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.

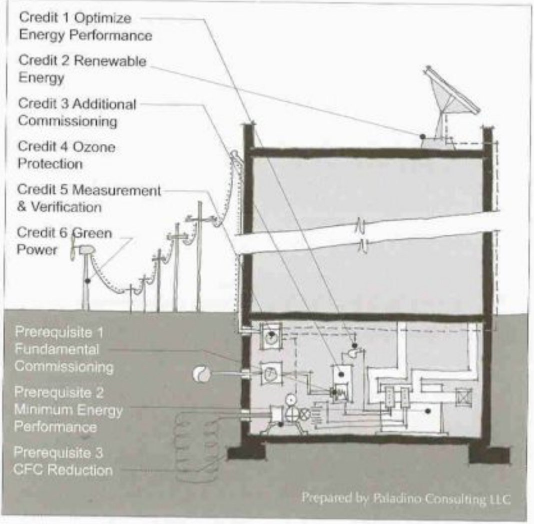

Figure 1: Overview of LEED Prerequisites & Credits

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).

Minimum Energy Performance

SS WE EA MR EQ ID

Prerequisite 2

Required

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 re-utilize 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 nameplate 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.

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)

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 [10³ 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


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™ 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.

SS	WE	EA	MR	EQ	ID

Credit 2.1

1 point

Renewable Energy

5%

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 non-polluting 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.

SS	WE	EA	MR	EQ	ID
Credit 3					

1 point

Additional Commissioning

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.

Ozone Protection

1 point

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.

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.

Measurement & Verification

1 point

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.

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

Courtesy of Zimmerman Design Group

Owner
Johnson Controls, Inc.

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.

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.