1, 2, 3, 6 and 7.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. To calculate the percentage of recycled content materials used on a project, use the spreadsheet in the LEED Letter Template to list all recycled content materials and products and their associated costs. For each product, identify the percentage of post-consumer and/or post-industrial recycled content by weight, and list the recycled content information source.

Mechanical and electrical systems components are not applicable to this credit (e.g., HVAC equipment, ductwork, wiring and lighting fixtures and controls). Plumbing products may be excluded. If plumbing products are included, the Letter Template's default materials cost can not be used (plumbing items must be added into the materials cost total).

Post-consumer recycled content is consumer waste that has become a raw material (feedstock) for another product. It originates from products that have served a useful purpose in the consumer market. Much of this feedstock comes from residential curbside recycling programs for aluminum, glass, plastic and paper. Other post-consumer feedstock is supplied by businesses that recycle construction and demolition debris. Post-industrial recycled content products are those that contain waste from industrial processes that has been traded through the marketplace. For instance, a composite board manufacturer may purchase (or haul away for free) sawdust from a lumber mill or waste straw from a wheat farm. This definition does not include in-house industrial scrap or trimmings, which are normally fed back into the same manufacturing process.

Most building products will only have one type of recycled content, but a few products contain both post-consumer and post-industrial recycled content. The Letter Template determines each product's recycled content values (post-consumer and post-industrial) using **Equation 1**, and calculates the total recycled content percentages using **Equation 2**. To determine point achievement, the spreadsheet uses the best one of two competing scenarios: post-consumer content value only, or post-consumer plus half of the post-industrial value.

In order to declare achievement of this credit within the Letter Templates, the project team should compile cut sheets, product literature (brochures) or other documentation that clearly indicate whether the material contains post-consumer or post-industrial recycled materials or both, and what percentages by weight. If nothing else is available, obtain an official statement from the product manufacturer stating the recycled content percentage by weight and if the recycled content is post-consumer or post-industrial. If there is no information for steel products, assume that recycled content is 25% post-consumer. Salvaged and refurbished materials are not considered to contain recycled content, and these materials should be applied to MR Credit 3: Resource Reuse.

Table 1 presents recycled content materials calculations for a sample project. Material costs exclude installation costs (e.g., labor and equipment). The total

Table 1: Letter Template Spreadsheet Example for Recycled Content Materials

Provide total construction cost for 45% default total materials cost; OR Provide total materials cost (exclude labor, equipment)		$ 2,879,744			
Product name	**Company**	**Product Cost**	**% Post-Consumer**	**% Post-Industrial**	**Recycled content information source**
Concrete	Concrete Company	$ 22,500	100.00%	0.00%	contractor submittal
Compost	Compost Company	$ 25,000	100.00%	0.00%	common knowledge
Rebar	Rebar Manufacturing Co.	$ 86,000	65.00%	0.00%	letter from factory
Brick (new)	Masonry Manufacturing Co.	$ 28,500	0.00%	15.00%	letter from factory
Misc. Metals	various	$ 179,000	60.00%	0.00%	manufacturer's inform.
Wheatboard Panels	Wheatboard Co.	$ 93,090	0.00%	25.00%	cut sheet
Metal Siding	Siding Co.	$ 38,000	25.00%	0.00%	product brochure
Metal Roofing	Roofing Co.	$ 35,000	85.00%	0.00%	product brochure
Ceramic Tile	Tile Co.	$ 11,396	95.00%	0.00%	product brochure
Acoustical Tile	Ceiling System Co.	$ 11,000	90.00%	0.00%	cut sheet
Carpet	Carpet Co.	$ 50,000	40.00%	0.00%	product brochure
Carpet Pad	Carpet Co.	$ 3,000	0.00%	100.00%	cut sheet
Toilet Partitions	Partition Co.	$ 4,000	100.00%	0.00%	product brochure
	Product Cost Subtotal	$ 586,486			

Total value of post-consumer content	$ 294,776
Total value of post-consumer content as a percentage of a total value of all materials	10.24%
Total value of post-industrial content	$ 30,548
Total value of post-industrial content as a percentage of total value of all materials	1.06%
Combined value of post-consumer and half of post-industrial content	$ 310,050
Combined value of post-consumer content plus half of post-industrial content as a percentage of total value of all materials	10.77%

Equation 1:

$$\text{Recycled Content Value [\$]} = \text{Material or Product Cost [\$]} \times \text{Recycled Content \%}$$

Equation 2:

$$\text{Recycled Content Rate [\%]} = \frac{\text{Recycled Content Value [\$]}}{\text{Total Materials Cost [\$]}}$$

Equation 3:

$$\text{Assembly Recycled Content} = \frac{\text{Material Weight [lbs]} \times \text{Recycled Content [\%]}}{\text{Total Weight [lbs]}}$$

materials cost figure may be derived from a default calculation (45% of total construction cost) or a tally of actual material costs. The sample project has chosen the latter. "Company" refers to the manufacturer or a manufacturer's representative. For each recycled content product, the percentage of post-consumer or post-industrial content by weight is noted. Then the recycled content value in dollars is calculated using **Equation 1**. In the example, rebar costs $86,000 and contains 65% post-consumer recycled content. This is equal to a recycled content dollar value of $55,900 ($86,000 x 65%) New bricks cost $28,500, contain 15% post-industrial content, and have a recycled content dollar value of $4275 ($28,500 x 15%)

As product data is entered, the spreadsheet sums each of the totals and uses **Equation 2** to calculate the percentages necessary for analysis and point assessment: post-consumer content value, post-industrial content value, and post-consumer content plus half of the post-industrial content. For this example, the total value of post-consumer recycled content plus half of the post-industrial content is 10.77% of the total materials cost and earns two points under this credit.

For assemblies, the assembly recycled content should be calculated. Use **Equation 3** to determine the assembly recycled content. Table 2 illustrates an assembly calculation for concrete containing 100% post-industrial fly ash. Fly ash constitutes 98 pounds in one ton of the example concrete mix. This results in an overall recycled content percentage of the concrete mix of 5% by weight.

Resources

Web Sites

CIWMB Recycled Content Product Database

www.ciwmb.ca.gov/rcp, (916) 341-6606

A searchable database for recycled content products, developed by the California Integrated Waste Management Board.

Government Resources

Check with the solid waste and natural resources departments in your city or county. Many local governments provide information on recyclers and recycled content product manufacturers within their region.

GreenSpec

www.greenspec.com, (802) 257-7300

Detailed listings for more than 1,500 green building products, including environmental data, manufacturer information and links to additional resources.

Table 2: Recycled Content Assembly Example

Concrete Components	Weight	Recycled Content	Percentage by Weight
	[lbs]	[%]	[%]
Water	160	--	8%
Cement	306	--	15%
Fly Ash	98	100%	5%
Coarse Aggregate	895	--	45%
Aggregate	541	--	27%
TOTAL	**2,000**		**100%**

Guide to Resource-Efficient Building Elements

www.crbt.org, (406) 549-7678

The Center for Resourceful Building Technology's directory of environmentally responsible building products. This resource provides introductory discussions per topic and contact information for specific products.

Oikos

oikos.com

A searchable directory of resource-efficient building products and sustainable design educational resources.

U.S. EPA Comprehensive Procurement Guidelines Program

www.epa.gov/cpg/products.htm

Contains EPA information on recycled content materials with guidelines for recycled percentages. Includes a searchable database of suppliers.

Definitions

Post-Consumer recycled content is consumer waste that has become a raw material (feedstock) for another product. It originates from products that have served a useful purpose in the consumer market. Much of this feedstock comes from residential and commercial (office) recycling programs for aluminum, glass, plastic and paper. Other post-consumer feedstock is supplied by businesses that recycle construction and demolition debris.

Post-Industrial recycled content is output from a process that has not been used as part of a consumer product, that is sold, traded, or exchanged under commercial terms (including auditable transactions between profit centers within an organization) as feedstock for another industrial process, and that would otherwise be landfilled, incinerated or somehow disposed of as a waste, as defined by the Federal Trade Commission. For instance, a composite board manufacturer may purchase (or haul away for free) sawdust from a lumber mill or waste straw from a wheat farm. Wood chips would not fit this definition.

Case Study

Greater Pittsburgh Community Food Bank
Pittsburgh, Pennsylvania

Courtesy of Gardner + Pope Architects

Owner
Greater Pittsburgh Community Food Bank

The Greater Pittsburgh Community Food Bank is a LEED™ Silver Pilot Project serving local food banks in Western Pennsylvania. The building houses distribution, warehouse and processing facilities and is designed to utilize site resources and be a positive workspace for building occupants. The building contains a substantial amount of recycled content building materials. These materials were required in specifications and included the following: reinforcing steel, structural steel, metal framing, ceramic tile flooring, sheet flooring, asphalt paving, gypsum wallboard, ceiling grid and tiles, and toilet partitions. In addition, a low-permeability, cementitious (LPC) material was used as structural fill, which consisted of 95% industrial waste products such as fly ash, lime and flue gas desulfurization material.

Regional Materials

20% Manufactured Regionally

SS	WE	EA	MR	EQ	ID
Credit 5.1					

1 point

Intent

Increase demand for building materials and products that are extracted and manufactured within the region, thereby supporting the regional economy and reducing the environmental impacts resulting from transportation .

Requirements

Use a minimum of 20% of building materials and products that are manufactured* regionally within a radius of 500 miles.

* Manufacturing refers to the final assembly of components into the building product that is furnished and installed by the tradesmen. For example, if the hardware comes from Dallas, Texas, the lumber from Vancouver, British Columbia, and the joist is assembled in Kent, Washington; then the location of the final assembly is Kent, Washington.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, declaring that the credit requirements have been met. Include calculations demonstrating that the project incorporates the required percentage of regional materials/products and showing their cost, percentage of regional components, distance from project to manufacturer, and the total cost of all materials for the project.

SS	WE	EA	MR	EQ	ID

Credit 5.2

1 point
in addition to
MR 5.1

Regional Materials

50% Extracted Regionally

Intent

Increase demand for building materials and products that are extracted and manufactured within the region, thereby supporting the regional economy and reducing the environmental impacts resulting from transportation.

Requirements

Of the regionally manufactured materials documented for MR Credit 5.1, use a minimum of 50% of building materials and products that are extracted, harvested or recovered (as well as manufactured) within 500 miles of the project site.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, declaring that the credit requirements have been met. Include calculations demonstrating that the project incorporates the required percentage of regional materials/products and showing their cost, percentage of regional components, distance from project to manufacturer, and the total cost of all materials for the project.

Summary of Referenced Standard

There is no standard referenced for this credit.

Green Building Concerns

By purchasing regionally manufactured building materials, the local economy is supported, transportation costs and environmental impacts are reduced, and dollars are retained in the region, supporting the regional economy. The availability of regionally manufactured building materials is dependent on the project location. In some areas, the majority of products needed for the project can be obtained within a 500-mile radius. In other areas, only a small portion or none of the building materials can be sourced locally. It is also important to address the source of raw materials used to manufacture building products. Raw materials for some building products are harvested or extracted far from the point of manufacture, creating air and water pollution due to transportation between point of extraction and point of manufacture.

Environmental Issues

The use of regional building materials reduces transportation activities and the accompanying pollution required to deliver the materials to the job site. Trucks, trains, ships and other vehicles deplete finite reserves of fossil fuels and generate air pollution. By selecting building materials that are produced from regional materials, transportation impacts are further reduced.

Economic Issues

Regional building materials are more cost-effective for projects due to reduced transportation costs. Also, the support of regional manufacturers and labor forces retains capital for community members and creates a more stable tax base and a healthier local economy.

Community Issues

Regional building materials are often consistent with regional design aesthetics and are sometimes more responsive to the local climate when compared with materials from other regions. The use of regional building materials supports the regional economy, helping to strengthen the local community and contribute to a high quality of life.

Design Approach

Strategies

Consider the incorporation of regional building materials early in the schematic design phase. Research regionally sourced and manufactured building materials for durability, performance and other environmental considerations. Create and maintain a current listing of regional manufacturers for future reference. Once the research of building materials is completed, specify appropriate regionally sourced and manufactured building materials in the contract documents.

Synergies & Trade-Offs

The location of the project site has a large effect on the availability of regionally sourced materials. Remote sites often require construction materials to be transported from great distances. In areas that have regional manufacturing facilities, it is advantageous to consider materials that are salvaged, that contain recycled content, that are rapidly renewable, and for wood products, those that are FSC-certified. Regional material dollar values can be applied to MR Credits 3, 4, 6 and 7 for those materials that meet the requirements of those credits. When choosing regional materials, it is also important to address volatile organic compounds (VOCs) and urea formaldehyde content as these can affect indoor air quality.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. To calculate the percentage of regional ma-

Credit Synergies

SS Credit 1
Site Selection

MR Credit 3
Resource Reuse

MR Credit 4
Recycled Content

MR Credit 6
Rapidly Renewable Materials

MR Credit 7
Certified Wood

EQ Credit 4
Low-Emitting Materials

terials used on a project, it is helpful to use the LEED Letter Template in addition to creating a spreadsheet listing all materials used on the project and their associated costs. This spreadsheet can also be used for MR Credits 3, 4, 6 and 7. Identify those products that were manufactured within 500 miles of the project site. The Letter Template sums all regionally manufactured product costs, and divides this value by the total materials cost to obtain the regionally manufactured product percentage (see **Equation 1**).

Next, identify those regionally manufactured products that contain materials extracted, harvested or recovered within 500 miles of the project site. The Letter Template sums all regionally extracted materials costs and divides this value by the regionally manufactured products cost to obtain the regionally extracted materials percentage (see **Equation 2**).

The Letter Template spreadsheet in **Table 1** presents regional materials calculations for a sample project. Note that material costs exclude installation expenses (e.g., labor and equipment), and "company" refers to the manufacturer or a manufacturer's representative. The total materials cost figure may be derived from a default calculation (45% of total construction cost) or a tally of actual material costs. The sample project has chosen the former.

The spreadsheet will add product costs to the "manufactured" and "extracted" totals depending on the distances data that is entered. For instance, compost is both manufactured and recovered within a short distance of the project and the material cost for compost is included in both totals. Rebar is manufactured within 500 miles of the project site, but the raw materials originate from locations greater than 500 miles from the project. Therefore, the material cost for rebar is only included in the regionally manufactured products tally.

The total regionally manufactured materials cost is divided by the total materials cost to obtain a regionally manufactured percentage of 22%. The total regionally extracted materials value is divided into the total of regionally manufactured materials dollar value to obtain the regionally extracted materials percentage of 55%. This example qualifies for two points under this credit.

If audited during the LEED certification review, the location of materials manufacture and extraction, harvesting, or recovery must be verified by a product cut sheet, product literature or letter from the manufacturer.

For assemblies, or when there are multiple sources for the same material (e.g., salvaged goods), use the following guidance. If all material sources are within 500 miles, use one line item in the table and state the greatest distance of the group. Otherwise, calculate the percentages of regionally and non-regionally extracted materials by weight (as detailed in MR Credit 4) and enter as two line items. In **Table 1**, see "wallboard" for an example.

Equation 1:

$$\text{Regionally Manufactured Products Rate [\%]} = \frac{\text{Regionally Manufactured Products Cost [\$]}}{\text{Total Materials Cost [\$]}}$$

Equation 2:

$$\text{Regionally Extracted Materials Rate [\%]} = \frac{\text{Regionally Extracted Materials Cost [\$]}}{\text{Regionally Manufactured Products Cost [\$]}}$$

Resources

Check with your local chamber of commerce and regional and state economic development agencies for building materials manufacturers in your area.

SS	WE	EA	MR	EQ	ID
Credit 5					

Table 1: Letter Template Spreadsheet Example for Regional Materials

Provide total construction cost			
for 45% default total materials cost; OR	$	6,582,471	
Provide total materials cost (exclude labor, equipment)	$	2,962,112	

Product name	Company	Product Cost	Distance between project & manufacturer (in miles)	Distance between project & extraction site (in miles)	Regional content information source
Reclaimed Concrete	Concrete Company	$ 22,500	9	31	Letter from manufacturer
Planting	Nursery Company	$ 35,066	42	42	Cut sheet
Compost	Compost Co.	$ 25,000	20	40	Cut sheet
Rebar	Supply Co.	$ 86,000	317	644	Letter from manufacturer
Brick (salvaged)	Salvage Co.	$ 33,700	39	58	Cut sheet
Brick (new)	Masonry Co.	$ 28,500	216	229	Letter from manufacturer
Misc. Metals	various	$ 58,700	439	?	Letters from manufacturers
Reclaimed Wood	Salvage Co.	$ 130,000	54	172	Cut sheet and letter
Millwork	Millwork Co.	$ 85,590	31	?	Cut sheets
Struct. Insulated Panels	SIP Co.	$ 80,500	500	497	Letter from manufacturer
Wallboard (gypsum)	Wallboard Co.	$ 60,000	294	566	Product literature
Wallboard (paper facing)	Wallboard Co.	$ 540	294	269	Letter from manufacturer
Toilet Partitions	Partition Co.	$ 4,000	311	427	Letter from manufacturer
	Product Cost Subtotal	**$** 650,096			

Total value of regionally manufactured products	**$**	**650,096**
Value of regionally manufactured products as a percentage of the value of all materials		**21.95%**
Total value of regionally extracted products	**$**	**359,806**
Value of regionally extracted materials as a percentage of regionally manufactured products		**55.35%**

Case Study

Monsanto Company Life Sciences Incubator
St Louis, Missouri

Courtesy of Monsanto Company

Owner
Monsanto Company

The Monsanto Company Life Sciences Incubator building is a LEED™ Silver Pilot Project housing research facilities committed to finding solutions to growing global needs for food and health. The design team specified regionally manufactured and sourced materials in the building where possible. Regional materials included cast-in-place and structural concrete, brick, structural and ornamental steel, structural and non-structural lumber, synthetic marble countertops, casework and millwork, insulation, door systems, gypsum wallboard, tack panels, signage, blinds, and toilet partitions. Overall, almost two-thirds of the materials for the project were sourced within 500 miles of the project site.

SS	WE	EA	MR	EQ	ID
Credit 6					

Rapidly Renewable Materials

1 point

Intent

Reduce the use and depletion of finite raw materials and long-cycle renewable materials by replacing them with rapidly renewable materials.

Requirements

Use rapidly renewable building materials and products (made from plants that are typically harvested within a ten-year cycle or shorter) for 5% of the total value of all building materials and products used in the project.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, declaring that the credit requirements have been met. Include calculations demonstrating that the project incorporates the required percentage of rapidly renewable products. Show their cost and percentage of rapidly renewable components, and the total cost of all materials for the project.

Summary of Referenced Standard

There is no standard referenced for this credit.

Credit Synergies

MR Credit 5
Local/Regional Materials

MR Credit 7
Certified Wood

EQ Credit 4
Low-Emitting Materials

Green Building Concerns

Many conventional building materials require large inputs of land, natural resources, capital and time. Conversely, rapidly renewable materials generally require less of these inputs and are therefore likely to be more environmentally friendly. Rapidly renewable resources are those materials that substantially replenish themselves faster than traditional extraction demand (i.e., planted and harvested in less than a 10-year cycle). Examples of such building materials include (but are not limited to) the materials listed in **Table 1**.

Environmental Issues

Rapidly renewable resources sometimes provide the opportunity to displace raw materials that have greater environmental impacts. Common examples include composite panels that are made from agricultural fiber such as wheat, substituting for composite wood panels. Irresponsible forestry practices cause ecosystem and habitat destruction, soil erosion, and stream sedimentation. Rapidly renewable crops require significantly less land—often due to higher density and shorter growing cycles—to produce the same amount of end product, and are often by-products that are otherwise considered waste.

Table 1: Rapidly Renewable Materials

Examples of Rapidly Renewable Materials
Bamboo flooring
Cotton batt insulation
Linoleum flooring
Sunflower seed board
Wheatgrass cabinetry
Wool carpet

Bio-based plastics (e.g., from corn starch) and other rapidly renewable resources are beginning to provide alternatives to some petroleum-based plastics.

Economic Issues

Because rapidly renewable resources may be harvested more quickly, they require less land to produce the same quantity of material, which equates to lower land costs. Rapidly renewable materials tend to give a faster payback on investment for manufacturers. Some rapidly renewable materials are new to the marketplace and are subsequently more expensive than their conventional counterparts. As demand for rapidly renewable materials increases, they will become more cost-competitive with conventional materials.

Community Issues

The land saved from the production requirements of rapidly renewable resources may be used for a variety of other uses, including open space and other agricultural products. Rapidly renewable materials create a more consistent harvesting cycle that can sustain a community instead of clearcutting and then abandoning the forest, as well as the workers, for decades.

Design Approach

Strategies

Research rapidly renewable materials for flooring, cabinetry, wood products and other project applications. Specify these materials in contract documents and create a current list of rapidly renewable products for future reference.

Equation 1:

$$\text{Rapidly Renewable Material Portion } [\%] = \frac{\text{Rapidly Renewable Material Cost } [\$]}{\text{Total Materials Cost } [\$]}$$

Synergies and Trade-Offs

Because many products made from rapidly renewable resources are relatively new, their long-term performance characteristics may be unknown. For example, the performance and stability of bamboo flooring has improved in recent years through the use of laminated layers of the material. Therefore it is important to evaluate a product's performance history prior to specifying.

Rapidly renewable materials costs can also be applied to MR Credits 5 and 7 if the materials meet the credit requirements. Some products made from rapidly renewable materials contain adhesives that may off-gas contaminants and have a negative impact on indoor air quality.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. To calculate the percentage of rapidly renewable materials used on a project, it is helpful to use the LEED Letter Template in addition to creating a spreadsheet listing all materials used on the project and their associated costs. Identify those products that are considered to be rapidly renewable. Sum all rapidly renewable material costs and divide this value by the total materials cost to obtain the rapidly renewable material percentage (see **Equation 1**). **For assemblies,** calculate the percentage of rapidly renewable materials by weight (as detailed in MR Credit 4).

Table 2 presents rapidly renewable materials calculations for a sample project. The total materials cost figure may be derived from a default calculation (45% of total construction cost) or a tally of actual material costs. The sample project has chosen the former. Material costs exclude installation expenses (e.g., labor and equipment). "Company" refers to the manufacturer or a manufacturer's representative. The costs for these materials are totaled and divided by the total material cost to obtain the rapidly renewable material percentage of 7%, which qualifies for one point under this credit.

If audited during the LEED certification review, cut sheets, product literature or a letter from the manufacturer must be submitted to confirm that the reported materials are manufactured with rapidly renewable resources.

Table 2: Letter Template Spreadsheet Example for Rapidly Renewable Materials

Total construction cost		$	6,399,431		
for 45% default total materials cost; OR		$	2,879,744		
Provide total materials cost (exclude labor, equipment)					
Product name	Company		Product Cost	% Renewable	Rapidly renewable content information source
Miscellaneous finish carpentry	Milling Company	$	21,380	100%	Letter
Wheatboard panels	Wheatboard Company	$	93,090	100%	Product literature
Linoleum	Linoleum Company	$	18,500	100%	Cut sheet
Bamboo flooring	Flooring Company	$	70,345	100%	Cut sheet
	Product Cost Subtotal	$	203,315		
			Total value of rapidly renewable products	**$**	**203,315**
	Rapidly renewable building materials as a percentage of total materials cost				**7.06%**

Resources

Web Sites

Environmental Building News

www.buildinggreen.com/products/bamboo.html, (802) 257-7300

An article in *Environmental Building News* on bamboo flooring, including a listing of bamboo flooring suppliers.

Environmental Design + Construction

www.edcmag.com (search for *Highlights of Environmental Flooring*)

An *Environmental Design & Construction* article providing information on bamboo flooring, linoleum and wool carpeting.

GreenSpec

www.greenspec.com, (802) 257-7300

Detailed listings for more than 1,500 green building products, including environmental data, manufacturer information, and links to additional resources.

Guide to Resource-Efficient Building Elements

www.crbt.org, (406) 549-7678

The Center for Resourceful Building Technology's directory of environmentally responsible building products. This resource provides introductory discussions per topic and contact information for specific products.

Oikos

oikos.com

A searchable directory of resource-efficient building products and sustainable design educational resources.

Case Study

The Solar Living Center
Hopland, California

Courtesy of Real Goods Trading Corporation

Owner
Real Goods Trading Corporation

The Solar Living Center is a retail facility, learning center and demonstration building for the Real Goods Trading Center. The materials selection process emphasized those materials that were high in recycled content and low in embodied energy. Two rapidly renewable materials were chosen based on these criteria: straw-bale walls and pressed strawboard. The north and west walls of the building were constructed with straw-bales, a local agricultural waste product that is routinely burned. The exterior and interior wall surfaces are covered with a cement and soil combination to protect the straw from moisture and to provide structural rigidity. The straw-bale walls have thermal insulating benefits as well as excellent sound insulation characteristics. In addition, pressed strawboard panels were installed between structural elements to serve as a sound absorber, insulator and radiant barrier.

Certified Wood

SS | WE | EA | MR | EQ | ID
Credit 7

1 point

Intent

Encourage environmentally responsible forest management.

Requirements

Use a minimum of 50% of wood-based materials and products, certified in accordance with the Forest Stewardship Council's Principles and Criteria, for wood building components including, but not limited to, structural framing and general dimensional framing, flooring, finishes, furnishings, and non-rented temporary construction applications such as bracing, concrete form work and pedestrian barriers.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, owner or responsible party, declaring that the credit requirements have been met and listing the FSC-certified materials and products used. Include calculations demonstrating that the project incorporates the required percentage of FSC-certified materials/products and their cost together with the total cost of all materials for the project. For each material/product used to meet these requirements, provide the vendor's or manufacturer's Forest Stewardship Council chain-of-custody certificate number.

Summary of Referenced Standard

Forest Stewardship Council's Principles and Criteria

www.fscus.org, (877) 372-5646

Certification is a "seal of approval" awarded to forest managers who adopt environmentally and socially responsible forest management practices, and to companies that manufacture and sell products made from certified wood. This seal enables consumers, including architects and specifiers, to identify and procure wood products from well-managed sources and thereby use their purchasing power to influence and reward improved forest management activities around the world.

LEED accepts certification according to the comprehensive system established by the internationally recognized Forest Stewardship Council (FSC). FSC was created in 1993 to establish international forest management standards (known as the FSC Principles and Criteria) to assure that forestry practices are environmentally responsible, socially beneficial and economically viable. These Principles and Criteria have been established to ensure the long-term health and productivity of forests for timber production, wildlife habitat, clean air and water supplies, climate stabilization, spiritual renewal, and social benefit, such as lasting community employment derived from stable forestry operations. These global Principles and Criteria are translated into meaningful standards at a local level through region-specific standards setting processes.

FSC also accredits and monitors certification organizations. These "certifiers" are independent, third-party auditors that are qualified to annually evaluate compliance with FSC standards on the ground and to award certifications. There are two types of certification.

- **Forest Management Certification** is awarded to responsible forest managers after their operations successfully complete audits of forestry practices and plans.
- **Chain of Custody Certification** is awarded after companies that process, manufacture and/or sell products made of certified wood successfully complete audits to ensure proper use of the FSC name and logo, segregation of certified and non-certified materials in manufacturing and distribution systems, and observation of other relevant FSC rules (e.g., meeting minimum requirements for FSC fiber content in assembled and composite wood products).

The majority of FSC certification audits performed in North America are conducted by SmartWood and Scientific Certification Systems (SCS), which are based in the United States. A more limited number are performed by SGS, which is based in Europe.

SS	WE	EA	MR	EQ	ID
Credit 7					

Credit Synergies

MR Credit 5
Local/Regional Materials

MR Credit 6
Rapidly Renewable Materials

EQ Credit 4
Low-Emitting Materials

Green Building Concerns

Wood has the potential to be a truly sustainable resource because it is renewable, biodegradable, non-toxic, energy efficient and recyclable. Too often, however, wood is linked to the degradation or destruction of ecologically important forest ecosystems, such as old-growth forests. Thus, responsible forestry practices aim to minimize or eliminate these problems. Responsible forestry meets the long-term forest product needs of humans while maintaining the function and biodiversity of forested landscapes. The primary goal is to restore, enhance and sustain a full range of forest values while producing a perpetual yield of quality forest products.

Environmental Issues

The negative environmental impacts of irresponsible forest practices can include destruction of forests, loss of wildlife habitat, soil erosion and stream sedimentation, water and air pollution, and waste generation. The FSC standard incorporates many criteria that contribute to the long-term health and integrity of forest ecosystems. From an environmental perspective, the elements of responsible FSC-certified forestry include sustainable timber harvesting (i.e., not removing more timber volume than replaces itself over the cutting interval or rotation), preserving wildlife habitat and biodiversity, maintaining soil and water quality, minimizing the use of harmful chemicals, and conserving high conservation value forests (e.g., endangered and old-growth forests).

Economic Issues

World trade in forest products has increased dramatically in the last 30 years, from $47 billion in 1970 to $139 billion in 1998. As more developing countries embrace world forest product markets and their growing economies encourage domestic consumption, the protection of forests will become a critical issue.

Currently, the costs of FSC-certified wood products are equal to or higher than conventional wood products, and availability varies by region. The price of FSC-certified wood products is expected to be more competitive with conventional wood products in future years as the world's forest resources are depleted and the forest industry embraces more widespread adoption of sustainable business principles.

Community Issues

Irresponsible logging practices can have negative social impacts. Thus, the socioeconomic and political components to FSC certification include respecting indigenous people's rights, adhering to all applicable laws and treaties, and involving forest workers and forest-dependent communities as stakeholders in, and beneficiaries of, responsible forest management. Through the encouragement of responsible forest practices, local timber economies are stabilized and forestland is preserved for future generations.

Design Approach

Strategies

Establish a project goal in which at least 50% of the dollar value of wood-based materials shall be FSC certified. Identify all major areas of wood usage in your project to determine the types of products needed (e.g., wooden doors and windows, interior millwork and casework, framing lumber, trim and structural panels, form ply and bracing, etc.).

Using the contacts and materials listed in the Resources section below, research the availability of the wood species and products that you wish to use to ensure that they are available from FSC-certified sources.

Research and specify quality grades that are most readily available from well-managed forests. Using lower grades of wood can dramatically reduce pressure on forests, which produce only limited quantities of top-grade timber (e.g., Architectural Woodwork Institute [AWI] Grades 2 or 3 for lumber or veneer rather than Grade 1, Select & Better rather than First And Second [FAS] for hardwood lumber graded to National Hardwood Lumber Association [NHLA] rules, or 2 and Better rather than Select Structural for softwood lumber graded to Western Wood Product Association [WWPA] rules). As an example, the typical yield of FAS-grade lumber in a deciduous forest is 5% - 20% of all hardwood lumber cut depending on many variables, i.e. thickness, length, etc. In structural applications, specify the lowest grade that will meet the project's performance and engineering requirements. In interior finishes and other exposed surfaces, consider specifying "character" grades that highlight the uniqueness of wood as a natural material.

At the earliest possible opportunity, make contact with, and develop for your bidders, a list of local vendors, suppliers and manufacturers that are certified for FSC chain-of-custody. Also, encourage project bidders to contact certified vendors as early as possible to establish product availability and pricing. As the availability of certain certified wood products may vary over the life of a project, consider having the owner pre-purchase, store and supply particular items to the contractor ("Furnished by the Owner, Installed by the Contractor," or FOIC).

Specify in contract documents that wood products shall come from forests that are certified as well-managed according to the rules of the FSC. Wherever possible, employ a line-item strategy based on current availability of specific products rather than a blanket approach. As evidence of compliance with your specification and to document your use of certified wood for LEED, require that project contractors and subcontractors submit vendor (supplier) invoices containing vendor's chain-of-custody certification numbers and identifying each certified product on a line-item basis.

Synergies and Trade-Offs

Some FSC-certified wood products may not be locally available. Certified wood products can be applied to MR Credits 5 and 6 if these products comply with requirements for those credits. Like their non-certified counterparts, some FSC-certified products contain adhesives and chemicals that have off-gassing characteristics that may affect indoor air quality, and may conflict with eligibility for IEQ Credit 4.4 (urea formaldehyde)

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. To calculate the percentage of certified wood products used on a project, use the spreadsheet in the LEED Letter Template listing all materials used on the project and their associated costs. First, identify all wood-based materials and product costs on the project, not including installation expenses (e.g., labor and equipment). Exclude salvaged and refurbished materials as well as the value of the post-consumer recycled wood fiber portion of any product. These exclusions ensure that applicants seeking the certified wood credit are not penalized for using non-virgin wood.

For assemblies, calculate cost percentage of the FSC-certified wood versus the to-

Equation 1:

$$\text{Certified Wood Material Portion } [\%] = \frac{\text{FSC Certified Wood Products Cost [\$]}}{\text{Total New Wood Based Products Cost [\$]}}$$

tal material cost for the product, then multiply that percentage by the total product price to get the cost value of the certified wood portion (to evenly distribute labor and other production costs). If the product itself has been FSC-certified, then the entire cost of the product is to be used.

The Letter Template calculates the total materials value of the wood-based products. Next, identify percentages (by weight, as detailed in MR Credit 4) of those wood-based products that are FSC-certified. All FSC-certified wood material costs are summed and then divided by the total value of wood-based products to obtain the certified wood products percentage (see **Equation 1**).

The example in **Table 1** presents certified wood calculations for a sample project. The total materials cost figure may be derived from a default calculation (45% of total construction cost) or a tally of actual material costs. The sample project has chosen the former. Material costs exclude installation costs (e.g., labor and equipment). This example qualifies for one point under this credit because more than 50% of new wood-based products are FSC-certified.

Keep copies of vendor invoices for each product used to meet these requirements in case of a LEED certification audit. Per Forest Stewardship Council rules, each invoice should include the vendor's chain-of-custody certificate number and should also identify certified products on an item-by-item basis. A "vendor" is defined as a company that furnishes wood products to project contractors or subcontractors for on-site installation. For example, a company that manufactures but does not install interior casework would be considered a vendor for the purposes of this definition, but an architectural woodworker that fabricates and installs interior case-

Table 1: Letter Template Spreadsheet Example for Certified Wood

Provide total construction cost	$	19,881,455
for 45% default total materials cost; OR	$	8,946,655
Provide total materials cost (exclude labor, equipment)		
Total cost of all wood-based products	$	709,026
Cost of Wood-based products as percentage of all materials		7.93%

Wood product	Vendor		Product Cost	Certified Wood %	Forest Stewardship Council chain-of-custody certificate number
Rough carpentry	Supply Company	$	85,629	46%	SW-COC-013
Millwork, casework	Supply Company	$	160,423	77%	SCS-COC-00067
Miscellaneous	various	$	31,557	0%	n/a
Roof Structure	Supply Company	$	175,309	89%	SCS-COC-00094
Doors, frames	Supply Company	$	141,100	70%	SW-COC-675
Finish carpentry – elevator interior	Supply Company	$	5,469	55%	SCS-COC-00067
Furniture	Office Furniture Company	$	73,775	71%	SCS-COC-00122
Workstations	Office Furniture Company	$	35,764	61%	SCS-COC-00122
	Product Cost Subtotal	**$**	709,026		

Total value of FSC-certified wood products	**$**	**494,914**
Value of FSC-certified wood products as a percentage of the value of all wood-based building materials		**69.80%**

work on a custom, project-by-project basis would not. In the case of the woodworker, the vendor would be the company that supplies his or her raw materials, such as veneer, plywood and lumber.

Resources

Web Sites

Certified Wood & Paper Association

www.cwpa.info, (503) 224-2205

A nonprofit business association that promotes environmentally and socially responsible forest products, it provides a free service to help architects who seek to specify FSC-certified wood, research product availability and identify potential vendors.

Forest Certification Resource Center

www.certifiedwood.org, (503) 224-2205

Contains a searchable database of FSC products and a variety of resources, including comparative information on forest certification systems.

Forest Stewardship Council

www.fscus.org, (877) 372-5646

The FSC promotes responsible forest management globally by certifying forest products that meet the rigorous forest management standard. The organization brings industry, environmentalists, and community groups together to promote practical solutions that meet its diverse stakeholders' needs. The organization was founded in 1993 by environmental groups, the timber industry, foresters, indigenous peoples and community groups from 25 countries.

GreenSpec

www.greenspec.com, (802) 257-7300

Detailed listings for more than 1,500 green building products, including environmental data, manufacturer information and links to additional resources.

Scientific Certification Systems

www.scs1.com/forestry.shtml, (802) 434-5491

Scientific Certification System's Forest Conservation Program is a third-party certifier that is accredited to conduct forest management and chain-of-custody audits in the United States and internationally according to the rules of the FSC.

Smartwood

www.smartwood.org, (802) 434-5491

SmartWood is a third-party certifier that is accredited to conduct forest management and chain-of-custody audits in the United States and globally according to the rules of the FSC. It is a nonprofit program of the Rainforest Alliance and is based in the United States.

Print Media

Sustainable Forestry: Philosophy, Science, and Economics by Chris Maser, CRC Press, 1994.

The Business of Sustainable Forestry: Strategies for an Industry in Transition by Michael B. Jenkins and Emily T. Smith, Island Press, 1999.

Definitions

Chain-of-Custody is a document that tracks the movement of a wood product from the forest to a vendor and is used to verify compliance with FSC guidelines. A "vendor" is defined as the company that supplies wood products to project contractors or subcontractors for on-site installation.

Sustainable Forestry is the practice of managing forest resources to meet the long-term forest product needs of humans while maintaining the biodiversity of forested landscapes. The primary goal is to restore, enhance and sustain a full range of forest values—economic, social and ecological.

Case Study

Bicentennial Hall Science Building
Middlebury, Vermont

The Bicentennial Hall Science Building at Middlebury College is a campus building that houses laboratories, classrooms, offices and a library. Over 125,000 board feet of FSC-certified wood was specified and installed for interior millwork. Wood species chosen were native to Vermont and included hard and soft maple, beech, yellow birch, red oak, black cherry, poplar, basswood and ash. These species were used for paneling, base molding, wainscoting, picture rails, chair rails and balcony railings. The cost of FSC-certified wood products on the project was estimated to be 3% greater than conventional wood products.

Courtesy of Middlebury College

Owner
Middlebury College

Indoor Environmental Quality

Americans spend an average of 90% of their time indoors, where levels of pollutants may be two to five times–and occasionally more than 100 times–higher than outdoor levels, according to the U.S. Environmental Protection Agency. In its *1999 Air Quality Guidelines*, the World Health Organization states that most of a person's daily exposure to many air pollutants comes through inhalation of indoor air. Many of these pollutants can cause health reactions in the estimated 17 million Americans who suffer from asthma and 40 million who have allergies, thus contributing to millions of days absent from school and work. The Asthma and Allergy Foundation estimates that asthma cost the U.S. economy $10.7 billion in 1994 alone.

Research over the past decade has increased our understanding of the indoor environment, revealing both problems and potential solutions. Major health disasters such as outbreaks of Legionnaires' disease and sick building syndrome have heightened the awareness of indoor air quality for building owners and occupants. An increasing number of legal cases emphasize the need for optimal indoor environmental quality (IEQ) strategies. Such strategies reduce potential liability for design team members (including building owners), increase the resale value of the building, and increase productivity of building occupants. In fact, case studies suggest that IEQ improvements can increase worker productivity by as much as 16%, resulting in rapid payback for IEQ capital investments (source: *Greening the Building and the Bottom Line*, Rocky Mountain Institute, 1994).

IEQ strategies include issues related to indoor air quality (IAQ) such as increased ratios of filtered outside air, ventilation effectiveness, moisture management, and control of contaminants. Prevention of air quality problems is generally much less expensive than cleaning up after these problems occur. For example, it is inexpensive and sensible to sequence construction activities so that materials are kept dry and those that absorb contaminants are installed after other materials have had the opportunity to off-gas contaminants. Specifying materials that release fewer and less harmful contaminants is even better. Another strategy is to protect air handling systems during construction and perform a building flush-out prior to occupancy. To provide optimal air quality for building occupants over the lifetime of the building, automatic sensors and controls can be integrated with the HVAC system to adjust temperature, humidity, and the percentage of outside air introduced to occupied spaces. Sensors can alert building maintenance staff to potential IAQ problems such as carbon dioxide (CO_2) build-up in occupied space.

Other IEQ issues to consider include daylighting and lighting quality, thermal comfort, acoustics, occupant control of building systems, and access to views. All of these issues have the potential to enhance the indoor environment and optimize interior spaces for building occupants.

Overview of LEED™ Prerequisites and Credits

EQ Prerequisite 1
Minimum IAQ Performance

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 3
Construction IAQ Management Plan

EQ Credit 4
Low-Emitting Materials

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

EQ Credit 7
Thermal Comfort

EQ Credit 8
Daylight & Views

There are 15 points available in the Indoor Environmental Quality category.

Minimum IAQ Performance

SS WE EA MR EQ ID

Prerequisite 1

Required

Intent

Establish minimum indoor air quality (IAQ) performance to prevent the development of indoor air quality problems in buildings, thus contributing to the comfort and well-being of the occupants.

Requirements

Meet the minimum requirements of voluntary consensus standard ASHRAE 62-1999, Ventilation for Acceptable Indoor Air Quality, and approved Addenda (see ASHRAE 62-2001, Appendix H, for a complete compilation of Addenda) using the Ventilation Rate Procedure.

Submittals

- ❑ Provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring that the project is fully compliant with ASHRAE 62-1999 and all published Addenda and describing the procedure employed in the IAQ analysis (Ventilation Rate Procedure).

Summary of Referenced Standard

ASHRAE Standard 62-1999: Ventilation For Acceptable Indoor Air Quality

ASHRAE, www.ashrae.org, (800) 527-4723

This standard specifies minimum ventilation rates and indoor air quality (IAQ) levels to reduce the potential for adverse health effects. The standard specifies that mechanical or natural ventilation systems be designed to prevent uptake of contaminants, minimize the opportunity for growth and dissemination of microorganisms, and filter particulates, if necessary. Makeup air inlets should be located away from contaminant sources such as cooling towers; sanitary vents; and vehicular exhaust from parking garages, loading docks, and street traffic.

A Ventilation Rate Procedure and an Indoor Air Quality Procedure are outlined to achieve compliance with the standard. The Ventilation Rate Procedure prescribes outdoor air quality acceptable for ventilation; outdoor air treatment measures; and ventilation rates for residential, commercial, institutional, vehicular, and industrial spaces. The procedure also includes criteria for the reduction of outdoor air quantities when recirculated air is treated by contaminant-removal equipment and criteria for variable ventilation when the air volume in the space is used as a reservoir to dilute contaminants. The Indoor Air Quality Procedure incorporates both quantitative and subjective evaluation and restricts contaminant concentrations to acceptable levels.

Credit Synergies

SS Credit 1
Site Selection

SS Credit 2
Urban Redevelopment

SS Credit 3
Brownfield Redevelopment

SS Credit 4
Alternative Transportation

WE Credit 1
Water Efficient Landscaping

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Prerequisite 1
Storage & Collection of Recyclables

MR Credit 1
Building Reuse

(continued)

Green Building Concerns

Optimal IAQ performance in buildings results in improved occupant comfort, well-being, and productivity. Key components for maintaining superior indoor air quality include using high-quality outdoor air and providing adequate ventilation rates. The referenced standard describes procedures for avoiding the introduction of contaminants such as location of air intakes relative to potential sources of contamination. The referenced standard also outlines general ventilation rates for a variety of building types.

Environmental Issues

Higher ventilation rates are sometimes necessary to optimize IAQ, and this can result in higher energy use to operate the building HVAC system. However, the additional energy cost can be offset by improved occupant productivity and lower absentee rates.

Economic Issues

Increased ventilation rates may result in greater annual energy costs. However, poor indoor air quality can cause occupant illnesses, resulting in increased expenses and liability costs for building owners, operators, and insurance companies. Personnel costs are a significant percentage of operating costs, much greater than energy or maintenance costs, and, thus, actions that affect employee attendance and productivity are significant. A 1991 statistical abstract by the Building Owners and Managers Association estimated employee salaries at $130 per square foot while energy costs were less than $2 per square foot.

ASHRAE Standard 62-1999 has become standard ventilation design practice and may not require additional design effort or cost. Good IAQ reduces potential liability for architects, builders, owners, building operators, and occupants, as well as increases the value and marketability of a building. Additional effort may be required to optimize the integration of the HVAC system with the layout of the structure and surrounding area.

Community Issues

IAQ optimization strategies can lead to a healthier environment for occupants, which typically results in fewer complaints, lower absenteeism and illness, and higher productivity. Improved occupant health results in decreased health care and insurance costs.

Design Approach

Strategies

Evaluate the project site prior to acquisition to avoid choosing a site with potential IAQ problems. These potential problems might include heavy traffic areas, nearby polluting industrial sites, or neighboring waste management sites. In addition, identify possible future uses of nearby sites that may impact outdoor air quality. Obtain ambient air quality data and local wind patterns from the U.S. EPA or local sources to identify sources of pollution most likely to affect the site.

After the building site has been chosen, identify site activities that may have a negative impact on air quality such as construction activities, materials installed in the building, and chemical handling activities during occupancy. Establish air quality standards early in the design process, and clearly state these design criteria in plans and specifications.

Specify, design, and install fresh air intakes away from possible sources of contamination (at least 25 feet is recommended and 40 feet is preferable). Possible sources of contamination include loading areas, building exhaust fans, cooling towers, street traffic, idling cars, standing water, parking garages, sanitary vents, dumpsters, and outside smoking areas.

Locating fresh air intakes appropriately requires coordination between HVAC designers and the project architect.

Ensure that the outside air capacity for the ventilation system can meet the requirements of the referenced standard in all modes of operation. Remember to consider the maximum potential occupancy load when calculating outside air needs in all spaces. Assess changes in occupant loads for renovation or retrofit projects and, where possible, plan for these future requirements. Avoid over-design and under-design of the ventilation system and anticipate future retrofits.

Upon project completion, include operational testing in the building commissioning report. Implement an operations and maintenance plan to maintain an uncontaminated HVAC system.

Synergies and Trade-Offs

Site location and landscape design affect the outdoor air volumes that can be circulated through the building. Dense neighborhoods, adjacent transportation facilities, and existing site contamination can adversely affect the quality of outside air available for ventilation purposes. Increased ventilation rates can solve some indoor air quality problems by diluting contaminant levels, but this strategy may affect indoor thermal comfort and may increase energy use. Building commissioning and measurement & verification processes are tools that can be used to optimize indoor air quality levels while minimizing energy efficiency losses.

During construction and building fit-out, protect building materials from moisture and specify materials and furnishings that do not release harmful or irritating chemicals, such as volatile organic compounds (VOCs) from paints and solvents, to reduce the detrimental effects these substances have on IAQ. Occupant activities such as chemical handling and smoking can reduce the amount of clean air in a space. More often, it is beneficial to reduce IAQ problems at the source, such as specifying low-VOC materials, than to use energy to ventilate the building and to condition a greater volume of air.

Resources

Web Sites

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

www.ashrae.org, (404) 636-8400

Advances the science of heating, ventilation, air conditioning, and refrigeration for the public's benefit through research, standards writing, continuing education, and publications.

Indoor Air Quality Links

outreach.missouri.edu/edninfo/airquality.htm

Web links that address health and building systems issues.

U.S. Environmental Protection Agency's Indoor Air Quality Web Site

www.epa.gov/iaq, (800) 438-4318

Includes a wide variety of tools, publications, and links to address IAQ concerns in schools and large buildings. The downloadable *IAQ Building Education and Assessment Model (I-BEAM)* software program provides comprehensive IAQ management guidance and calculates the cost, revenue, and productivity impacts of planned IAQ activities. Publications include the *Energy Cost and IAQ Performance of Ventilation Systems and Controls Modeling Study*; the *Building Assessment, Survey and Evaluation Study*; and the *Building Air Quality Action Plan.*

Credit Synergies

(continued)

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 3
Construction IAQ Management Plan

EQ Credit 4
Low-Emitting Materials

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 7
Thermal Comfort

Print Media

Air Contaminants and Industrial Hygiene Ventilation: A Handbook of Practical Calculations, Problems, and Solutions by Roger Wabeke, CRC Press & Lewis Publishers, 1998.

Handbook of Indoor Air Quality Management by Donald Moffatt, Prentice Hall, 1997.

Improving Indoor Air Quality Through Design, Operation and Maintenance by Marvin Meckler, Prentice Hall, 1996.

Indoor Air Quality, Construction Technology Centre Atlantic. Written as a comprehensive review of indoor air quality issues and solutions, the report is available for purchase from http://ctca.unb.ca/IAQ/index.htm or (506) 453-5000.

Indoor Pollution: A Reference Handbook (Contemporary World Issues) by E. Willard Miller, et al., ABC-CLIO, 1998.

Definitions

Indoor Air Quality is the nature of air that affects the health and well-being of building occupants.

Sick Building Syndrome is a situation in which a substantial proportion of building occupants experience acute discomfort and negative health effects as a result of exposure to contaminated air in the building.

Ventilation is the process of supplying and removing air to and from interior spaces by natural or mechanical means.

SS	WE	EA	MR	EQ	ID
Prerequisite 2					

Required

Environmental Tobacco Smoke (ETS) Control

Intent

Prevent exposure of building occupants and systems to Environmental Tobacco Smoke (ETS).

Requirements

Zero exposure of non-smokers to ETS by EITHER:

- prohibiting smoking in the building and locating any exterior designated smoking areas away from entries and operable windows;

OR

- providing a designated smoking room designed to effectively contain, capture and remove ETS from the building. At a minimum, the smoking room must be directly exhausted to the outdoors with no recirculation of ETS-containing air to the non-smoking area of the building, enclosed with impermeable deck-to-deck partitions and operated at a negative pressure compared with the surrounding spaces of at least 7 PA (0.03 inches of water gauge).
- Performance of the smoking rooms shall be verified by using tracer gas testing methods as described in the ASHRAE Standard 129-1997. Acceptable exposure in non-smoking areas is defined as less than 1% of the tracer gas concentration in the smoking room detectable in the adjoining non-smoking areas. Smoking room testing as described in ASHRAE Standard 129-1997 is required in the contract documents and critical smoking facility systems testing results must be included in the building commissioning plan and report or as a separate document.

Submittals

- ❑ Provide the LEED Letter Template, signed by the building owner or responsible party, declaring that the building will be operated under a policy prohibiting smoking.

OR

- ❑ Provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring and demonstrating that designated smoking rooms are exhausted to the outdoors with no recirculation of ETS-containing air to the non-smoking area of the building, enclosed with impermeable deck-to-deck partitions, operated at a negative pressure compared with the surrounding spaces of at least 7 PA (0.03 inches of water gauge), and performance has been verified using the method described in the credit requirements.

SS | WE | EA | MR | EQ | ID

Prerequisite 2

Summary of Referenced Standard

ASHRAE 129-1997: Measuring Air-Change Effectiveness

ASHRAE,www.ashrae.org, (800) 527-4723

This standard provides a method for measuring air-change effectiveness in mechanically ventilated buildings and spaces. Air-change effectiveness (E) is determined by the pattern of natural airflow within the building's ventilated air spaces along with the effect of mechanical recirculation by ventilation systems. The measurement of air-change effectiveness involves a tracer gas procedure that determines the age of air in building spaces.

SS	WE	EA	MR	EQ	ID

Prerequisite 2

Green Building Concerns

The relationship between smoking and various health risks, including lung disease, cancer, and heart disease, has been well documented. A strong link between Environmental Tobacco Smoke (ETS) or "secondhand smoke" and health risks has also been demonstrated. The most effective way to avoid health problems associated with tobacco smoke is to prohibit smoking in indoor areas. If this is not possible or desirable, indoor smoking areas should be isolated from non-smoking areas and have separate ventilation systems to avoid the introduction of tobacco smoke contaminants to non-smoking areas.

Environmental Issues

Separate smoking areas occupy space in the building and may result in a larger building, additional material use, and increased energy for ventilation. However, these environmental impacts can be offset by building occupants who are more comfortable, have higher productivity rates, and have lower absenteeism and illnesses.

Economics Issues

Separate smoking areas may result in first costs for increased building space and more extensive mechanical ventilation systems. Smoking within a building contaminates indoor air and can instigate occupant reactions ranging from irritation and illness to decreased productivity. These problems increase expenses and liability for building owners, operators, and insurance companies. A nonsmoking policy avoids these problems and eliminates the need for a separate ventilation system for isolated smoking areas. Prohibition of indoor smoking can also increase the useful life of interior fixtures and furnishings.

Community Issues

Air is a community natural resource, and promoting clean air benefits everyone. Strict no- smoking policies improve the health of the community as a whole, resulting in lower health care and insurance costs.

Design Approach

Strategies

Prohibit smoking in the building. Provide designated smoking areas outside the building in locations where ETS will not enter the building or ventilation system and away from concentrations of building occupants or pedestrian traffic. Post information on the nonsmoking policy for occupants to read.

If interior smoking areas are designed for the building, a separate ventilation system must be installed, and these areas must be tested to ensure that they are isolated from nonsmoking portions of the building. ASHRAE Standard 62-1999 designates outdoor air requirements for smoking rooms. Smoking areas are typically operated at higher ventilation rates than nonsmoking rates to remove contaminants from the conditioned space. In general, buildings that allow smoking require twice the ventilation volumes of nonsmoking buildings. See the standard for more information on designing ventilation for smoking areas.

Synergies and Trade-Offs

The use of separate ventilation systems to physically separate smoking areas from the rest of the building requires additional energy and requires commissioning and measurement & verification attention. Smoking activities, both indoor and outdoor, affect IAQ performance of the building. Smoke can enter the building areas through operable windows and intake vents or through the ventilation system for indoor smokers. It may be advantageous to address smoking loads in the building in conjunction with chemical and pollutant sources in the building.

Credit Synergies

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

Resources

Web Sites

Secondhand Smoke: What You Can Do About Secondhand Smoke as Parents, Decision Makers, and Building Occupants

www.epa.gov/iaq/pubs/etsbro.html, (800) 438-4318

An EPA document on the effects of ETS and measures to reduce human exposure to it.

Setting the Record Straight: Secondhand Smoke Is a Preventable Health Risk

www.epa.gov/iaq/pubs/strsfs.html

An EPA document with a discussion of laboratory research on ETS and federal legislation aimed at curbing ETS problems.

Print Media

The Chemistry of Environmental Tobacco Smoke: Composition and Measurement, Second Edition by R.A. Jenkins, B.A. Tomkins, et al., CRC Press & Lewis Publishers, 2000.

The Smoke-Free Guide: How to Eliminate Tobacco Smoke from Your Environment by Arlene Galloway, Gordon Soules Book Publishers, 1988.

Definitions

The **Age of Air** is the average amount of time that has elapsed since a sample of air molecules at a specific location has entered the building.

Air-Change Effectiveness is a measurement based on a comparison of the age of air in the occupied portions of the building to the age of air that would exist under conditions of perfect mixing of the ventilation air.

Environmental Tobacco Smoke (ETS), or secondhand smoke, consists of airborne particles emitted from the burning end of cigarettes, pipes, and cigars, and exhaled by smokers. These particles contain about 4,000 different compounds, up to 40 of which are known to cause cancer.

Carbon Dioxide (CO_2) Monitoring

1 point

Intent

Provide capacity for indoor air quality (IAQ) monitoring to help sustain long-term occupant comfort and well-being.

Requirements

Install a permanent carbon dioxide (CO_2) monitoring system that provides feedback on space ventilation performance in a form that affords operational adjustments. Refer to the CO_2 differential for all types of occupancy in accordance with ASHRAE 62-2001, Appendix C.

Submittals

- ❑ Provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring and summarizing the installation, operational design and controls/zones for the carbon dioxide monitoring system. For mixed-use buildings, calculate CO_2 levels for each separate activity level and use.

Summary of Referenced Standard

There is no standard referenced for this credit.

Credit Synergies

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

EQ Credit 7
Thermal Comfort

Green Building Concerns

Buildings are supplied with outdoor air to flush airborne contaminants and to replenish fresh air on a regular basis. Ventilation rates are conventionally determined using ventilation standards for a particular building design. A better method for determining and maintaining adequate outdoor air ventilation rates in buildings is to measure carbon dioxide (CO_2) concentrations. High CO_2 levels are generally an indication of poor indoor air quality (IAQ). Maintaining low CO_2 concentrations similar to those found outdoors is one strategy by which indoor air quality can be optimized.

Environmental Issues

Optimal IAQ may require higher ventilation rates, increasing energy use in the building. However, these environmental impacts can be offset by a more productive work space that reduces absenteeism and illness for building occupants.

Economic Issues

A permanent air monitoring system enables building owners, maintenance personnel, and occupants to detect air quality problems quickly so that corrective actions can be applied. Potential impacts of air quality problems range from reduced work productivity to temporary or permanent health issues for building occupants. CO_2 monitoring systems increase initial construction costs due to equipment and installation costs. Initial costs typically range from $1,000 to $1,500 per sampling point (depending on the quality of the equipment and number of sampling points), while annual costs for equipment maintenance and calibration procedures are usually less than $2,000 overall. The initial monitoring system cost is offset by reduced absenteeism and increased occupant productivity. Often, the lifetime of the HVAC system is extended and more efficient HVAC operation is achieved as a result of effective air quality monitoring.

Community Issues

A permanent air monitoring system ensures that the means to maintain high-quality indoor air is provided, with the potential to protect the well-being of the building occupants and enhance productivity. Increased occupant health results in decreased health insurance costs and health care costs.

Design Approach

Strategies

Development of an appropriate and effective carbon dioxide sampling methodology is largely dependant upon the type of ventilation system being used. This section seeks to provide guidance on development of an effective sampling methodology.

Carbon dioxide sampling locations must be selected so that they provide representative readings of the CO_2 concentrations in the occupied spaces served by each HVAC system used in a building. Carbon dioxide monitoring locations should be selected such that they are positioned in locations that present the greatest challenges for the HVAC system to adequately ventilate. These spaces include those with variable occupant densities (e.g., conference rooms, auditoriums, training rooms, etc.) and those locations within the space served by the longest lengths of ductwork.

Automatic ventilation control should be provided for all HVAC systems serving a large number of spaces or spaces with variable occupant densities. Manual ventilation control may be used for spaces with static occupant densities, but the most responsive comfort control is provided by an automated system. Spaces with static occupant densities must each be controlled or they can be combined into small groups if the combined floor area of the group is reasonably small. The optimum location for sampling in a room is six to ten feet from the nearest person. Sampling locations should be positioned to avoid low CO_2 concentration air entering the space through open windows and supply air vents.

For HVAC systems that serve multiple spaces with a small combined floor area, the indoor CO_2 sampling point may be located in the return air duct at the junction point where the return air is combined from all of the multiple spaces served, provided this point is far enough away from the location where return air is exhausted or outside air is introduced into the HVAC system. Siting the sampling point in this location will mitigate the risk of diluting the return air. The duct joints should be effectively sealed. Occupant use and schedule changes should be considered when establishing and reassessing ventilation setpoints.

Indoor CO_2 concentrations must be compared to outdoor CO_2 concentrations to determine the differential point at which ventilation rates should be adjusted. The differential CO_2 level that activates ventilation within each space must be based on occupant activity level and the corresponding metabolic rate (MET) defined in ASHRAE Standard 55-1992, Table 4. MET is the rate of energy production of an individual, which varies depending on activity level. For offices where occupants are sedentary, the CO_2 differential level is approximately 530 parts per million (ppm). The maximum CO_2 differential in ppm is equal to: (8,600 cfm of CO_2 per MET) x (MET level)/cfm of outside air per occupant, as adapted from ASHRAE 62-2001 Appendix C.

CO_2 ventilation control systems must be calibrated and tested by the contractor and proper operation must be verified as part of the building commissioning process.

Technologies

Current systems include shared-sensor vacuum-draw systems and distributed sensors. Distributed sensors are either hard-wired or plugged into power circuitry and use carrier wave communication. Once the system is properly calibrated, it is used to assess the adequacy of airflows throughout the building interior. Specify annual calibration activities for sensors per manufacturer instructions in the HVAC system operation manual. Include sensor and system operational testing and initial set point adjustment in the commissioning plan and report.

Synergies and Trade-Offs

CO_2 monitoring requires additional equipment to be installed and requires additional commissioning and measurement & verification (M&V) attention. Building reuse may prohibit optimization of ventilation rates due to inflexible HVAC equipment or inadequate outside air intakes.

Monitoring CO_2 levels has significant impacts on all indoor environmental quality issues, including overall IAQ performance, ventilation rates, chemical and pollutant control, and thermal comfort. Proper ventilation rates are integral to successful energy efficiency and air quality programs. CO_2 monitoring can be used either actively or passively to alter ventilation rates as appropriate.

Resources

Web Sites

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

www.ashrae.org, (404) 636-8400

Advances the science of heating, ventilation, air conditioning, and refrigeration for the public's benefit through research, standards writing, continuing education, and publications.

Building Air Quality: A Guide for Building Owners and Facility Managers

www.epa.gov/iaq/largebldgs, (800) 438-4318

An EPA publication on IAQ sources in buildings and methods to prevent and resolve IAQ problems.

Print Media

Air Handling Systems Design by Tseng-Yao Sun, McGraw Hill, 1992.

ASHRAE Standard 55-1992 (and Approved Addenda of 1995): Thermal Environmental Conditions for Human Occupancy, ASHRAE, 1992.

ASHRAE Standard 62-1999: Ventilation for Acceptable Indoor Air Quality, ASHRAE, 1999.

ASTM D 6245-1998: Standard Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation, ASTM, 1998.

Efficient Building Design Series, Volume 2: Heating, Ventilating, and Air Conditioning by J. Trost and Frederick Trost, Prentice Hall, 1998.

Definitions

Carbon Dioxide (CO_2) is an indicator of ventilation effectiveness inside buildings. CO_2 concentrations greater than 540 ppm above outdoor CO_2 conditions are generally considered to be an indicator of inadequate ventilation. Absolute concentrations of CO_2 greater than 800-1,000 ppm are generally considered to be an indicator of poor breathing air quality.

Return Air is air removed from conditioned spaces that is either recirculated in the building or exhausted to the outside.

Supply Air is air delivered to conditioned spaces for use in ventilating, heating, cooling, humidifying, and dehumidifying those spaces.

Case Study

Brengel Technology Center
Milwaukee, Wisconsin

The Brengel Technology Center is a LEED™ Certified Pilot Project that showcases advanced building controls technologies to maximize energy efficiency and indoor environmental quality. To improve occupant comfort and productivity, the HVAC system in the building includes an integrated comfort component to measure carbon dioxide (CO_2) concentrations in occupied spaces in parts per million (ppm). The monitoring system also measures temperature, humidity, outdoor airflow, carbon monoxide (CO), and total volatile organic compounds (TVOCs). The HVAC system automatically adjusts ventilation rates based on the measured parameters to maintain optimal indoor air quality.

Courtesy of Zimmerman Design Group

Owner
Johnson Controls, Inc.

Ventilation Effectiveness

SS | WE | EA | MR | EQ | ID

Credit 2

1 point

Intent

Provide for the effective delivery and mixing of fresh air to support the safety, comfort and well-being of building occupants.

Requirements

For mechanically ventilated buildings, design ventilation systems that result in an air change effectiveness (E_{ac}) greater than or equal to 0.9 as determined by ASHRAE 129-1997. For naturally ventilated spaces demonstrate a distribution and laminar flow pattern that involves not less than 90% of the room or zone area in the direction of air flow for at least 95% of hours of occupancy.

Submittals

- ❑ For mechanically ventilated spaces: provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring that the design achieves an air change effectiveness (E_{ac}) of 0.9 or greater in each ventilated zone. Complete the table summarizing the air change effectiveness achieved for each zone.

OR

- ❑ For mechanically ventilated spaces: provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring that the design complies with the recommended design approaches in ASHRAE 2001 Fundamentals Handbook Chapter 32, Space Air Diffusion. Complete the table summarizing the air change effectiveness achieved for each zone (must be 0.9 or greater).

OR

- ❑ For naturally ventilated spaces: provide the LEED Letter Template, signed by the mechanical engineer or responsible party, declaring that the design provides effective ventilation in at least 90% of each room or zone area in the direction of airflow for at least 95% of hours of occupancy. Include a table summarizing the airflow simulation results for each zone. Include sketches indicating the airflow pattern for each zone.

Summary of Referenced Standard

ASHRAE 129-1997: Measuring Air-Change Effectiveness

ASHRAE, www.ashrae.org, (800) 527-4723

This standard provides a method for measuring air-change effectiveness in mechanically ventilated buildings and spaces. Air-change effectiveness (E) is influenced by the pattern of natural airflow within the building's ventilated spaces in addition to the effect of mechanical recirculation by ventilation systems. Measurement of air-change effectiveness involves a tracer gas procedure to determine the age of air in ventilated spaces.

Air-change effectiveness is based on a comparison of the age of air in the occupied portions of the building to the age of air that would exist under conditions of perfect mixing of the ventilation air. If the ventilation air within a space is perfectly mixed (E=1), the outdoor airflow rate to the ventilated space should be identical to the required rate of outdoor airflow. The credit requirement specifies a minimum E value of 0.9.

ASHRAE Fundamentals Handbook 2001, Chapter 32: Space Air Diffusion

ASHRAE, www.ashrae.org, (800) 527-4723

This guideline provides descriptions of air diffusion strategies and technologies, methods of evaluation, and system design considerations.

Green Building Concerns

Inadequate ventilation in buildings has a negative effect on occupant comfort and well-being, while overventilation consumes significant amounts of energy without benefiting building occupants. Designing the ventilation system to take maximum advantage of regional climate characteristics can help cut down on energy costs and increase ventilation options. Through proper system design, ventilation rates and energy efficiency can be optimized.

Environmental Issues

Increased ventilation in buildings typically requires additional energy use, which in turn causes additional air and water pollution. However, optimal indoor air quality (IAQ) is beneficial to building occupants, resulting in greater comfort, lower absenteeism, and greater productivity.

Economic Issues

Adequate ventilation in buildings may result in higher worker productivity, which in turn can translate into increased profitability for a company. However, increased ventilation requires more operation energy inputs for increased HVAC operation. Therefore, these operations should be balanced to provide maximum ventilation effectiveness while avoiding overventilation.

Natural ventilation strategies are typically much less expensive to construct and operate than mechanical ventilation strategies, but require an appropriate climate and more comprehensive design analysis.

Community Issues

Optimal ventilation rates improve IAQ, thus protecting the well-being of the building occupants. Increased occupant health may result in decreased health care and insurance costs.

Design Approach

Strategies

The minimum values for ventilation air rates in a space are determined by ASHRAE 62-1999 as part of IEQ Prerequisite 1. IEQ Credit 2 enhances the minimum indoor air quality requirements by ensuring that superior ventilation is delivered to the building occupants. In general, this credit rewards the employment of architectural and mechanical system design strategies that increase ventilation effectiveness and prevent short-circuiting of airflow delivery. Ventilation effectiveness refers to the movement of the supply air (that contains fresh outdoor air) through the occupied space.

There are two approaches to ventilating buildings: mechanical ventilation and natural ventilation. Mechanical ventilation strategies use fan energy to ventilate occupied spaces. Mechanical systems provide the most reliability and control. Natural ventilation strategies take advantage of physical properties of the building design and site such as stack effects, operable windows, and site wind patterns to ventilate occupied spaces. Natural ventilation strategies provide a connection to the outdoors and have low operation and maintenance costs. Project teams should evaluate the strengths and weaknesses of the two approaches, including building location, regional climate patterns, and enthalpic conditions, as well as client preferences in the final decision for ventilation systems.

ASHRAE 129-1997 describes a test method for quantifying the air-change effectiveness (E) for a given room design. The measured value is influenced by the shape of room, the extent of mechanical recirculation, the location of heat-generating objects, and air motion. Because these variables are highly specific to each design, a full-scale mock-up is the most effective way to verify E with a high level

Credit Synergies

SS Credit 1
Site Selection

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Prerequisite 1
Minimum IAQ Performance

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 5
Indoor Chemical & Pollutant Source Control

EQ Credit 6
Controllability of Systems

EQ Credit 7
Thermal Comfort

of confidence. See the referenced standard for more information on the prescribed testing procedure.

It is important to note that testing under ASHRAE 129-1997 is suitable mainly for laboratory-based conditions and is not appropriate in most field applications. ASHRAE states "the test method has been used successfully in laboratory test rooms to study the performance of different ventilation systems, but there is considerably less experience in the field where many factors can complicate the measurement process and increase measurement uncertainties. Therefore, the standard places strict limitations on the characteristics of the spaces that can be tested with the method. While the test method will not be usable in all field situations, it is generally applicable in laboratory test rooms."

ASHRAE also states that the data set of current test results is very small, and the test requires very close attention to the protocol described in the standard, in addition to factors that contribute to some uncertainty when evaluating test results. Therefore, the standard is generally used as a design guide for ventilation effectiveness.

Credit compliance may also be achieved by following the recommended design approaches in the ASHRAE Fundamentals Handbook 2001, Chapter 32: Space Air Diffusion.

Technologies

Conventional ventilation design (that locates supply and return air vents in the ceiling) is not preferred. Instead, consider displacement ventilation (that locates air supply vents at the bottom of the occupied space and return vents at the top of the space) and natural ventilation.

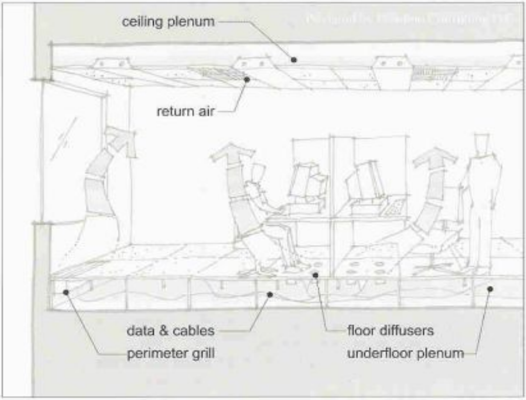
For mechanical HVAC systems, the ASHRAE Fundamentals Handbook 2001, Chapter 32, Space Air Diffusion lists the five major types of outlet types: **Group A**, mounted near the ceiling discharging horizontally; **Group B**, mounted in or near the floor discharging a vertical non-spreading jet; **Group C**, mounted in or near the floor discharging a vertical spreading jet; **Group D**, mounted in or near the floor that discharge horizontally; and **Group E**, mounted in or near the ceiling projecting vertically. Each of these types has strengths and weaknesses depending on the load conditions. See the ASHRAE handbook for details.

There are several new applications for mechanical ventilation systems in the market today that are very effective at preventing short-circuiting of airflow delivery. These applications include the use of displacement ventilation, low velocity ventilation, and plug flow ventilation such as underfloor or near-floor delivery.

Figure 1 illustrates an underfloor ventilation system. Supply air is introduced through diffusers and grills in the floor. The air travels upward through the occupied space and is exhausted in return grills in the ceiling. The underfloor plenum can also be used as a cabling conduit.

Natural ventilation strategies rely on openings in the building envelope to develop airflows. Operable windows are the most common architectural strategy employed to create natural ventilation, cross ventilation, and stack effects. Application of operable windows and other openings as elements of the ventilation system requires analysis of inlet and outlet location, size, and regional climate patterns. Operable windows combined with fan-powered mixing boxes **do not** qualify under this credit without a demonstrable architectural strategy for natural ventilation. Other factors to consider in the building ventilation design scheme include windows, doors, non-powered ventilators, and building infiltration. Computer models are helpful to predict ventilation processes and determine the best location for ventilation elements. Computational Fluid Dynamics (CFD) modeling tools

Figure 1: Example of Underfloor Ventilation System



are becoming available to designers and show great promise.

Synergies and Trade-Offs

Regional climate characteristics of the selected project site may dictate whether mechanical or natural ventilation strategies can be used. Ventilation strategies influence the overall energy performance of the building and require commissioning as well as measurement & verification (M&V). Reuse of existing buildings may preclude the use of natural ventilation strategies because the overall airflow is already determined. In some locations it may not be possible to employ natural ventilation schemes due to poor outdoor air quality, prevailing airflows, undesirable outdoor temperatures, or security concerns.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. There are two compliance paths for mechanically ventilated buildings.

The first compliance path is to field-test the completed HVAC system. Testing must be performed as described in ASHRAE 129-1997 after the building is constructed to demonstrate that air-change effectiveness of 0.9 or greater is achieved in all regularly occupied areas.

The second compliance path is through design verification. The designer must prepare a detailed narrative illustrating the design approaches that were used per the ASHRAE Fundamentals Handbook 2001, Chapter 32: Space Air Diffusion. To demonstrate the ventilation design, the mechanical engineer must describe the essential elements of the ventilation system in a narrative. If this credit is audited during the LEED certification review, provide a section and plan drawings of each major room type, showing inlets, outlets, furniture, and occupants specific to the following system types:

- Mixing Systems: the outlet types, the characteristic room lengths, the return/exhaust openings, all air velocities, and the predicted Air Diffusion Performance Index (ADPI).
- Displacement/Unidirectional Systems: the outlet types, the return and exhaust openings, all air velocities, and the predicted distribution of the upper and lower stratification zones.

Airflow patterns must be graphically illustrated to scale. Cut sheets and specification tables for all terminal vents, grills, and registers must be provided and cross-referenced to the drawings.

For naturally ventilated spaces, conduct airflow simulations for each zone and summarize the results. Provide a narrative describing system operation and sketches or graphics that indicate air flow patterns.

Resources

Web Sites

Air Change Effectiveness Measurements in Two Modern Office Buildings

www.fire.nist.gov/bfrlpubs/build94/PDF/b94024.pdf

A case study on ventilation effectiveness.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)

www.ashrae.org, (404) 636-8400

Advances the science of heating, ventilation, air conditioning, and refrigeration for the public's benefit through research, standards writing, continuing education, and publications.

Mixed Mode Ventilation: HVAC Meets Mother Nature

www.esmagazine.com (see May 2000 archive)

A May 2000 article in *Engineered Systems* about various options for building ventilation.

Print Media

ASHRAE Handbook: Fundamentals, ASHRAE, 1997.

ASHRAE Handbook: HVAC Systems and Equipment, ASHRAE, 2000.

Heating, Ventilating, and Air Conditioning: Analysis and Design, 4th Edition, by Faye McQuiston and Jerald Parker, John Wiley & Sons, 1993.

Definitions

The **Age of Air** is the average amount of time that has elapsed since a sample of air molecules at a specific location has entered the building.

Air-Change Effectiveness is a measurement based on a comparison of the age of air in the occupied portions of the building to the age of air that would exist under conditions of perfect mixing of the ventilation air.

Conditioned Space is the portion of the building that is heated or cooled, or both, for the comfort of building occupants.

Natural Ventilation is the process of supplying and removing air without mechanical ductwork in building spaces by using openings such as windows and doors, non-powered ventilators, and infiltration processes.

A **Tracer Gas** is a gas that can be mixed with building air in small amounts to study airflow patterns and measure the age of air and air-change rates.

Ventilation is the process of supplying and removing air by natural or mechanical means in building spaces.

Ventilation Effectiveness refers to the movement of the supply air (that contains fresh outdoor air) through the occupied space.

Case Study

PNC Firstside Center
Pittsburgh, Pennsylvania


Courtesy of Paladino Consulting LLC

Owner
PNC Bank

The PNC Firstside Center is a LEED™ Silver Project that functions as a banking facility. The building incorporates a hybrid local ventilation system that combines underfloor air distribution with a conventional VAV system. Air is introduced through floor diffusers at each workstation to deliver fresh air directly to building occupants. Natural air convection is used to create upward air movement in conditioned spaces and air is exhausted through ceiling vents. This ventilation strategy creates temperature stratification about six feet from the floor. The zone below the stratification is cool and provides a comfortable working environment for building occupants. The zone above the stratification acts as a reservoir for warmer air. This ventilation pattern is effective at providing optimal conditioned temperatures to building occupants, resulting in increased productivity while decreasing HVAC operating costs.

Construction IAQ Management Plan

SS WE EA MR **EQ** ID

Credit 3.1

During Construction

1 point

Intent

Prevent indoor air quality problems resulting from the construction/renovation process in order to help sustain the comfort and well-being of construction workers and building occupants.

Requirements

Develop and implement an Indoor Air Quality (IAQ) Management Plan for the construction and pre-occupancy phases of the building as follows:

- During construction meet or exceed the recommended Design Approaches of the Sheet Metal and Air Conditioning National Contractors Association (SMACNA) IAQ Guideline for Occupied Buildings under Construction, 1995, Chapter 3.
- Protect stored on-site or installed absorptive materials from moisture damage.
- If air handlers must be used during construction, filtration media with a Minimum Efficiency Reporting Value (MERV) of 8 must be used at each return air grill, as determined by ASHRAE 52.2-1999.
- Replace all filtration media immediately prior to occupancy. Filtration media shall have a Minimum Efficiency Reporting Value (MERV) of 13, as determined by ASHRAE 52.2-1999 for media installed at the end of construction.

Submittals

- ❑ Provide the LEED Letter Template, signed by the general contractor or responsible party, declaring that a Constuction IAQ Management Plan has been developed and implemented, and listing each air filter used during construction and at the end of construction. Include the MERV value, manufacturer name and model number.

AND EITHER

- ❑ Provide 18 photographs—six photographs taken on three different occasions during construction—along with identification of the SMACNA approach featured by each photograph, in order to show consistent adherence to the credit requirements

OR

- ❑ Declare the five Design Approaches of SMACNA IAQ Guideline for Occupied Buildings under Construction, 1995, Chapter 3, which were used during building construction. Include a brief description of some of the important design approaches employed.

SS	WE	EA	MR	EQ	ID

Credit 3.2

1 point

Construction IAQ Management Plan

After Construction/Before Occupancy

Intent

Prevent indoor air quality problems resulting from the construction/renovation process in order to help sustain the comfort and well-being of construction workers and building occupants.

Requirements

Develop and implement an Indoor Air Quality (IAQ) Management Plan for the pre-occupancy phase as follows:

- After construction ends and prior to occupancy conduct a minimum two-week building flush-out with new Minimum Efficiency Reporting Value (MERV) 13 filtration media at 100% outside air. After the flush-out, replace the filtration media with new MERV 13 filtration media, except the filters solely processing outside air.

OR

- Conduct a baseline indoor air quality testing procedure consistent with the United States Environmental Protection Agency's current *Protocol for Environmental Requirements, Baseline IAQ and Materials, for the Research Triangle Park Campus, Section 01445.*

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect, general contractor or responsible party, describing the building flush-out procedures and dates.

OR

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, declaring that the referenced standard's IAQ testing protocol has been followed. Include a copy of the testing results.

Summary of Referenced Standards

IAQ Guidelines for Occupied Buildings Under Construction

Sheet Metal and Air Conditioning National Contractors Association (SMACNA), www.smacna.org, (703) 803-2980

This standard provides an overview of air pollutants associated with construction, control measures, construction process management, quality control, communications with occupants, and case studies. Consult the referenced standard for measures to protect the building HVAC system during construction and demolition activities.

ANSI/ASHRAE 52.2-1999: Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

ASHRAE, www.ashrae.org, (800) 527-4723

This standard presents methods for testing air cleaners for two performance characteristics: the ability of the device to remove particles from the air stream and the device's resistance to airflow. The minimum efficiency reporting value (MERV) is based on three composite average particle size removal efficiency (PSE) points. Consult the standard for a complete explanation of MERV value calculations. Filtration media used during the construction process must have a MERV of 13. **Table 1** summarizes the requirements for a MERV value of 13.

EPA Protocol for Environmental Requirements, Testing for Indoor Air Quality, Baseline IAQ and Materials for Research Triangle Park Campus, Specification Section 01445

www.epa.gov/rtp/new-bldg/environmental/specs.htm, (919) 541-0249

This specification section was a part of the construction documents for the EPA's Research & Administration Facility at Research Triangle Park. The section addresses baseline indoor air quality testing and materials testing.

Table 1: Requirements for a MERV Value of 13

Composite Average Particle Size Efficiency [%]			Minimum Final Resistance	
0.30-0.10 µm	1.0-3.0 µm	3.0-10.0 µm	[Pa]	[in. of water]
< 75%	≥ 90%	≥ 90%	350	1.4

SS | WE | EA | MR | EQ | ID

Credit 3

Credit Synergies

MR Credit 2
Construction Waste Management

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 4
Low-Emitting Materials

Green Building Concerns

Building construction processes invariably include activities that contaminate the building during construction. Often, these activities result in residual building contamination that continues to impact indoor air quality over the lifetime of the building. HVAC systems are especially prone to contamination from particulate matter generated during construction activities. This particulate matter can include dust, volatile organic compounds (VOCs), microorganisms, and other contaminants that remain in HVAC systems for years. Building occupants may experience reduced productivity and adverse well-being effects as a result.

Fortunately, construction management strategies can be instituted during construction and before occupancy to minimize the potential for building contamination and to remediate or clean up any contamination that has occurred. Protection of HVAC systems during construction, IAQ testing, and flush-out of the building prior to occupancy are effective methods to mitigate the impact of construction activities and products on IAQ.

Environmental Issues

A ventilation flush-out prior to occupancy may require additional energy use, which is associated with air and water pollution. However, contaminant reduction is beneficial to building occupants, resulting in greater comfort, lower absenteeism, and greater productivity.

Economic Issues

Superior indoor air quality is likely to increase worker productivity, translating to greater profitability for companies. Additional time and labor may be required during and after construction to protect and clean ventilation systems. However, these actions can extend the lifetime of the ventilation system and improve ventilation system efficiency, resulting in reduced energy use. The sequencing of material installation may require additional time and could potentially delay the date of initial occupancy. Early coordination between the contractor and subcontractors can minimize or eliminate scheduling delays.

Community Issues

Contaminants from the construction process can affect the health of construction workers during construction and building users during occupancy. If these contaminants remain in the building after occupancy commences, they may affect the quality of indoor air, leading to expensive and complicated clean-up procedures. Construction worker health issues are addressed by federal and state regulations, primarily those of the Occupational Safety and Health Administration (OSHA). However, building occupants are not covered under these regulations.

Design Approach

Strategies

This credit hinges on performance by the builder. Regardless of the project delivery mechanism, be it design/bid/build or design/build, it is imperative that the general contractor implement an IAQ Management Plan for the construction process. In some cases the architect may provide a draft plan that the contractor then tailors to the situation. In other cases, the contractor is charged with creating the plan in order to keep the roles and responsibilities perfectly clear.

The plan should address the protection of the ventilation system components during construction and cleanup of contaminated components after construction is complete. Require temporary ventilation in the General Conditions of the construction contract.

Include construction-related IAQ procedures in the pre-construction and construction progress meeting agendas. Also, make efforts to ensure that all participants in the construction process are aware of the IAQ procedures and understand the importance of the goals of the IAQ Management Plan. If necessary, identify an owner's representative as the IAQ Manager to identify IAQ problems and require mitigation as necessary.

The referenced SMACNA standard recommends control measures in five areas: HVAC protection, source control, pathway interruption, housekeeping, and scheduling. The second portion of this credit provides an additional point for a sixth control measure: building flush-out or IAQ testing. For each project, review the applicability of each control measure and include those that apply in the final IAQ Management Plan. The control measures are as follows:

HVAC Protection—Shut down the return side of the HVAC system (which is, by definition, ductwork under negative pressure) whenever possible during heavy construction or demolition. The return side should also be isolated from the surrounding environment whenever possible. For example, all ceiling tiles for the ceiling plenum should be in place and all leaks in ducts and air handlers should be repaired promptly. If the ventilation system must be operated during construction, it should be fitted with temporary filters that can be replaced with clean media just prior to completion and occupancy.

The return side of the HVAC system should be dampered off in the heaviest work areas and return system openings should be sealed with plastic. Upgraded filter efficiency is recommended where major loading is expected.

Source Control—Specify finish materials (such as paints, carpet, composite wood, adhesives, and sealants) that have low toxicity levels, or none at all. Low-toxic materials selection is covered under IEQ Credit 4. Materials that are potentially noxious should be identified by the project architect, and control measures specified (options as described in the SMACNA guidelines).

Pathway Interruption—During construction, isolate areas of work to prevent contamination of clean or occupied spaces. Depending on the climate, ventilate using 100% outside air to exhaust contaminated air directly to the outside during installation of VOC-emitting materials. Pressure differentials between construction areas and clean areas can be utilized to prevent contaminated air from entering clean areas. Such strategies often require the erection of temporary barriers between work areas and non-work areas.

Housekeeping—Institute cleaning activities concentrating on HVAC and building spaces to remove contaminants from the building prior to occupancy. Building materials should be protected from weather and stored in a clean area prior to unpacking for installation. All coils, air filters, and fans should be cleaned before performing testing and balancing procedures and especially before conducting baseline air quality tests.

Scheduling—Specify construction sequencing to reduce absorption of VOCs by porous materials. Complete applications of wet and odorous materials such as paints, sealants, and coatings before installing absorbent "sink" materials such as ceiling tiles, carpets, insulation, gypsum products, and fabric-covered furnishings. Materials directly exposed to moisture through precipitation, plumbing leaks, or condensation from the HVAC system are susceptible to microbial contamination and should be replaced.

Flush-out—Conduct a minimum two-week building flush-out with MERV 13 filtration media and 100% outside air after construction ends and prior to occupancy. After flush-out, new MERV 13 filters must replace all filters except those solely processing outside air.

IAQ Testing—For each building area where the maximum concentration limits are exceeded, identify and mitigate pollutant sources (if possible) and conduct a partial building flush-out for a maximum of two weeks. Retest for any contaminant concentrations that were exceeded. Repeat this process until appropriate concentration levels are achieved.

Synergies and Trade-Offs

Proper construction waste management procedures can minimize the possibility of building contamination. It is also important to choose building materials that have a low potential for contaminating the building, such as low-VOC paints, adhesives, and sealants.

Resources

Web Sites

EPA Baseline IAQ Specifications

www.epa.gov/rtp/new-bldg/environmental/specs.htm, (919) 541-0249

These specifications were used for the EPA's Research Triangle Park Campus and include baseline IAQ testing and materials testing procedures.

EPA Fact Sheet: Ventilation and Air Quality in Offices

www.epa.gov/iaq/pubs/ventilat.html, (800) 438-4318

This EPA publication addresses IAQ issues for office buildings.

Sheet Metal and Air Conditioning National Contractors Association (SMACNA)

www.smacna.org, (703) 803-2980

Professional trade association that publishes the referenced standard as well as *Indoor Air Quality: A Systems Approach*, a comprehensive discussion of the sources of pollutants, measurement, methods of control, and management techniques.

Print Media

Indoor Air Quality, Construction Technology Centre Atlantic. Written as a comprehensive review of indoor air quality issues and solutions, the report is available for purchase from ctca.unb.ca/IAQ/index.htm or (506) 453-5000.

Definitions

A **Construction IAQ Management Plan** is a document specific to a building project that outlines measures to minimize contamination in the building during construction and to flush the building of contaminants prior to occupancy.

HVAC Systems include heating, ventilating, and air-conditioning systems used to provide thermal comfort and ventilation for building interiors.

Case Study

Greater Pittsburgh Community Food Bank
Pittsburgh, Pennsylvania

The Greater Pittsburgh Community Food Bank is a LEED™ Silver Pilot Project serving local food banks in Western Pennsylvania. The building houses distribution, warehouse, and processing facilities and is designed to utilize site resources and be a positive workspace for building occupants. An indoor air quality management plan was adopted to avoid air contamination in the building during construction activities. VOCs were controlled through source reduction and housekeeping efforts. Particulate contamination was reduced by physically separating the HVAC system from construction activities and by cleaning the HVAC system before occupancy. Combustion was controlled by limiting combustion activities on site and locating combustion sources away from air supply intakes. Finally, cleaning agents were specified to contain no chlorine or ammonia.


Courtesy of Gardner + Pope Architects

Owner
Greater Pittsburgh Community Food Bank

SS WE EA MR EQ ID

Credit 4.1

Low-Emitting Materials

Adhesives and Sealants

1 point

Intent

Reduce the quantity of indoor air contaminants that are odorous, potentially irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

The VOC content of adhesives and sealants used must be less than the current VOC content limits of South Coast Air Quality Management District (SCAQMD) Rule #1168, AND all sealants used as fillers must meet or exceed the requirements of the Bay Area Air Quality Management District Regulation 8, Rule 51.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, listing the adhesives and sealants used in the building and declaring that they meet the noted requirements.

SS | WE | EA | MR | EQ | ID

Credit 4.2

1 point

Low-Emitting Materials

Paints and Coatings

Intent

Reduce the quantity of indoor air contaminants that are odorous, potentially irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

VOC emissions from paints and coatings must not exceed the VOC and chemical component limits of Green Seal's Standard GS-11 requirements.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, listing all the interior paints and coatings used in the building that are addressed by Green Seal Standard GS-11 and stating that they comply with the current VOC and chemical component limits of the standard.

SS	WE	EA	MR	EQ	ID
Credit 4.3					

Low-Emitting Materials

Carpet

1 point

Intent

Reduce the quantity of indoor air contaminants that are odorous, potentially irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

Carpet systems must meet or exceed the requirements of the Carpet and Rug Institute's Green Label Indoor Air Quality Test Program.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, listing all the carpet systems used in the building and stating that they comply with the current VOC limits of the Carpet and Rug Institute's Green Label Indoor Air Quality Test Program.

SS | WE | EA | MR | EQ | ID

Credit 4.4

1 point

Low-Emitting Materials

Composite Wood

Intent

Reduce the quantity of indoor air contaminants that are odorous, potentially irritating and/or harmful to the comfort and well-being of installers and occupants.

Requirements

Composite wood and agrifiber products must contain no added urea-formaldehyde resins.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, listing all the composite wood products used in the building and stating that they contain no added urea-formaldehyde resins.

Summary of Referenced Standards

South Coast Rule #1168 by the South Coast Air Quality Management District

South Coast Air Quality Management District, www.aqmd.gov/rules/html/r1168.html, (909) 396-2000,

The South Coast Air Quality Management District is a governmental organization in Southern California with the mission to maintain healthful air quality for its residents. The organization established source specific standards to reduce air quality impacts.

The South Coast Rule #1168 VOC limits for adhesives are summarized in **Tables 1a and 1b.**

Table 1a: South Coast Rule #1168 VOC Limits

Welding & Installation	VOC Limit [g/L]	Welding & Installation	VOC Limit [g/L]
Non-vinyl backed installation	150	PVC welding	510
Carpet pad inatallation	150	CPVC welding	490
Wood flooring installation	150	ABS welding	400
Ceramic tile installation	130	Plastic cement welding	350
Dry wall & panel installation	200	Cove base installation	150
Subfloor installation	200	Adhesive primer for plastic	650
Rubber floor installation	150	All others	250
VCT & asphalt tile installation	150		

Table 1b: Substrate VOC Limits

Substrates	VOC Limit [g/L]
Metal to metal	30
Plastic foams	120
Porous material except wood	120
Wood	30
Fiberglass	200

Regulation 8, Rule 51 of the Bay Area Air Quality Management District (January 7, 1998)

Bay Area Air Quality Management District, www.baaqmd.gov, (415) 771-6000

This California regulatory agency develops and enforces air pollution regulations in its seven-county jurisdiction. **Tables 2** and **3** summarize Regulation 8, Rule 51 limits on VOCs for sealants and sealant primers.

Table 2: Sealant VOC Limits

Sealants	VOC Limit [g/L]
Architectural	250
Roadways	250
Roofing material installation	450
PVC welding	480
Other	420

Table 3: Sealant Primer VOC Limits

Sealant Primer	VOC Limit [g/L]
Architectural (non-porous)	250
Architectural (porous)	775
Other	750

Green Seal Standard GS-11

Green Seal, www.greenseal.org, (202) 872-6400

Green Seal is a nonprofit organization that promotes the manufacture and sale of environmentally responsible consumer products. Standard GS-11 was developed for paints and primers. **Table 4** summarizes limits on VOCs in grams per liter for interior paints from April 1999.

Table 4: Green Seal Limits for Interior Paints

Paint	VOC Limit [g/L]
Non-flat	150
Flat	50

Carpet and Rug Institute Green Label Testing Program

Carpet and Rug Institute, www.carpet-rug.com, (800) 882-8846

The Carpet and Rug Institute is a trade organization representing the carpet and rug industry. The organization established the Green Label Testing Program Limits to identify low-emitting carpet products for consumers. The Program established limits on VOCs for carpets, cushion, and adhesives, as summarized in **Table 5**.

Table 5: Carpet and Rug Institute VOC Limits

Emission Factor Limit	[mg/m2 x h]	Emission Factor Limit	[mg/m2 x h]
Carpets Total VOCs	**0.50**	**Cushion Total VOCs**	**1.00**
4-Phenylcyclohexene	0.05	4-PC (4-phenylcyclohexene)	0.05
Formaldehyde	0.05	Formaldehyde	0.05
Styrene	0.40	BHT (butylated hydroxytoluene)	0.30
Adhesives Total VOCs	**10.0**		
Formaldehyde	0.05		
2-Ethyl-1-Hexanol	3.00		

Credit Synergies

MR Credit 1
Building Reuse

MR Credit 4
Recycled Content

MR Credit 5
Local/Regional Materials

MR Credit 6
Rapidly Renewable Materials

MR Credit 7
Certified Wood

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 3
Construction IAQ Management Plan

Green Building Concerns

A large number of building products contain compounds that have a negative impact on indoor air quality and the Earth's atmosphere. The most prominent of these compounds, volatile organic compounds (VOCs), contribute to smog generation and air pollution outdoors while having an adverse effect on the well-being of building occupants indoors. By selecting low-emitting materials, both outdoor and indoor air quality impacts can be avoided. This credit targets those building materials that are commonly associated with high-VOC content, including adhesives, paints and coatings, carpet systems, composite wood, and agrifiber products.

Environmental Issues

VOCs are chemical compounds that contribute to air pollution inside and outside of buildings. VOCs are of concern because they react with sunlight and nitrogen in the atmosphere to form ground-level ozone, a chemical that has a detrimental effect on human health, agricultural crops, forests, and ecosystems. Ozone damages lung tissue, reduces lung function, and sensitizes the lungs to other irritants. Ozone is also a major component of smog, which affects agricultural crops and forestland.

Economic Issues

Healthy occupants are more productive and have less illness-related absenteeism. Use of high-VOC content materials can cause illness and may decrease occupant productivity. These problems result in increased expenses and liability for building owners, operators, and insurance companies. As a result, the construction market is driving product manufacturers to offer low-VOC alternatives to conventional building products. Costs for these low-VOC products are generally competitive with conventional materials. However, some low-VOC materials are more expensive than conventional materials, particularly when the products are first introduced to the marketplace. Low-VOC products may also be difficult to obtain for some product types. However, these problems will recede as application of low-VOC products become more commonplace.

Community Issues

VOCs impact indoor air quality and contribute to sick building syndrome, building-related illnesses, and multiple chemical sensitivities. Application of products containing VOCs also affects outdoor air quality, creating smog and producing an unhealthy environment. By using low-VOC products, these problems can be avoided, creating a more favorable environment for building occupants and neighbors.

Design Strategies

Strategies

This credit applies to products and installation processes that have the ability to adversely affect indoor air quality (IAQ) on site: those that are exposed to interior spaces accessible by occupants. While projects should strive to limit the use of VOC-emitting materials on the building exterior or the project site, their use is not addressed under this credit.

Develop a project outline specification in early design stages, and include criteria for materials with low-VOC characteristics. Materials to address include construction and finishing materials.

Research and specify low-VOC products based on durability, performance, and environmental characteristics. Material Safety Data Sheets (MSDS) from product manufacturers may not include information on VOC content. Thus, it may be necessary to request emissions test data from product manufacturers and compare this test data with comparable products. VOC emissions data should exclude the colorants in paints. Ensure that contaminant limits are clearly stated in Division 1 and in specification sections where adhesives, sealants, coatings, carpets, and composite woods are addressed.

Consider field monitoring for emission levels in the building during installation and prior to building occupancy. Consider implementing an ongoing, periodic review of IAQ over the lifetime of the building.

Synergies and Trade-Offs

Material selection is important to creating interior spaces with low-VOC levels. Locally sourced materials and those materials created with recycled content, rapidly renewable materials, and certified wood may have high VOC content and, thus, may be inappropriate for the project. Use of low-VOC products improves indoor air quality during the construction process as well as over the lifetime of the building.

Calculations

This credit applies to products and installation processes that have the ability to adversely affect indoor air quality (IAQ) on site: those that are exposed to interior spaces accessible by occupants. While projects should strive to limit the use of VOC-emitting materials on the building exterior or the project site, their use is not addressed under this credit.

Documentation for the four subcredits normally consists of recordkeeping. Enter summary VOC data for products in the LEED Letter Template. If this credit is audited during the LEED certification review, provide cut sheets containing VOC data.

Calculations are necessary only when using the "VOC budget," which is an alternative compliance path that allows for specialty applications for which there are no low-VOC product options. Such a budget can be used to demonstrate *overall* low-VOC performance for paints or adhesives (not a combination of both). The applicant must establish a baseline VOC budget based on the appropriate referenced standard and meet the budget based on the amount of each product used and respective VOC concentrations. To develop a VOC budget, define application rates of products and how much of each is necessary for the project. Compare this baseline case to a design case that lists and sums VOCs for the products that are (or will be) specified for the project, for the same areas of application. If the total VOC limit of the design case is lower than the baseline case, the point can be earned.

Resources

Web Sites

Formaldehyde Update

www.cpsc.gov/CPSCPUB/PUBS/725.html

An informational document from the Consumer Product Safety Commission.

GreenSpec

www.greenspec.com, (802) 257-7300

Detailed listings for more than 1,500 green building products, including environmental data, manufacturer information, and links to additional resources.

Master Painters Institute's Environmental Issues Web Page

www.paintinfo.com/green

Ten Basic Concepts for Architects and Other Building Designers

www.buildinggreen.com/elists/halpaper.html, (802) 257-7300

A primer on IAQ basics from *Environmental Building News.*

Zero VOC Paint Manufacturers

www.aqmd.gov/business/brochures zerovoc.html

A listing of paint manufacturers that offer products with no or low VOC content, provided by the South Coast Air Quality Management District.

Print Media

ASTM D5116-97: Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products, ASTM, 1997.

Indoor Air Quality Primer, by Dagmar Schmidt Etkin, Cutter Information Corp., 1993.

"Paint the Room Green" in Environmental Building News, Volume 8, Number 2, February 1999.

Definitions

Formaldehyde, a naturally occurring VOC, is found in small amounts in animals and plants, but is carcinogenic and an irritant to most people when present in high concentrations—causing headaches, dizziness, mental impairment, and other symptoms. When present in the air at levels above 0.1 ppm (parts per million parts of air), it can cause watery eyes, burning sensations in the eyes, nose, and throat; nausea; coughing; chest tightness; wheezing; skin rashes; and asthmatic and allergic reactions. Urea formaldehyde is a combination of urea and formaldehyde that is used in some glues and readily decomposes at room temperature. Phenol formaldehyde, which off-gasses only at high temperature, is used for exterior products, although many of those products are suitable for interior applications.

Volatile Organic Compounds (VOCs) are carbon compounds that participate in atmospheric photochemical reactions (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonates, and ammonium carbonate). The compounds vaporize (become a gas) at normal room temperatures.

Indoor Chemical & Pollutant Source Control

SS | WE | EA | MR | EQ | ID

Credit 5

1 point

Intent

Avoid exposure of building occupants to potentially hazardous chemicals that adversely impact air quality.

Requirements

Design to minimize pollutant cross-contamination of regularly occupied areas:

- Employ permanent entryway systems (grills, grates, etc.) to capture dirt, particulates, etc. from entering the building at all high volume entryways.
- Where chemical use occurs (including housekeeping areas and copying/printing rooms), provide segregated areas with deck to deck partitions with separate outside exhaust at a rate of at least 0.50 cubic feet per minute per square foot, no air re-circulation and maintaining a negative pressure of at least 7 PA (0.03 inches of water gauge).
- Provide drains plumbed for appropriate disposal of liquid waste in spaces where water and chemical concentrate mixing occurs.

Submittals

❑ Provide the LEED Letter Template, signed by the architect or responsible party, declaring that:

- Permanent entryway systems (grilles, grates, etc.) to capture dirt, particulates, etc. are provided at all high volume entryways.
- Chemical use areas and copy rooms have been physically separated with deck-to-deck partitions; independent exhaust ventilation has been installed at 0.50 cfm/square foot and that a negative pressure differential of 7 PA has been achieved.
- In spaces where water and chemical concentrate mixing occurs, drains are plumbed for environmentally appropriate disposal of liquid waste.

Summary of Referenced Standard

There is no standard referenced for this credit.

Credit Synergies

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Prerequisite 1
Storage & Collection of Recyclables

MR Credit 1
Building Reuse

EQ Prerequisite 1
Minimum IAQ Performance

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

Green Building Concerns

Some common building activities have a negative impact on indoor air quality. Occupants and visitors entering the building may bring in contaminants on their shoes or clothing that can infiltrate the ventilation system. Other seemingly benign practices such as photocopying, faxing, and mixing housekeeping liquids can contribute significantly to airborne contaminants, affecting the health and productivity of building occupants. By reducing the impacts of these activities, superior indoor air quality can be maintained.

Environmental Issues

Additional materials and energy may be required to provide entryway systems and isolated chemical use areas. This can increase natural resource consumption as well as air and water pollution. However, through proper management of hazardous chemicals used for building operations and maintenance, chemical spills and accidents can be avoided that would otherwise harm wildlife and ecosystems.

Economic Issues

Additional sinks, drains, and separate exhausts for copying and housekeeping areas can increase the project's overall initial cost. However, effective cleaning spaces and systems coupled with good human health initiatives should prove economically sound over the lifetime of the building. Clean air can help support worker productivity, and this translates into increased profitability for the company. Reducing the potential for spills can avoid costly environmental cleanups.

Community Issues

Good housekeeping benefits the community by reducing the potential for chemical spills that can impact neighboring properties. An environmentally sound building also supports the well-being of occupants, which may contribute to lowering health insurance rates and health care costs.

Design Approach

Design all exterior entrances with permanent entryway systems (e.g., grills and grates) to catch and hold dirt particles and to prevent contamination of the building interior. Design exterior stone, brick, or concrete surfaces to drain away from building entrances. The landscape design at building entrances should utilize low maintenance vegetation. Species that drop berries, flowers, and leaves should be avoided in entrance areas so that organic matter does not migrate into the building on occupants' shoes. Plant selection should also be based on an integrated pest management approach to eliminate pesticide applications that have the potential for tracking into the building. Provide a water spigot and electrical outlet at entryways for maintenance and cleaning activities.

Physically isolate occupant activities associated with chemical use through proper building design. Isolation includes adequate and secure storage areas for housekeeping equipment and products. All of these areas should accommodate sinks and drains plumbed for appropriate disposal of liquid waste and separate exhausts vented to the outside that are operated under negative pressure. To ensure that these features remain effective over time, building owners should institute operations and maintenance training programs for chemical usage and storage.

During early blocking and stacking studies, design copy and printing rooms with structural deck-to-deck partitions and dedicated exhaust ventilation systems. Locate high-volume equipment (e.g., copiers, printers, and fax machines) away from regularly occupied areas and provide physical isolation of this equipment. Provide dedicated localized exhaust systems and locate discharge points away from

SS	WE	EA	MR	EQ	ID
Credit 5					

HVAC system air intakes. Convenience (small) copier and printer use should be minimized where possible. Although encouraged, designing exhaust systems that account for convenience copier and printer use is not a required part of this credit.

Synergies and Trade-Offs

Additional ventilation systems to mitigate contaminating building activities may affect building energy performance and require commissioning and measurement and verification attention. Ventilation system design will also be affected. If an existing building is being reused, the building layout may prohibit deck-to-deck separation and separate ventilation systems for chemical use areas. Recyclable storage areas may be considered to be contaminant sources, depending on the items recycled. Janitorial supplies may impact indoor air quality if not wisely chosen.

Resources

Web Sites

Green Seal

www.greenseal.org/recommendations, (202) 872-6400

Product recommendations for general purpose cleaning solutions.

Janitorial Products Pollution Prevention Project

www.westp2net.org/janitorial/jp4.htm

A governmental and nonprofit project that researches issues and provides fact sheets, tools, and links.

EPA Environmentally Preferable Product Information

www.epa.gov/opptintr/epp/tools/toolsuite.htm

This list of tools includes links to cleaning product information and a database of environmental information on over 600 products, including janitorial and pest control products.

Print Media

Clean and Green: The Complete Guide to Non-Toxic and Environmentally Safe Housekeeping by Annie Berthold-Bond, Ceres Press, 1994.

Controllability of Systems

SS	WE	EA	MR	EQ	ID
Credit 6.1					

Perimeter Spaces

1 point

Intent

Provide a high level of thermal, ventilation and lighting system control by individual occupants or specific groups in multi-occupant spaces (i.e. classrooms or conference areas) to promote the productivity, comfort and well-being of building occupants.

Requirements

Provide at least an average of one operable window and one lighting control zone per 200 square feet for all regularly occupied areas within 15 feet of the perimeter wall.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, demonstrating and declaring that for regularly occupied perimeter areas of the building a minimum of one operable window and one lighting control zone are provided per 200 square feet on average.

Controllability of Systems

Non-Perimeter Spaces

Intent

Provide a high level of thermal, ventilation and lighting system control by individual occupants or specific groups in multi-occupant spaces (i.e. classrooms or conference areas) to promote the productivity, comfort and well-being of building occupants.

Requirements

Provide controls for each individual for airflow, temperature and lighting for at least 50% of the occupants in non-perimeter, regularly occupied areas.

Submittals

- ❑ Provide the LEED Letter Template, signed by the architect or responsible party, demonstrating and declaring that controls for individual airflow, temperature and lighting are provided for at least 50% of the occupants in non-perimeter, regularly occupied areas.

Summary of Referenced Standard

There is no standard referenced for this credit.

Green Building Concerns

Conventional buildings are sometimes designed as sealed environments with no occupant control over temperature and ventilation and virtually no physical connection to the building grounds and neighboring areas. By providing individual controls such as thermostats, vents, operable windows and shading devices, occupants can customize the indoor environment to their own preferences.

Environmental Issues

Individual control of building systems can increase occupant comfort and save energy by eliminating unwanted or unnecessary space conditioning.

Economic Issues

The most frequent occupant complaint involves thermal discomfort. Greater thermal comfort may increase occupant performance and attendance and, at least, will reduce complaints. Since workers are by far the largest expense for most companies (according to the Rocky Mountain Institute's *Green Developments in Real Estate*, office worker salaries are estimated to be 72 times higher than energy costs, and they account for 92% of the life-cycle cost of a building), this issue has a tremendous effect on overall costs. Case studies have shown productivity increases from 1% to 16%, saving companies millions of dollars per year.

Additional thermostats, operable windows and lighting controls can increase first costs for the building. However, these costs are generally offset by energy savings through lower conditioned temperatures, natural ventilation and less solar gain through proper use of shading devices. Conversely, abuse of personal controls such as setting thermostats too high or leaving windows open during non-working hours increases energy costs. Therefore, it is important to educate occupants on the design and function of system controls.

Community Issues

Building occupants with more control over their environment tend to be more productive and healthier. This may lead to stabilized health insurance rates and decreased health care costs.

Design Approach

Strategies

The credit encourages the design to begin with the occupants in mind. Space planning, lighting schemes and HVAC design must be well integrated early in the design.

Operable windows are perhaps the single most desired feature building occupants request in the programming phase of a project. The design team should be cautioned that the inclusion of this feature raises a host of issues that need to be resolved early in the project design stages. The first decision regarding the window design is whether the opening provides a vision function, a daylighting function, or both. This decision will help determine the preferred size, orientation and aspect ratio of the windows. Next, the ventilation function of the operable sash should be determined. The ventilation characteristics of a window that provides a modest connection to the outdoors are different from a window that can provide a portion of the cooling requirements for the interior space. Once all of these parameters are established, the design of the operable portion of the window can be incorporated into the total fenestration design.

In modern buildings, good engineering practice leads to a positive ventilation scheme for all regularly occupied spaces. In a traditional HVAC mixing system such as variable air volume (VAV), oper-

Credit Synergies

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Prerequisite 2
Environmental Tobacco Smoke (ETS) Control

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 7
Thermal Comfort

EQ Credit 8
Daylight & Views

able windows are difficult to accommodate. Either operable window designs need to be modest in size and low in quantity, or a control interface with the HVAC system should be specified to prevent counterproductive operation.

A simple control interface might include a light indicating when the HVAC is operating and when closed windows would provide the greatest comfort. An intermediate system might only allow economizer operation when windows are open. A more complex scheme would sense if there were too many windows open, signal the building energy management system to close the windows with actuators, and then start the HVAC system.

The lighting controls required in the perimeter zone go beyond those required by the AHSRAE 90.1–1999 requirements, and simple switching satisfies the credit requirement. However, more sophisticated occupancy and dimming controls may result in increased productivity and energy conservation.

Individual temperature and ventilation controls can increase first costs when implemented in the core of a building plan. As there is no access to operable windows for ventilation, the only system left to control is the mechanical delivery of air. The cost of individual VAV mixing boxes may be prohibitive for conventional HVAC systems, both for the additional boxes and the cost of the extra ductwork. VAV systems for non-perimeter areas can use a 1:1:2 terminal box to controller to occupant ratio to capture this credit.

There are a number of new systems that combine an underfloor air system with individual controls at the desktop. These Personal Environmental Control (PEC) systems transfer a large portion of the HVAC system control from the capital improvement budget to the furnishing budget. This can create challenges or opportunities, depending on the financial structure of the project.

Individual lighting control in core locations of a floor plan is a relatively straightforward installation. Further control is then provided at the individual level with task lighting. For example, furniture systems can include built-in task lighting. For finer control, larger ambient lighting zones can be sub-switched or controlled by occupancy sensors to provide smaller lighting zones.

Educate occupants on individual control of their office space environment. A monitoring system can be implemented to maintain proper system operation and signage if effective to remind occupants of their responsibilities (e.g., turning down the thermostat at night and closing windows).

Synergies and Trade-Offs

Conventional HVAC systems have a cost structure that drives building design towards larger ventilation zones with fewer controls. To successfully integrate controllability of systems into building design, the economic benefits of user satisfaction and productivity should be compared with first costs.

Alteration of the ventilation and lighting scheme may change the energy performance of the building and may require commissioning and measurement and verification attention. Controllability of systems may not be possible for occupants in existing buildings being rehabilitated, especially with regard to operable windows. The degree of occupant controls will affect the performance of the ventilation system. Daylighting and view strategies are affected by the window design.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first pages of this credit. To calculate the degree of occupant control, follow the calculation methodology as outlined in the following paragraphs. The methodology is separated into perimeter calculations and non-perimeter calculations for regularly occupied spaces. Multi-occupant group spaces, such as conference rooms and classrooms, should be accounted for separately in the calculations, following the special requirements for these spaces. Exclude zones such as hallways and lobbies, which are non-regularly occupied spaces, and non-occupied areas such as storage rooms.

Identifying Perimeter and Non-Perimeter Areas

1. On a plan drawing of the building, draw an offset line 15 feet from the outer wall of the building. This 15-foot boundary represents the typical ASHRAE 90.1 method of calculating thermal loads in perimeter zones; it is used in this credit to distinguish between the type of controls in perimeter and non-perimeter spaces.

2. Perimeter areas of the building include all regularly occupied areas that are 15 feet or less from a perimeter wall and share a physical connection with the exterior of the building.

3. Non-perimeter areas of the building are all regularly occupied areas that are greater than 15 feet from a perimeter wall.

4. For rooms that are intersected by the 15-foot line (offset from the perimeter wall) and share a physical connection with the building exterior, the area of the entire room must be included as perimeter if 75% or more of the room is contained within the 15-foot offset line. If less than 75% of the room is contained within the 15-foot offset line—e.g., in **Figure 1**, Room 1—then only the area within the 15-foot boundary is considered perimeter space (area 1A), and the remaining area is factored into the non-perimeter space calculation (area 1B).

5. For group multi-occupant spaces, perimeter calculations are used if 75% or more of the floor area falls within the 15-foot offset line and the space shares a physical connection with the building exterior. Non-perimeter calculations are used if less than 75% of the floor area falls within the 15-foot offset line OR if the space is not connected to the building exterior. In an instance where less than 75% of the floor area falls within the 15-foot offset line but the space shares a physical connection to the building exterior, the space must meet the requirements outlined in non-perimeter calculations in addition to providing an average of one operable window per 200 square feet of perimeter floor area.

Perimeter Space Calculations for Credit 6.1

Occupant controls to consider in perimeter areas include operable windows and lighting.

1. Using the method described above, identify all perimeter areas for the building.

2. Identify the number of operable windows and lighting controls in each perimeter room. Task lighting is applicable only if hardwired. For group multi-occupant spaces, meet the requirements for operable windows according to Perimeter Space Calculations and meet the requirements for lighting controls according to Group Multi-Occupant Space Calculations.

3. The credit requires one operable window and one lighting control on average for every 200 square feet of perimeter floor area.

Table 1 provides an example of the LEED Letter Template's perimeter calculations for the partial office building floor plan presented in **Figure 1**. The table includes all perimeter rooms that are regularly occupied.

Non-Perimeter Space Calculations for Credit 6.2

Occupant controls to consider in non-perimeter areas include airflow, temperature and lighting.

1. Using the method described above, determine the total non-perimeter floor area of all regularly occupied spaces.

2. Determine the total number of non-perimeter occupants based on each space's usage type by referencing the occupancy densities in ASHRAE 62–2001, Table 2. Exceptions to standard occupancy loads (e.g., executive suites and office space used partially for special purposes) must be justified in a narrative attached to the LEED Letter Template.

3. Identify the total numbers of airflow, temperature and lighting controls for this non-perimeter area. Task lighting is applicable only if hardwired.

4. The credit requires that the number of airflow, temperature, and lighting controls provided must each represent 50% or more of the non-perimeter occupants in aggregate. These controls must be provided in areas where corresponding occupants regularly work. Controls in corridors and other non-work areas are not included in the calculations.

It is acceptable for thermal and ventilation control to be provided by a single device. For example, an individual could have control of an underfloor air diffuser

Figure 1: A Sample Floor Plan Indicating Perimeter and Non-Perimeter Spaces

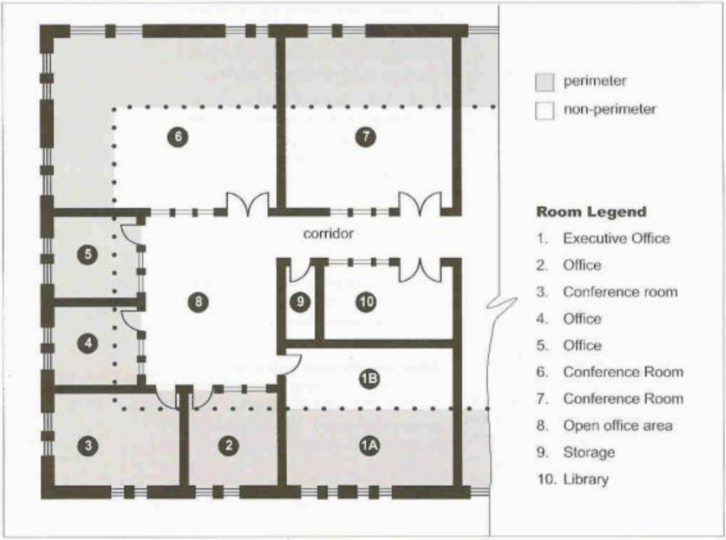


Table 1: Sample Calculations for Space 1A and Rooms 2, 4 and 5

Perimeter Spaces (where 75% or more of a room is within the 15-foot offset line)				
Perimeter Area	Operable Windows		Lighting Controls	
[SF]	[Qty]	Pass?	[Qty]	Pass?
1,290	10	Yes	8	Yes

that adjusts the airflow and also the temperature of his or her personal space.

5. For group multi-occupant spaces, meet the requirements for airflow, temperature and lighting controls according to the Group Multi-Occupant Space Calculations outlined below.

Table 2 provides an example of the LEED Letter Template's non-perimeter calculations for the partial office building floor plan presented in **Figure 1**. Room 9 and the corridor are not regularly occupied and are therefore excluded from the calculation.

Group Multi-Occupant Space Calculations for Credits 6.1 and 6.2

For group multi-occupant spaces, meet the requirements for operable windows according to the Perimeter Space Calculations. Each perimeter and non-perimeter group multi-occupant space must meet the following lighting control requirements. Each non-perimeter group multi-occupant space must also satisfy the following airflow and temperature control requirements.

1. For each space less than or equal to 10,000 square feet in floor area, provide at least three separate lighting controls, one airflow control and one temperature control each for every 2,500 square feet.

2. For each space greater than 10,000 square feet in floor area, provide at least three separate lighting controls, one airflow control and one temperature control each for every 10,000 square feet.

The following lighting controls can each be counted as two separate controls: occupancy sensor, daylighting control, dimming control and manual on/automatic off switch. Other lighting controls, such as an on/off switch, are each counted as one separate control. For example, for a room with one occupancy sensor, one daylighting control and one on/off switch, "5" would be entered in the lighting control's column of the LEED Letter Template.

Airflow and temperature controls must be devices that allow occupants to actively control the space's thermal conditions. Control devices must be easily adjustable (i.e., less than six feet above the floor) and

Table 2: Sample Calculations for Space 1B and Room 8

Non-Perimeter Spaces (where less than 75% of a room is within the 15-foot offset line)							
Non-Perimeter Area	Occupants	Airflow Controls		Temperature Controls		Lighting Controls	
[SF]		[Qty]	Pass?	[Qty]	Pass?	[Qty]	Pass?
1,020	3	3	Yes	3	Yes	6	Yes

Table 3: Sample Calculations for Room 3

Group Multi-Occupant Perimeter Rooms (where 75% or more of a room is within the 15-foot offset line)					
Number of Rooms	Total Area	Operable Windows		Lighting Controls	
[Qty]	[SF]	[Qty]	Pass?	[Qty]	Pass?
1	500	4	Yes	3	Yes

Table 4: Sample Calculations for Rooms 6, 7 and 10

Group Multi-Occupant Perimeter and Non-Perimeter Spaces (where less than 75% of a room is within the 15-foot offset line)												
Room Size Range	#	Per. Area	Non-Per. Area	Operable Windows		Airflow Controls		Temperature Controls		Lighting Controls		
[SF]	[Qty]	[SF]	[SF]	[Qty]	Pass?	[Qty]	Pass?	[Qty]	Pass?	[Qty]	Pass?	
<2,500	3	1,330	1,420	10	Yes	3	Yes	3	Yes	9	Yes	
>=2,500 and <5,000												
>=5,000 and <7,500												
>=7,500 and <=10,000												
>10,000												

readily accessible (i.e., not locked in an enclosure) by the occupants.

Tables 3 and 4 provide examples of the LEED Letter Template's perimeter and non-perimeter calculations for group multi-occupant spaces in the partial office building floor plan presented in **Figure 1**. The spreadsheet in **Table 3** is used for rooms that share a physical connection with the building exterior and 75% or more of the room is within the 15-foot offset line. These rooms are treated as 100% perimeter space.

The spreadsheet in **Table 4** is used for group multi-occupant rooms where less than 75% of the space is within the 15-foot offset line—such as 100% non-perimeter rooms and rooms that contain both perimeter and non-perimeter space. The example in **Table 4** indicates that three rooms, each less than 2,500 SF, account for a total of 1,330 SF perimeter area and 1,420 SF of non-perimeter area. Based on the perimeter area, seven operable windows are required (1,330/200 = 6.65, rounded up). Ten operable windows are provided, thus meeting this particular credit requirement for rooms 6 and 7. According to the Group Multi-Occupant Space Calculations, rooms that are less than 2,500 SF must each have one airflow control, one temperature control and three separate lighting controls. The example shows that these requirements are met for all three rooms.

Resources

Web Sites

Center for the Built Environment

www.cbe.berkeley.edu

This University of California, Berkeley research center provides information on underfloor air distribution technologies and other topics. See the publications page for articles such as "A Field Study of PEM (Personal Environmental Module) Performance in Bank of America's San Francisco Office Buildings."

Environmental Design + Construction

www.edcmag.com (see archives)

"Do Green Buildings Enhance the Well Being of Workers? Yes," an article by Judith Heerwagen in the July/August 2000 edition, quantifies the effects of green building environments on productivity.

Print Media

Controls and Automation for Facilities Managers: Applications Engineering by Viktor Boed, CRC Press, 1998.

Definitions

Group Multi-Occupant Spaces include conference rooms, classrooms and other indoor spaces used as a place of congregation for presentations, trainings, etc. Individuals using these spaces share the lighting and temperature controls.

An **Individual Multi-Occupant Space** is typically an open office plan. These spaces normally contain standard workstations where each individual must have comfort controls to earn Credit 6.2.

Non-Occupied Spaces include all rooms used by maintenance personnel and not open for use by occupants. Included are janitorial, storage and equipment rooms, and closets.

Non-Regularly Occupied Spaces include corridors, hallways, lobbies, break rooms, copy rooms, storage rooms, kitchens, restrooms, stairwells, etc.

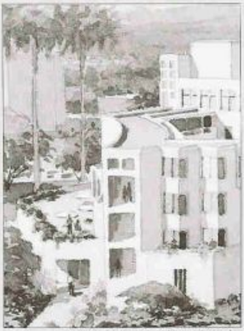
Regularly Occupied Spaces are areas where workers are seated or standing as they work inside a building.

SS | WE | EA | MR | EQ | ID
Credit 6

Case Study

Donald Bren School of Environmental Science and Management
Santa Barbara, California

The University of California at Santa Barbara's Donald Bren School of Environmental Science and Management is a LEED™ Version 1.0 Platinum Pilot Project housing campus facilities including research and teaching laboratories, and offices. The ventilation system incorporates operable windows for flow-through ventilation that can be controlled by occupants. The operable windows interface with the heating elements and the elements are automatically turned off when the windows are open. The lighting plan includes occupant-controlled energy-efficient fixtures.



Courtesy of Zimmer Gunsul Frasca Partnership

Owner
University of California at Santa Barbara

Thermal Comfort

SS	WE	EA	MR	EQ	ID
Credit 7.1					

1 point

Compliance with ASHRAE 55-1992

Intent

Provide a thermally comfortable environment that supports the productivity and well-being of building occupants.

Requirements

Comply with ASHRAE Standard 55-1992, Addenda 1995, for thermal comfort standards including humidity control within established ranges per climate zone. For naturally ventilated buildings, utilize the adaptive comfort temperature boundaries, using the 90% acceptability limits as defined in the Collaborative for High Performance Schools (CHPS) Best Practices Manual, Appendix C – A Field Based Thermal Comfort Standard for Naturally Ventilated Buildings, Figure 2.

Submittals

- ❑ For mechanically ventilated spaces: provide the LEED Letter Template, signed by the engineer or responsible party, declaring that the project complies with ASHRAE Standard 55-1992, Addenda 1995. Include a table that identifies each thermally controlled zone, and that summarizes for each zone the temperature and humidity control ranges and the method of control used.

OR

- ❑ For naturally ventilated spaces: provide the LEED Letter Template, signed by the engineer or responsible party declaring that the project complies with the 90% acceptability limits of the adaptive comfort temperature boundaries in the Collaborative for High Performance Schools (CHPS) Best Practices Manual Appendix C – A Field Based Thermal Comfort Standard for Naturally Ventilated Buildings, Figure 2.

SS	WE	EA	MR	EQ	ID
Credit 7.2					

1 point
in addition to
EQ 7.1

Thermal Comfort

Permanent Monitoring System

Intent

Provide a thermally comfortable environment that supports the productivity and well-being of building occupants.

Requirements

Install a permanent temperature and humidity monitoring system configured to provide operators control over thermal comfort performance and the effectiveness of humidification and/or dehumidification systems in the building.

Submittals

- ❑ Provide the LEED Letter Template, signed by the engineer or responsible party, declaring that a permanent temperature and humidity monitoring system will operate throughout all seasons to permit control of the building zones within the seasonal thermal comfort ranges defined in ASHRAE 55-1992, Addenda 1995. Confirm that the temperature and humidity controls were (or will be) tested as part of the scope of work for Energy and Atmosphere Prerequisite 1, Fundamental Building Systems Commissioning. Include the document name and section number where the commissioning work is listed.

Summary of Referenced Standards

ASHRAE 55–1992: Thermal Environmental Conditions for Human Occupancy

ASHRAE, www.ashrae.org, (800) 527-4723

This standard identifies the range of design values for temperature, humidity and air movement that provide satisfactory thermal comfort for a minimum of 80% of building occupants. The acceptable range of operative temperatures for the winter and summer, for people performing light, primarily sedentary activities, at 50% relative humidity and a mean air speed of 30 fpm (0.15m/s), are summarized in **Table 1**.

The standard includes specific details for occupant thermal comfort and provisions for building occupants at various activity levels and non-uniformity in air temperatures. It also describes appropriate instruments and procedures for measurement of thermal environment conditions. An addendum to the standard was released in 1995.

Table 1: Operative Temperatures

Room	Temperature Range [°F]	Optimum Temperature [°F]
Winter	68 - 74	71
Summer	73 - 79	76

The Collaborative for High Performance Schools (CHPS) Best Practices Manual, Appendix C–A Field Based Thermal Comfort Standard for Naturally Ventilated Buildings, Figure 2

www.chps.net/manual/index.htm

The result of research funded by ASHRAE, this standard provides an updated approach to thermal comfort using an adaptive model. Occupants of naturally ventilated buildings were found to prefer a wider range of temperatures that extend beyond the comfort zones defined in ASHRAE Standard 55–1992. Refer to the CHPS Best Practices Manual's Appendix C for an in-depth description.

SS | WE | EA | MR | EQ | ID

Credit 7

Credit Synergies

SS Credit 7
Landscape & Exterior Design to Reduce Heat Islands

WE Credit 1
Water Efficient Landscaping

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Prerequisite 1
Minimum IAQ Performance

EQ Credit 1
Carbon Dioxide (CO_2) Monitoring

EQ Credit 2
Increase Ventilation Effectiveness

EQ Credit 6
Controllability of Systems

Green Building Concerns

A green building provides the desired indoor climate while reducing the amount of energy required for ventilation. The building envelope must be designed to manage the flow of air, moisture and heat.

Temperature and humidity are important parameters in maintaining optimal environmental conditions for occupant comfort. Optimal temperature set points depend on occupant activity levels as well as air movement in the space. Another important environmental consideration in buildings is humidity. Spaces with low humidity create static electricity, which has detrimental effects on office equipment, human respiratory systems and certain types of furniture. Conversely, spaces with high humidity provide conditions conducive to mold and mildew growth on furnishings and interior surfaces, creating potential health hazards and increased maintenance requirements. A properly designed building can provide optimal temperatures and humidity levels throughout the year.

Environmental Issues

HVAC components use fuel and electricity to provide an indoor climate that is different than the outdoor climate and thereby contributes to the environmental impacts of producing and distributing these resources. In fragile climates, such as those with permafrost, conditioning buildings may damage the local environment. Conversely, a comfortable and healthy indoor environment may increase occupant productivity and reduce illnesses and absenteeism.

Economic Issues

Providing the thermal conditions set forth in ASHRAE 55–1992 or CHPS Appendix C may increase or decrease the cost of designing, constructing and operating the building. Designing the envelope and mechanical systems in an iterative process that includes occupant needs, desires and activities can result in lower loads, smaller conditioning and distribution equipment, and consequently reduced fuel consumption while providing greater thermal comfort. Natural ventilation has the likely potential to reduce first costs and operating costs.

Designers generally select one set of thermal conditioning criteria for the entire year. ASHRAE 55–1992 recommends that designers adjust thermal conditions to address seasonal clothing levels of occupants. This strategy would reduce energy used for summer cooling and winter heating.

The most frequent occupant complaint involves lack of thermal comfort. Greater thermal comfort may increase occupant performance and attendance and, at least, will reduce complaints. Since workers are by far the largest expense for most companies (according to the Rocky Mountain Institute's *Green Developments in Real Estate*, office worker salaries are estimated to be 72 times higher than energy costs, and they account for 92% of the life-cycle cost of a building), this issue has a tremendous effect on overall costs. Case studies have shown productivity increases from 1% to 16%, saving companies millions of dollars per year.

Community Issues

Optimal building operation creates a positive work space for building occupants, resulting in higher productivity rates and lower absenteeism and illness. Such results may be used to present a case for lower health insurance rates based on lower health care costs.

Design Approach

Strategies

The environmental parameters that combine to create human thermal comfort include air temperature, air velocity, humidity, clothing, activity and the temperature of surrounding materials. The referenced standards provide ranges of expected values for these various parameters that in combination provide a comfortable environment. To narrow the parameters for a particular building design, it is necessary to make a realistic assessment of the clothing and activity level of occupants. If these parameters can be fixed, or at least limited to a narrow range, the remaining parameters can be manipulated to create design comfort levels.

To provide thermal comfort while avoiding increased energy use, the building envelope must first be designed so that:

- it is airtight enough to prevent the comfort, condensation and excessive energy use problems caused by unplanned and undesired airflows. Return air and supply plenums must be particularly well detailed;
- it uses shading, insulation and thermal mass to manage interior surface temperatures of walls, ceilings, floors and windows;
- it diverts rainwater safely away from moisture-sensitive materials in the building; and
- it manages the flow of water vapor by combining the thermal conductivity, vapor resistance and vapor storage capacity properties of materials well enough to prevent accidental humidification of interior spaces and condensation within the building shell.

In a mechanically ventilated building, equipment must be able to efficiently heat, cool, humidify and dehumidify the spaces in a building as necessary. Using envelope design to reduce loads is an important design strategy that not only conserves energy, but also improves the surface temperatures of the inner envelope surfaces and is resource-efficient in that it reduces the amount of material that is needed for the equipment and distribution systems.

An important consideration in envelope design is internal heat and moisture gains. For example, as the insulating value of the envelope increases and air leakage decreases, internal heat gains from lights, plug loads, and occupants begin increasing cooling loads.

If the gains are not well understood and accounted for, thermal comfort may be difficult to maintain, especially in interior rooms and perimeter rooms without operable windows. For example, if the cooling system for a conference room is designed for a maximum of 20 people seated at a table, and yet the occupants add an outer circle of 25 more chairs, the room will overheat and likely become too humid.

Use of dehumidification and humidification must be considered carefully. It is crucial to dehumidify and to minimize accidental outdoor airflows in buildings when the indoor temperature is maintained below the outdoor air dewpoint. Otherwise condensation problems can become unavoidable. To address this problem, mechanical systems must be designed to deal with part-load cooling conditions in ways that maintain dehumidification. Dehumidification can be enhanced using run-around-loops, split-face staged cooling coils and desiccant systems—all with or without energy and latent recovery.

As outdoor air temperature drops below the indoor setpoints, the ventilating air begins to dehumidify and cool a building. At times, this is a particularly energy-efficient way to provide thermal comfort. Without proper controls, air-side economizers become the source of comfort problems by bringing in too much humidity. As outdoor air temperatures continue to drop, the ventilating air may dehumidify the building to the point of discomfort for the occupants. The greatest discomfort comes to those who have dry skin problems, like eczema, and those who are acclimated to higher humidity levels. People from humid climates have a great deal of trouble in dry climates until they physically acclimate to a new moisture regime, while natives experience no such problems.

Active humidification systems that are used to maintain humidity levels per ASHRAE Standard 55 can contribute to condensation problems in buildings. The problems may occur in the building envelope or in the mixing and distribution system. In Section 5.1.3 Humidity, Standard 55 states that other ASHRAE Standards (e.g., 62, 90.1 and 90.2) may have other requirements and "special precautions may be required to assure overall occupant acceptability even though the conditions of Standard 55 have been met." It further advises that biological air contaminants, whose production depends on humidity levels, are outside the scope of Standard 55. Section 5.1.3 provides a basis for carefully controlling humidification systems to maintain humidity levels at the lower boundary of the Standard 55 comfort zone or for avoiding active humidification altogether. Psychometric analysis can be used to provide a basis for not including active humidification systems in a building.

Complex combinations of envelope and mechanical system strategies can be evaluated by computer simulation. Natural ventilation strategies may be modeled using methods that incorporate interzonal airflow modeling such as TAS and CONTAMW.

Appendix C of the CHPS Standard allows greater latitude in defining thermally acceptable conditions for naturally ventilated buildings. For conditions to not just be acceptable, but preferable, the occupant must have control over them—by adjusting the extent of cool breezes, warm air and, in some climates, humidity level. Accordingly, an operable window is a design feature that can help provide this control.

The second portion of the credit can only be earned with active controls. Projects utilizing natural ventilation strategies cannot earn the second portion of this credit because humidity control is not achievable in naturally ventilated buildings.

Technologies

A wide variety of temperature and humidity control devices are available. These devices can be stand-alone units or may be integrated into the building control system to automatically control temperature and when required humidity levels. Seasonally programmable thermostats can be set to automatically adjust winter and summer temperature conditions to respond to ASHRAE Standard 55's seasonal clothing levels. Humidity monitors can also be used to alert building operations personnel to unusual moisture conditions within a building, which, if left uncontrolled, could lead to mold growth or moisture problems and also cause an active dehumidification system to run unnecessarily and waste energy.

Synergies and Trade-Offs

The interdependence of a mechanical system (size, type and distribution) with envelope characteristics (for moisture, heat and air flow control) can be used to:

- minimize energy use;
- maximize the effectiveness of mechanical systems;
- make better use of renewable energy sources; and
- design the structure to provide non-fan powered ventilation and cooling.

The design of the project site impacts the thermal comfort of building interiors. Sites that minimize heat islands and have landscaping that shades building surfaces tend to reduce temperature peaks. Addition of temperature and humidity monitoring equipment can affect the energy performance of the building and requires commissioning and measurement & verification attention. Buildings that are reused may not be as amenable to temperature and humidity monitoring and control because the building systems are already in place. Thermal and humidity measures can be integrated with CO_2 sensors, ventilation systems and occupant controls.

Resources

Web Sites

Advanced Desiccant Cooling & Dehumidification Program

www.nrel.gov/desiccantcool

A research and development program of the U.S. Department of Energy that works with industry to realize the potential of desiccant systems for reducing energy consumption and improving indoor air quality and comfort.

NIST Multizone Modeling Software

www.bfrl.nist.gov/IAQanalysis/Software.htm

The National Institute of Standards and Technology provides software such as CONTAMW, a multizone indoor air quality and ventilation analysis computer program designed to predict airflows and contaminant concentrations.

The Whole Building Design Guide

www.wbdg.org

The Indoor Environmental Quality section provides a wealth of resources including definitions, fundamentals, materials and tools.

Print Media

ASHRAE Guideline 1–1989: Guideline for the Commissioning of HVAC Systems, ASHRAE, 1989.

ASHRAE Standard 52–76: Method of Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter, ASTM, 1976.

ASHRAE Standard 62–1989: Ventilation for Acceptable Indoor Air Quality, ASHRAE, 1989.

ASHRAE Standard 111–1988: Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning and Refrigeration Systems, ASHRAE, 1988.

Dehumidification Enhancements for 100-Percent-Outside-Air AHUs: Parts I, II and III by Donald Gatley, *Heating Piping and Air Conditioning Magazine,* September, October and November, 2000 (available as fee-based downloads at HPAC.com)

Humidity Control Design Guide by L. Harriman, G.W. Brundett and R. Kittler, ASHRAE, 2000.

The Impact of Part-Load Air-Conditioner Operation on Dehumidification Performance: Validating a Latent Capacity Degradation Model by Hugh Henderson, Conference Proceedings IAQ and Energy 98, ASHRAE, 1998.

"The New Comfort Equation For Indoor Air Quality"by P.O. Fanger, *ASHRAE Journal,* October, pp. 33-38, 1989.

Selecting HVAC Systems for Schools by Arthur Wheeler and Walter Kunz, Jr., Maryland State Department of Education, 1994.

Thermal Comfort, by P.O. Fanger, McGraw Hill, 1973.

Thermal Delight in Architecture by Lisa Heschong, MIT Press, 1979.

"Unplanned Airflows and Moisture Problems" by T. Brennan, J. Cummings and J. Lstiburek, *ASHRAE Journal*, November, 2000

Definitions

Natural Ventilation provides acceptable air-change effectiveness and thermal comfort without the use of mechanical heating and cooling equipment. The natural effect of wind, stack effect and interior/exterior temperature differentials induce air circulation and replacement. Airflow is fan-assisted only when necessary.

The **Occupied Zone** is the region in an occupied space from 3 inches above the floor to 72 inches above the floor and greater than 2 feet from walls or fixed air conditioning equipment.

Relative Humidity is the ratio of partial density of water vapor in the air to the saturation density of water vapor at the same temperature.

Thermal Comfort is a condition of mind experienced by building occupants expressing satisfaction with the thermal environment.

Daylight and Views

Daylight 75% of Spaces

1 point

Intent

Provide for the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

Requirements

Achieve a minimum Daylight Factor of 2% (excluding all direct sunlight penetration) in 75% of all space occupied for critical visual tasks. Spaces excluded from this requirement include copy rooms, storage areas, mechanical plant rooms, laundry and other low occupancy support areas. Other exceptions for spaces where tasks would be hindered by the use of daylight will be considered on their merits.

Submittals

- ❑ Provide the LEED Letter Template signed by the architect or responsible party. Provide area calculations that define the daylight zone and provide prediction calculations or daylight simulation.

SS | WE | EA | MR | EQ | ID

Credit 8.2

1 point

Daylight and Views

Views for 90% of Spaces

Intent

Provide for the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

Requirements

Achieve direct line of sight to vision glazing for building occupants in 90% of all regularly occupied spaces. Examples of exceptions include copy rooms, storage areas, mechanical, laundry and other low occupancy support areas. Other exceptions will be considered on their merits.

Submittals

- ❑ Provide the LEED Letter Template and calculations describing, demonstrating and declaring that the building occupants in 90% of regularly occupied spaces will have direct lines of site to perimeter glazing. Provide drawings highlighting the direct line of sight zones.

Summary of Referenced Standard

There is no standard referenced for this credit.

Green Building Concerns

Daylighting improves the indoor environment of buildings by exposing occupants to natural light. Studies have demonstrated that productivity increases dramatically for those building occupants working in daylit areas. In addition, daylighting decreases energy costs for buildings by providing natural solar lighting. A well-designed daylit building is estimated to reduce lighting energy use by 50% to 80% (*Sustainable Building Technical Manual*, page IV.7).

Daylighting design involves a careful balance of heat gain and loss, glare control and variations in daylight availability. Shading devices, light shelves, courtyards, atriums and window glazing are all strategies employed in daylighting design. Important considerations include building orientation, window size and spacing, glass selection, reflectance of interior finishes and locations of interior walls.

Environmental Issues

Daylighting reduces the need for electric lighting of building interiors, resulting in decreased energy use. This conserves natural resources and reduces air pollution impacts due to energy production and consumption. Daylit spaces also increase occupant productivity and reduce absenteeism and illness.

Economic Issues

Specialized glazing can increase initial costs for a project and can lead to excessive heat gain if not designed properly. Glazing provides less insulating effects compared to standard walls and requires additional maintenance. However, offices with sufficient natural daylight have proven to increase occupant productivity and comfort. In most cases, occupant salaries significantly outweigh first costs of incorporating daylighting measures into a building design. Studies of schools and stores have shown that daylighting can improve student performance and retail sales (see the Resources section).

Daylighting can significantly reduce artificial lighting requirements and energy costs in many commercial and industrial buildings, as well as schools, libraries and hospitals. Daylighting, combined with energy-efficient lighting and electronic ballasts, can reduce the lighting power density in some office buildings by up to 30%.

Community Issues

Daylighting and outdoor views provide a connection with the building site and adjacent sites, creating a more integrated neighborhood. Daylit spaces increase occupant productivity and reduce illness and absenteeism.

Design Approach

Strategies

Determine if daylighting and direct line of sight to the outdoors is feasible and appropriate for the building. Some buildings cannot utilize natural daylighting goals due to site constraints or specialized building uses that prohibit sunlight penetration.

Orient the building on the project site to maximize daylighting options and adopt a building design with shallow floor plates to maximize daylit areas. Courtyards, atriums, clerestory windows, skylights, interior light shelves, exterior fins, louvers and adjustable blinds used alone or in combination are effective strategies to achieve deep daylight penetration. **Figure 1** illustrates various daylighting strategies.

The desired amount of daylight will differ depending on the tasks occurring in a daylit space. Daylit buildings often have several daylight zones with differing target light levels. In addition to light lev-

Credit Synergies

SS Credit 1
Site Selection

SS Credit 2
Urban Redevelopment

SS Credit 5
Reduced Site Disturbance

WE Credit 1
Water Efficient Landscaping

EA Prerequisite 1
Fundamental Building Systems Commissioning

EA Prerequisite 2
Minimum Energy Performance

EA Credit 1
Optimize Energy Performance

EA Credit 2
Renewable Energy

EA Credit 3
Additional Commissioning

EA Credit 5
Measurement & Verification

MR Credit 1
Building Reuse

EQ Credit 6
Controllability of Systems

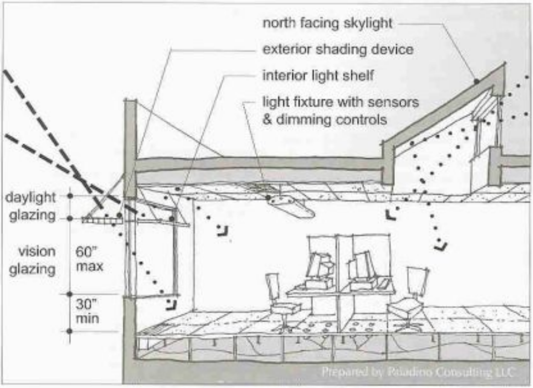


Figure 1: An Illustration of Various Daylighting Strategies

els, daylighting strategies should address interior color schemes, direct beam penetration and integration with the electric lighting system.

Glare control is perhaps the most common failure in daylighting strategies. Glare is defined as any excessively bright source of light within the visual field that creates discomfort or loss in visibility. Large window areas provide generous amounts of daylight to the task area. If not controlled properly, this daylight can produce unwanted glare. Measures to control glare include light shelves, louvers, blinds, fins and shades.

Technologies

Computer modeling software can be used to simulate daylighting conditions. Daylighting software produces continuous daylight contours to simulate the daylighting conditions of interior spaces and to account for combined effects of multiple windows within a daylit space.

Photo-responsive controls for electric lighting can be incorporated into daylighting strategies to maintain consistent light levels and to minimize occupant perception of the transition from natural light to artificial light. These controls result in energy savings by reducing electric lighting in high daylight conditions while preserving footcandle levels on the task surface.

Synergies and Trade-Offs

Project site selection and building orientation have a significant effect on the success of daylighting strategies. Vertical site elements such as neighboring buildings and trees may reduce the potential for daylighting. Reused buildings may have limited daylighting potential due to their orientation, number and size of building openings and floor plate dimensions. Finally, light sensors and automatic controls will affect the energy performance of the building and will require commissioning and measurement & verification attention.

Calculations

The following calculation methodology is used to support the credit submittals listed on the first page of this credit. The calculation methodology is divided into two sections: daylighting and views.

The **daylighting** calculation methodology below can be applied to approximate the daylight factor for each regularly occupied room in the building. The Daylight Factor (DF) is the ratio of exterior illumination to interior illumination and is expressed as a percentage. The variables used to determine the daylight factor include the floor area, window area, window geometry, visible transmittance (T_{vis}) and window height. This calculation method aims to provide a minimum 2% DF at the back of a space.

Areas to include in the daylighting calculations include all regularly occupied spaces such as office spaces, meeting areas and cafeterias. Areas that should not be considered include support areas for copying, storage, mechanical equipment, laundry and restrooms.

The daylighting calculations for this credit may be determined by either using daylighting simulation software or by following the methodology outlined in the following paragraphs:

1. Create a spreadsheet and identify all regularly occupied rooms. Determine the floor area of each applicable room using construction documents.

2. For each room identified, calculate the window area and use **Table 1** to indicate the acceptable window types. Note that window areas above 7'6" are considered to be daylight glazing. Glazing at this height is the most effective at distributing daylight deep into the interior space. Window areas from 2'6" to 7'6" are considered to be vision glazing. These window areas are primarily used for viewing and lighting interior spaces close to the building perimeter. Window areas below 2'6" do not contribute to daylighting of interior spaces and are excluded from the calculations.

3. For each window type, insert the appropriate geometry and height factors as listed in **Table 1**. The geometry factor indicates the effectiveness of a particular aperture to distribute daylight relative to window location. The height factor accounts for where light is introduced to the space.

4. For each window type, indicate the visible transmittance (T_{vis}), a variable number that differs for each product. T_{vis} is the recommended level of transmittance for selected glazing.

5. Calculate the Daylight Factor for each window type using **Equation 1**. For rooms with more than one window type, sum all window types to obtain a total Daylight Factor for the room.

6. If the total daylight factor for a room is 2% or greater, then the square footage of the room is applicable to the credit.

7. Sum the square footage of all applicable rooms and divide by the total square footage of all regularly occupied spaces. If this percentage is greater than 75%, then the building qualifies for the first point of this credit.

8. Note that glare control is also required for each window. **Table 1** provides best-practice glare control measures for different window types. Create a second spreadsheet that identifies the type of glare control applied to each window type.

Equation 1:

$$\text{Daylight Factor} = \frac{\text{Window Area [SF]}}{\text{Floor Area [SF]}} \times \text{Window Geometry} \times \frac{\text{Actual } T_{vis}}{\text{Minimum } T_{vis}} \times \text{Window Height Factor}$$

Table 1: Daylight Design Criteria

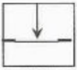
Window Type	Geometry Factor	Minimum T_{vis}	Height Factor	Best Practice Glare Control
 sidelight daylight glazing	0.1	0.7	1.4	Adjustable blinds Interior light shelves Fixed translucent exterior shading devices
 sidelighting vision glazing	0.1	0.4	0.8	Adjustable blinds Exterior shading devices
 toplighting vertical monitor	0.2	0.4	1.0	Fixed interior Adjustable exterior blinds
 toplighting sawtooth monitor	0.33	0.4	1.0	Fixed interior Exterior louvers
 toplighting horizontal skylights	0.5	0.4	1.0	Interior fins Exterior fins Louvers

Table 2 provides an example of daylighting calculations for an office building. All of the offices are considered to be regularly occupied spaces, while support areas such as hallways, foyers, storage areas, mechanical rooms and restrooms are not considered to be regularly occupied.

The example qualifies for the first point of this credit because it exceeds the minimum square footage for daylit area and includes glare control on all windows in daylit rooms.

Views are required for at least 90% of all regularly occupied rooms in order to achieve IEQ Credit 8.2. Use the following steps to perform view calculations.

1. Note if it is possible to view vision glazing in each regularly occupied room. Windows below 2'6" and windows above 7'6" (including daylight glazing, skylights and roof monitors) do not qualify for the credit. For best results use a copy of the floor plans and highlight areas of regularly occupied rooms that have a direct line of sight. Construct line of sight geometries at each window to identify non-view areas in each room (see **Figure 2** for guidance). Remember to take into account the wall thickness when determining oblique angles of sight through windows. Visually inspect each room and

Table 2: Sample Daylighting Calculations

Room	Floor Area	Glazing Area	Window Geometry		Transmittance (T^{vis})		Window Height	Daylight Factor		Daylit Area	Glare Control
	[SF]	[SF]	Type	Factor	Actual	Minimum	Factor	Each	Room	[SF]	
A	820	120	vision	0.1	0.9	0.4	0.8	2.6%	3.3%	820	2
		40	daylight	0.1	0.7	0.7	1.4	0.7%			3
B	410	75	vision	0.1	0.9	0.4	0.8	3.3%	4.1%	410	2
		25	daylight	0.1	0.7	0.7	1.4	0.9%			3
C	120	36	vision	0.1	0.4	0.4	0.8	2.4%	2.4%	120	2
D	95	25	vision	0.1	0.4	0.4	0.8	2.1%	2.1%	95	2
E	410	75	vision	0.1	0.9	0.4	0.8	3.3%	4.1%	410	2
		25	daylight	0.1	0.7	0.7	1.4	0.9%			3
F	820	75	vision	0.1	0.9	0.4	0.8	1.6%	2.1%	820	2
		25	daylight	0.1	0.7	0.7	1.4	0.4%			3
G	600	36	vision	0.1	0.4	0.4	0.8	0.5%	0.5%	0	2
H	120	36	vision	0.1	0.4	0.4	0.8	2.4%	2.4%	120	6
I	95	32	vision	0.1	0.4	0.4	0.8	2.7%	2.7%	95	6
J	95	32	vision	0.1	0.4	0.4	0.8	2.7%	2.7%	95	1
K	410	36	sawtooth	0.33	0.4	0.4	1.0	2.9%	2.9%	410	4
TOTAL	**3,730**									**3,395**	
Percentage of Daylit Area										**85%**	

Glare Control Chart

Type	Description
1	Fixed Exterior Shading Devices
2	Light shelf, exterior
3	Light Shelf, interior
4	Interior Blinds
5	Pull-down shades
6	Fritted glazing
7	Drapes
8	Electronic black-out glazing

compare areas with access to views against areas without access. If the view area is greater than or equal to 90% of the room area, then the square footage of the **entire** room is applicable to the credit.

In cases where it is difficult to determine the percentage visually, measure the actual square footage on the plans more precisely. For non-perimeter spaces with vision glazing, include a narrative and detailed building section drawing to explain access to views.

2. Sum the square footage of all applicable rooms and divide by the total square footage of all regularly occupied spaces. If this percentage is greater than 90%, then the building qualifies for the second point of this credit.

Resources

Web Sites

Analysis of the Performance of Students in Daylit Schools

www.innovativedesign.net

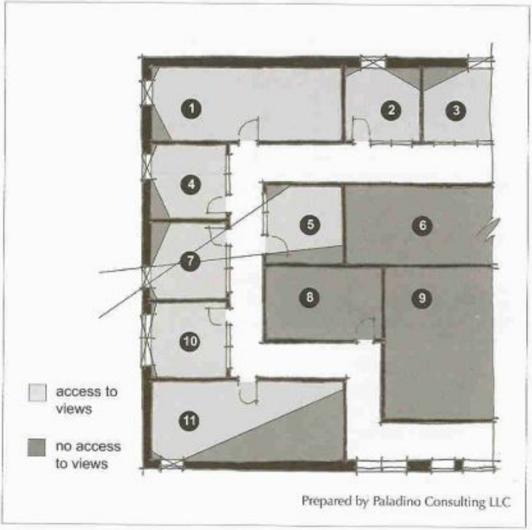
Nicklas and Bailey's 1996 study of three daylit schools in North Carolina.

The Art of Daylighting

www.edcmag.com (see Jan/Feb 1998 archive)

This *Environmental Design & Construction* article provides a solid introduction to daylighting.

Figure 2: An Illustration Showing Access to Views



New Buildings Institute's Productivity and Building Science Program

www.newbuildings.org/pier

Provides links to case studies and reports on the benefits of daylighting.

Radiance Software

radsite.lbl.gov

Free daylighting simulation software from the Lawrence Berkeley National Laboratory

Tips for Daylighting with Windows

eande.lbl.gov/BTP/pub/designguide/download.html

A daylighting comprehensive guide from Lawrence Berkeley National Laboratory

The Whole Building Design Guide

www.wbdg.org

The Daylighting and Lighting Control section provides a wealth of resources including definitions, fundamentals, materials and tools.

Print Media

"Daylighting Design" by Benjamin Evans, in *Time-Saver Standards for Architectural Design Data*, McGraw-Hill, Inc., 1997.

Daylighting for Sustainable Design by Mary Guzowski, McGraw-Hill, Inc., 1999.

Daylighting Performance and Design by Gregg D. Ander, John Wiley & Sons, 1997.

Sustainable Building Technical Manual, Public Technology, Inc., 1996 (www.pti.org).

Definitions

Daylight Factor is the ratio of interior illuminance at a given point on a given plane (usually the workplane) to the exterior illuminance under known overcast sky conditions. LEED uses a simplified approach for its credit compliance calculations.

Daylighting is the controlled admission of natural light into a space through glazing with the intent of reducing or eliminating electric lighting. By utilizing solar light, daylighting creates a stimulating and productive environment for building occupants.

Visible Transmittance (T_{vis}) is the ratio of total transmitted light to total incident light. In other words, it is the amount of light passing through a glazing surface divided by the amount of light striking the glazing surface. A higher T_{vis} value indicates that a greater amount of incident light is passing through the glazing.

Case Study

NW Federal Credit Union
Seattle, Washington

Courtesy of Paladino Consulting LLC

Owner
NW Federal Credit Union

The NW Federal Credit Union building is a commercial office facility that houses a financial institution. The building was designed to harvest site resources and create a positive work atmosphere for building occupants as well as showcase environmental measures for banking patrons. The building is oriented on an east-west axis, and the floor plates are elongated to maximize solar access into the building interiors. Exterior shading devices and interior light shelves direct sunlight into the space without causing undesirable glare. Window glazing was selected to reduce glare on computer monitors while allowing natural light into the occupied spaces. Finally, interior finish colors were chosen to bounce light to the deep interior spaces, creating a vibrant and positive workspace.

Innovation & Design Process

SS | WE | EA | MR | EQ | ID

Overview

Sustainable design strategies and measures are constantly evolving and improving. New technologies are continually introduced to the marketplace and up-to-date scientific research influences building design strategies. The purpose of this LEED™ category is to recognize projects for innovative building features and sustainable building knowledge.

Occasionally, a strategy results in building performance that greatly exceeds those required in an existing LEED credit. Other strategies may not be addressed by any LEED prerequisite or credit but warrant consideration for their sustainability benefits. Finally, expertise in sustainable building is essential to the design and construction process. All of these issues are rewarded in this category.

Overview of LEED™ Credits

ID Credit 1
Innovation in Design

ID Credit 2
LEED™ Accredited Professional

There are 5 points available in the Design Excellence category.

SS	WE	EA	MR	EQ	ID

Credit 1

1–4 points

Innovation in Design

Intent

To provide design teams and projects the opportunity to be awarded points for exceptional performance above the requirements set by the LEED Green Building Rating System and/or innovative performance in Green Building categories not specifically addressed by the LEED Green Building Rating System.

Requirements

Credit 1.1 (1 point)	Identify the **intent** of the proposed innovation credit, the proposed **requirements** for compliance, the proposed **submittals** to demonstrate compliance, and the **design approach** (strategies) that might be used to meet the requirements.
Credit 1.2 (1 point)	Same as Credit 1.1
Credit 1.3 (1 point)	Same as Credit 1.1
Credit 1.4 (1 point)	Same as Credit 1.1

Submittals

- ❑ Provide the proposal(s) within the LEED Letter Template (including intent, requirements, submittals and possible strategies) and relevant evidence of performance achieved.

Summary of Referenced Standard

There is no standard referenced for this credit.

Green Building Concerns

The LEED Green Building Rating System was devised to address current sustainable issues involved in commercial building design. However, the building industry is constantly evolving and introducing new sustainable strategies and measures. It is important to stay abreast of current developments in sustainable building and incorporate those strategies and products that optimize built spaces. Innovation credits are the vehicle by which LEED recognizes and awards such accomplishments.

Additionally, innovation in design may be awarded if a project achieves exemplary performance under an existing LEED credit. Points for exemplary performance are available only for those credits where the outcome provides substantial benefits.

Environmental Issues

With all sustainable design strategies and products, it is important to consider the related impacts to the environment and occupant well-being, and to assure that other building aspects are not adversely impacted.

Economic Issues

Innovative strategies and measures have variable first costs and operating costs, depending on the degree of complexity, materials incorporated, and the novelty of the technology. Initial costs can range from free to prohibitively expensive. To understand the implications of design features, a life cycle analysis can be applied to determine if the strategy or product is cost-effective over the lifetime of the building.

Community Issues

Community issues are those that affect others in close proximity to the project, as well as members of regional and world communities. Local actions can have dramatic effects on the world when considered in aggregate.

Case Study

Phillip Merrill Environmental Center Headquarters
Annapolis, Maryland

Courtesy of U.S. Green Building Council

Owner
Chesapeake Bay Foundation

The Phillip Merrill Environmental Center Headquarters is a LEED Version 1.0 Platinum project housing the Chesapeake Bay Foundation. The project is located on 31 acres of diverse habitat on the Chesapeake Bay and functions as an office building as well as an education and training facility. A rigorous water efficiency program was instituted to minimize potable water use in the building. A water recovery system collects roof runoff and filters these volumes before reuse in non-potable applications such as hand washing, mop sinks, dessicant makeup, and laundry. The stored water is also used as supply for the fire suppression system. Potable water volumes are only used for showers and kitchen sinks. Composting toilets are used to further reduce potable water use and greatly reduce sewage volume. In aggregate, these measures result in water savings that exceed the Energy Policy Act (EPACT) of 1992 by over 90%, greatly exceeding the requirements of Water Efficiency Credit 3: Water Use Reduction.

Design Approach

Strategies

There are two types of innovation strategies that qualify under this credit. The first type includes those strategies that greatly exceed the requirements of existing LEED credits. For instance, a project that incorporates energy or water efficiency measures that provide extraordinary savings and greatly exceed the requirements of their respective LEED credits would be appropriate for this credit. Points for exemplary performance are available only for those credits where the outcome provides outstanding, measurable benefits to the environment and/or building occupants.

The second type of innovation strategies are those that are not addressed by any existing LEED credits. Only those strategies that have significant environmental and occupant benefits are applicable.

Simple signage in a building would not be considered a significant educational effort by itself. Conversely, a visitor's center and interactive display, coupled with a Web site and video would be an appropriate level of effort for earning an innovation credit. In other words, substantial efforts must be applied to innovation credits. A separate set of submittals is required for each point awarded and no strategy can achieve more than one point. Four independent sustainability measures may be applied to this credit.

Case Study

Oquirrh Park Speed Skating Oval
Salt Lake City, Utah

Courtesy of GSBS Architects

Owner
Salt Lake Organizing Committee

The Utah Olympic Speed Skating Oval is a LEED Version 1.0 Certified project that hosted skating events for the 2002 Olympic Winter Games. Several roof systems were analyzed for the project and a cable suspension roof was chosen over conventional truss and arch systems for two significant benefits. First, the cable suspension system reduced the enclosed volume of the building by 20% when compared with a parallel chord truss system. This resulted in a smaller HVAC system and lower air conditioning costs. The second benefit of the cable suspension system was substantial material use reduction. The weight of the chosen system is 18 lbs/sf, 25% less than the next lightest system (a tied arch roof). This resulted in an estimated savings of 600 tons of steel, equivalent to $850,000. Overall, the choice of the cable suspension roof for the project reduced the amount of raw materials and processing for the roof, reduced construction cost, and reduced operating costs over the lifetime of the building.

LEED™ Accredited Professional

SS WE EA MR EQ **ID**

Credit 2

1 point

Intent

To support and encourage the design integration required by a LEED Green Building project and to streamline the application and certification process.

Requirement

At least one principal participant of the project team that has successfully completed the LEED Accredited Professional exam

Submittals

- ❑ Provide the LEED Letter Template stating the LEED Accredited Professional's name, title, company and contact information. Include a copy of this person's LEED Accredited Professional Certificate.

Summary of Referenced Standard

There is no standard referenced for this credit.

SS | WE | EA | MR | EQ | ID

Credit 2

Green Building Concerns

LEED Accredited Professionals have the expertise required to design a building to LEED standards and to coordinate the documentation process that is necessary for LEED certification. The Accredited Professional understands the importance of integrated design and the need to consider interactions between the prerequisites and credits and their respective criteria. Architects, engineers, consultants, owners, and others who have a strong interest in sustainable building design are all appropriate candidates for accreditation. The Accredited Professional should be the champion for the project's LEED application and this person should be an integral member of the project design team.

Design Approach

Strategies

To become a LEED Accredited Professional, the LEED Accreditation Exam must be successfully passed. To prepare for the exam, it is helpful to attend a LEED Workshop offered by, or authorized by, the USGBC. Workshops include details on prerequisites and credits, calculation and documentation examples, and case studies from projects that have achieved certification.

For more information on workshops and the Accreditation Exam, visit the LEED section of the USGBC Web site: www.leedbuilding.org.

Index of Definitions

CERCLA 28
Refers to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly known as Superfund. CERCLA addresses abandoned or historical waste sites and contamination. It was enacted in 1980 to create a tax on the chemical and petroleum industries and provided federal authority to respond to releases of hazardous substances.

Chain-of-Custody 211
A tracking procedure to document the status of a product from the point of harvest or extraction to the ultimate consumer end use.

Chain-of-Custody 236
A document that tracks the movement of a wood product from the forest to a vendor and is used to verify compliance with FSC guidelines. A "vendor" is defined as the company that supplies wood products to project contractors or subcontractors for on-site installation.

Chlorofluorocarbons (CFCs) 132, 172
Hydrocarbons that deplete the stratospheric ozone layer.

Community 16
An interacting population of individuals living in a specific area.

Composting Toilet 107
A dry plumbing fixture that contains and treats human waste via microbiological processes.

Conditioned Space 258
The portion of the building that is heated or cooled, or both, for the comfort of building occupants.

Constructed Wetland 57
An engineered system designed to simulate natural wetland functions for water purification. Constructed wetlands are essentially treatment systems that remove contaminants from wastewaters.

Construction, Demolition and Land Clearing (CDL) Debris 205
Includes waste and recyclables generated from construction, land clearing (e.g., vegetation, but not soil), renovation, and demolition or deconstruction of pre-existing structures.

Construction IAQ Management Plan 266
A document specific to a building project that outlines measures to minimize contamination in the building during construction and to flush the building of contaminants prior to occupancy.

Curfew Hours 76
Locally determined times when greater lighting restrictions are imposed.

Cutoff Angle 76
The angle between the vertical axis of a luminaire and the first line of sight (of a luminaire) at which the light source is no longer visible.

Daylight Factor 309
The ratio of interior illuminance at a given point on a given plane (usually the workplane) to the exterior illuminance under known overcast sky conditions. LEED uses a simplified approach for its credit compliance calculations.

Daylighting 309
The controlled admission of natural light into a space through glazing with the intent of reducing or eliminating electric lighting. By utilizing solar light, daylighting creates a stimulating and productive environment for building occupants.

Development Footprint 16, 47
The area on the project site that has been impacted by any development activity. Hardscape, access roads, parking lots, non-building facilities and building structure are all included in the development footprint.

Drip Irrigation 89
A high-efficiency irrigation method in which water drips to the soil from perforated tubes or emitters.

Ecosystem 16
A basic unit of nature that includes a community of organisms and their nonliving environment linked by biological, chemical, and physical process.

Endangered Species 16
An animal or plant species that is in danger of becoming extinct throughout all or a significant portion of its range due to harmful human activities or environmental factors.

Energy Conservation Measures (ECMs) 179
Installations of equipment or systems, or modifications of equipment or systems, for the purpose of reducing energy use and/or costs.

Environmental Tobacco Smoke (ETS) 248
Also known as secondhand smoke, consists of airborne particles emitted from the burning end of cigarettes, pipes, and cigars, and exhaled by smokers. These particles contain about 4,000 different compounds, up to 40 of which are known to cause cancer.

Erosion 11
A combination of processes in which materials of the earth's surface are loosened, dissolved or worn away, and transported from one place to another by natural agents.

Evapotranspiration 89
The loss of water by evaporation from the soil and transpiration from plants.

Ex-Situ Remediation 28
Involves the removal of contaminated soil and groundwater. Treatment of the contaminated media occurs in another location, typically a treatment facility. A traditional method of ex-situ remediation is pump-and-treat technology that uses carbon filters and incineration. More advanced methods of ex-situ remediation include chemical treatment or biological reactors.

Fixture Sensors 107
Applied to lavatories, sinks, water closets and urinals to sense fixture use and automatically turn on and off.

Footcandle (fc) 77
A measure of light falling on a given surface. One footcandle is equal to the quantity of light falling on a one-square-foot area from a one candela light source at a distance of one foot. Footcandles can be measured both horizontally and vertically by a footcandle or "light meter."

Formaldehyde 278
A naturally occurring VOC, is found in small amounts in animals and plants, but is carcinogenic and an irritant to most people when present in high concentrations—causing headaches, dizziness, mental impairment, and other symptoms. When present in the air at levels above 0.1 ppm (parts per million parts of air), it can cause watery eyes, burning sensations in the eyes, nose, and throat; nausea; coughing; chest tightness; wheezing; skin rashes; and asthmatic and allergic reactions. Urea formaldehyde is a combination of urea and formaldehyde that is used in some glues and readily decomposes at room temperature. Phenol formaldehyde, which off-gasses only at high temperature, is used for exterior products, although many of those products are suitable for interior applications.

Full Cutoff Luminaire 77
Has zero candela intensity at an angle of 90 degrees above the vertical axis (nadir) and at all angles greater than 90 degrees from nadir. Additionally, the candela per 1000 lamp lumens does not numerically exceed 100 (10 %) at an angle of 80 degrees above nadir. This applies to all lateral angles around the luminaire.

Glare 77
The sensation produced by luminance within the visual field that is significantly greater than the luminance to which the eyes are adapted, which causes annoyance, discomfort or loss in visual performance and visibility

Graywater 89
Wastewater from lavatories, showers, bathtubs, washing machines and sinks that are not used for disposal of hazardous or toxic ingredients or wastes from food preparation.

Greenfield 24, 47
Undeveloped land or land that has not been impacted by human activity.

Group Multi-Occupant Spaces 291
Include conference rooms, classrooms and other indoor spaces used as a place of congregation for presentations, trainings, etc. Individuals using these spaces share the lighting and temperature controls.

Halons 172
Substances used in fire suppression systems and fire extinguishers in buildings. These substances deplete the stratospheric ozone layer.

Heat Island Effects 66
Occur when warmer temperatures are experienced in urban landscapes compared to adjacent rural areas as a result of solar energy retention on constructed surfaces. Principal surfaces that contribute to the heat island effect include streets, sidewalks, parking lots and buildings.

Daylighting 309
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Installations of equipment or systems, or modifications of equipment or systems, for the purpose of reducing energy use and/or costs.

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Erosion 11
A combination of processes in which materials of the earth's surface are loosened, dissolved or worn away, and transported from one place to another by natural agents.

Evapotranspiration 89
The loss of water by evaporation from the soil and transpiration from plants.

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Involves the removal of contaminated soil and groundwater. Treatment of the contaminated media occurs in another location, typically a treatment facility. A traditional method of ex-situ remediation is pump-and-treat technology that uses carbon filters and incineration. More advanced methods of ex-situ remediation include chemical treatment or biological reactors.

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Applied to lavatories, sinks, water closets and urinals to sense fixture use and automatically turn on and off.

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Undeveloped land or land that has not been impacted by human activity.

Group Multi-Occupant Spaces 291
Include conference rooms, classrooms and other indoor spaces used as a place of congregation for presentations, trainings, etc. Individuals using these spaces share the lighting and temperature controls.

Halons 172
Substances used in fire suppression systems and fire extinguishers in buildings. These substances deplete the stratospheric ozone layer.

Heat Island Effects 66
Occur when warmer temperatures are experienced in urban landscapes compared to adjacent rural areas as a result of solar energy retention on constructed surfaces. Principal surfaces that contribute to the heat island effect include streets, sidewalks, parking lots and buildings.

HVAC Systems 266
Include heating, ventilating, and air-conditioning systems used to provide thermal comfort and ventilation for building interiors.

Hydrochlorofluorocarbons (HCFCs) 132
Refrigerants that cause significantly less depletion of the stratospheric ozone layer compared to CFCs.

Hydrochlorofluorocarbons (HCFCs) 172
Refrigerants used in building equipment that deplete the stratospheric ozone layer, but to a lesser extent than CFCs.

Hydrofluorocarbons (HFCs) 172
Refrigerants that do not deplete the stratospheric ozone layer. However, some HFCs have high global warming potential and, thus, are not environmentally benign.

Illuminance 77
The amount of light falling on a surface, measured in units of footcandles (fc) or lux (lx).

Impervious Surfaces 57
Promote runoff of precipitation volumes instead of infiltration into the subsurface. The imperviousness or degree of runoff potential can be estimated for different surface materials.

Individual Multi-Occupant Space 291
Typically an open office plan. These spaces normally contain standard workstations where each individual must have comfort controls to earn Credit 6.2.

Indoor Air Quality 244
The nature of air that affects the health and well-being of building occupants.

Infrared Emittance 66
Refers to thermal emittance (see page 327).

In-Situ Remediation 28
Involves treatment of contaminants in place using technologies such as injection wells or reactive trenches. These methods utilize the natural hydraulic gradient of groundwater and usually require only minimal disturbance of the site.

Landfill 190
A waste disposal site for the deposit of solid waste from human activities.

Light Pollution 77
Caused by stray light from unshielded light sources and light reflecting off surfaces that enters the atmosphere where it illuminates and reflects off dust, debris and water vapor to cause an effect know as "sky glow." Light pollution can substantially limit visual access to the night sky, compromise astronomical research, and adversely affect nocturnal environments. Stray light that enters the atmosphere does not increase nighttime safety or security and needlessly consumes energy and natural resources.

Light Trespass 77
Commonly thought of as "the light shining in my window." It is defined as obtrusive light that is unwanted, because of quantitative, directional or spectral attributes. Light trespass causes annoyance, discomfort, distraction or a loss of visibility

Local Zoning Requirements 47
Local government regulations imposed to promote orderly development of private lands and to prevent land use conflicts.

Luminance 77
What we commonly call brightness or the light coming from a surface or light source. Luminance is composed of the intensity of light striking an object or surface and the amount of that light reflected back toward the eye. Luminance is measured in footlamberts (fl) or candela per square meter (cd/m2).

Mass Transit 40
Includes transportation facilities designed to transport large groups of persons in a single vehicle such as buses or trains.

Native/Adapted Plants 47
Those that are indigenous to a locality or have adapted to the local climate and are not invasive. Such plants do not require irrigation or fertilization once root systems are established in the soil.

Natural Ventilation 258
The process of supplying and removing air without mechanical ductwork in building spaces by using openings such as windows and doors, non-powered ventilators, and infiltration processes.

Natural Ventilation 300
Provides acceptable air-change effectiveness and thermal comfort without the use of mechanical heating and cooling equipment. The natural effect of wind, stack effect and interior/exterior temperature differentials induce air circulation and replacement. Airflow is fan-assisted only when necessary.

Non-Occupied Spaces 291
Include all rooms used by maintenance personnel and not open for use by occupants. Included are janitorial, storage and equipment rooms, and closets.

Non-Regularly Occupied Spaces 291
Include corridors, hallways, lobbies, break rooms, copy rooms, storage rooms, kitchens, restrooms, stairwells, etc.

Occupied Zone 300
The region in an occupied space from 3 inches above the floor to 72 inches above the floor and greater than 2 feet from walls or fixed air conditioning equipment.

On-Site Wastewater Treatment 98
Uses localized treatment systems to transport, store, treat and dispose of wastewater volumes generated on the project site.

Open-Grid Pavement 67
Defined for LEED purposes as pavement that is less than 50% impervious.

Open Space Area 47
The property area minus the development footprint. Open space must be vegetated and pervious, thus providing habitat and other ecological services.

Post-Consumer Recycled Content 220
Consumer waste that has become a raw material (feedstock) for another product. It originates from products that have served a useful purpose in the consumer market. Much of this feedstock comes from residential and commercial (office) recycling programs for aluminum, glass, plastic and paper. Other post-consumer feedstock is supplied by businesses that recycle construction and demolition debris.

Post-Industrial Recycled Content 220
Output from a process that has not been used as part of a consumer product, that is sold, traded, or exchanged under commercial terms (including auditable transactions between profit centers within an organization) as feedstock for another industrial process, and that would otherwise be landfilled, incinerated or somehow disposed of as a waste, as defined by the Federal Trade Commission. For instance, a composite board manufacturer may purchase (or haul away for free) sawdust from a lumber mill or waste straw from a wheat farm. Wood chips would not fit this definition.

Potable Water 89
Water that is suitable for drinking and is supplied from wells or municipal water systems.

Potable Water 98
Water that meets drinking water quality standards and is approved for human consumption by the state or local authorities having jurisdiction.

Property Area 24
The legal property boundary of a project and includes all areas of the site including constructed areas and non-constructed areas.

Public Transportation 40
Bus, rail or other transportation service for the general public on a regular, continual basis that is publicly or privately owned.

RCRA 28
Refers to the Resource Conservation and Recovery Act. RCRA focuses on active and future facilities. It was enacted in 1976 to give the EPA authority to control hazardous wastes from cradle to grave, including generation, transportation, treatment, storage and disposal. Some non-hazardous wastes are also covered under RCRA.

Recycling 190, 205
The collection, reprocessing, marketing and use of materials that were diverted or recovered from the solid waste stream.

Refrigerants 132
The working fluids of refrigeration cycles. They absorb heat from a reservoir at low temperatures and reject heat at higher temperatures.

Regularly Occupied Spaces 291
Areas where workers are seated or standing as they work inside a building.

Relative Humidity 300
The ratio of partial density of water vapor in the air to the saturation density of water vapor at the same temperature.

Remediation 29
The process of cleaning up a contaminated site by physical, chemical or biological means. Remediation processes are typically applied to contaminated soil and groundwater.

Return Air 252
Air removed from conditioned spaces that is either recirculated in the building or exhausted to the outside.

Reuse 205
A strategy to return materials to active use in the same or a related capacity.

Risk Assessment 29
A methodology used to analyze for potential health effects caused by contaminants in the environment. Information from the risk assessment is used to determine cleanup levels.

Salvaged Materials 211
Construction materials recovered from existing buildings or construction sites and reused in other buildings. Common salvaged materials include structural beams and posts, flooring, doors, cabinetry, brick and decorative items. See the Synergies section for more LEED-related details.

Sedimentation 11
The addition of soils to water bodies by natural and human-related activities. Sedimentation decreases water quality and accelerates the aging process of lakes, rivers and streams.

Shielding 77
A non-technical term that describes devices or techniques that are used as part of a luminaire or lamp to limit glare, light trespass and light pollution.

Sick Building Syndrome 244
A situation in which a substantial proportion of building occupants experience acute discomfort and negative health effects as a result of exposure to contaminated air in the building.

Site Area 24
Defined the same as property area.

Site Assessment 29
An evaluation of above-ground (including facilities) and subsurface characteristics, including the geology and hydrology of the site, to determine if a release has occurred, as well as the extent and concentration of the release. Information generated during a site assessment is used to support remedial action decisions.

Solar Reflectance (albedo) **67**
The ratio of the reflected solar energy to the incoming solar energy over wavelengths of approximately 0.3 to 2.5 micrometers. A reflectance of 100% means that all of the energy striking a reflecting surface is reflected back into the atmosphere and none of the energy is absorbed by the surface. The best standard technique for its determination uses spectro-photometric measurements with an integrating sphere to determine the reflectance at each different wavelength. An averaging process using a standard solar spectrum then determines the average reflectance (see ASTM Standard E903).

Square Footage (of a building) **24**
The total area in square feet of all rooms including corridors, elevators, stairwells and shaft spaces.

Stormwater Runoff **57**
Consists of water volumes that are created during precipitation events and flow over surfaces into sewer systems or receiving waters. All precipitation waters that leave project site boundaries on the surface are considered to be stormwater runoff volumes.

Supply Air **252**
Air delivered to conditioned spaces for use in ventilating, heating, cooling, humidifying, and dehumidifying those spaces.

Sustainable Forestry **236**
The practice of managing forest resources to meet the long-term forest product needs of humans while maintaining the biodiversity of forested landscapes. The primary goal is to restore, enhance and sustain a full range of forest values—economic, social and ecological.

Tertiary Treatment **98**
The highest form of wastewater treatment and includes removal of organics, solids and nutrients as well as biological or chemical polishing, generally to effluent limits of 10 mg/L BOD_5 and 10 mg/L TSS.

Thermal Comfort **300**
A condition of mind experienced by building occupants expressing satisfaction with the thermal environment.

Thermal Emittance **66**
A parameter between 0 and 1 (or 0% and 100%) that indicates the ability of a material to shed infrared radiation (heat). The wavelength range for this radiant energy is roughly 3 to 40 micrometers. Most building materials (including glass) are opaque in this part of the spectrum, and have an emittance of roughly 0.9. Materials such as clean, bare metals are the most important exceptions to the 0.9 rule. Thus clean, untarnished galvanized steel has low emittance, and aluminum roof coatings have intermediate emittance levels.

Threatened Species **16**
An animal or plant species that is likely to become endangered within the foreseeable future.

Tipping Fees **205**
Fees charged by a landfill for disposal of waste volumes. The fee is typically quoted for one ton of waste.

Total Phosphorous (TP) 57
Consists of organically bound phosphates, poly-phosphates and orthophosphates in stormwater, the majority of which originates from fertilizer application. Chemical precipitation is the typical removal mechanism for phosphorous.

Total Suspended Solids (TSS) 57
Particles or flocs that are too small or light to be removed from stormwater via gravity settling. Suspended solid concentrations are typically removed via filtration.

Tracer Gas 258
A gas that can be mixed with building air in small amounts to study airflow patterns and measure the age of air and air-change rates.

Underground Parking 67
A "tuck-under" or stacked parking structure that reduces the exposed parking surface area.

Ventilation 244
The process of supplying and removing air to and from interior spaces by natural or mechanical means.

Ventilation 258
The process of supplying and removing air by natural or mechanical means in building spaces.

Ventilation Effectiveness 258
Refers to the movement of the supply air (that contains fresh outdoor air) through the occupied space.

Visible Transmittance (T_{vis}) 309
The ratio of total transmitted light to total incident light. In other words, it is the amount of light passing through a glazing surface divided by the amount of light striking the glazing surface. A higher T_{vis} value indicates that a greater amount of incident light is passing through the glazing.

Volatile Organic Compounds (VOCs) 278
Carbon compounds that participate in atmospheric photochemical reactions (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonates, and ammonium carbonate). The compounds vaporize (become a gas) at normal room temperatures.

Waterless Urinal 107
A dry plumbing fixture that uses advanced hydraulic design and a buoyant fluid instead of water to maintain sanitary conditions.

Wetland Vegetation 17
Consists of plants that require saturated soils to survive as well as certain tree and other plant species that can tolerate prolonged wet soil conditions.

Xeriscape 89
Also known as "dry landscape" designs. Adopt water conservation as the primary objective. Xeriscape landscapes are based on sound horticultural practices and incorporate native plant species that are adapted to local climate conditions.