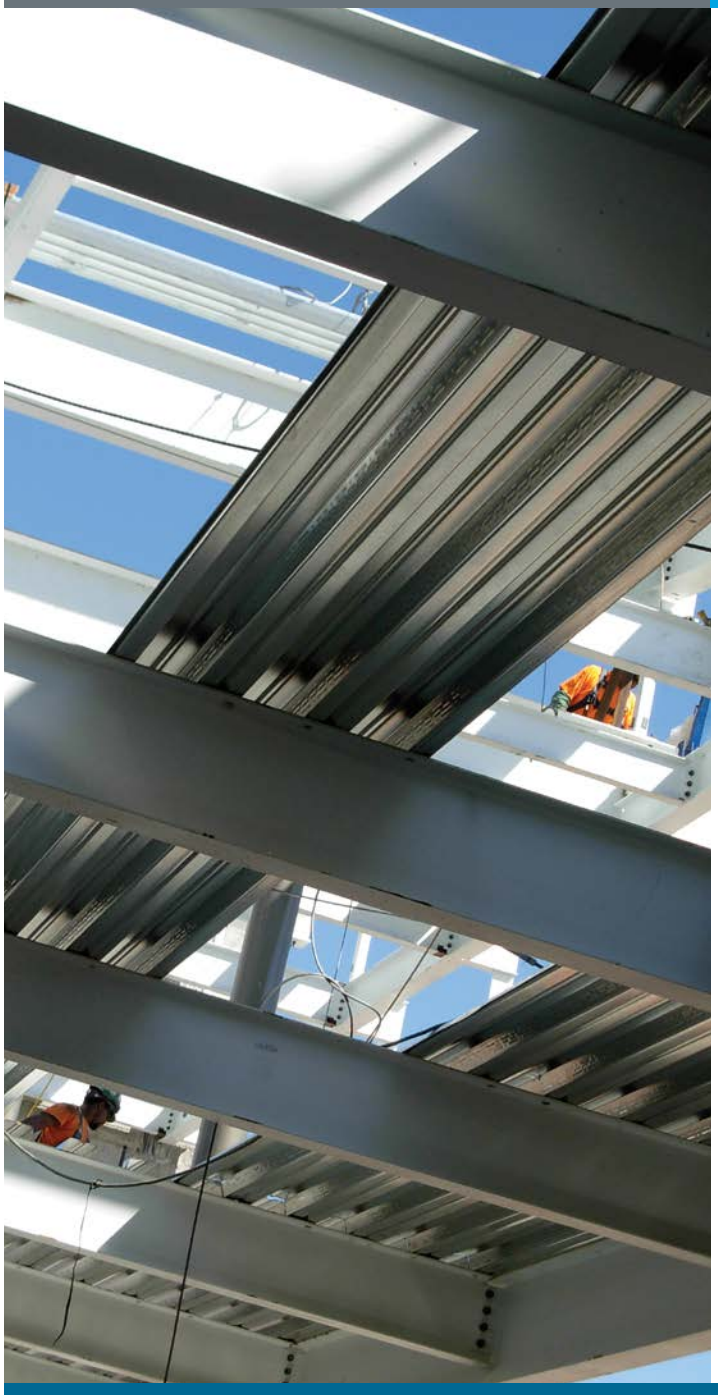
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FEDERAL ENERGY MANAGEMENT PROGRAM



Procuring Architectural and Engineering Services for Energy Efficiency and Sustainability

A Resource Guide for Federal Construction Project Managers

U.S. Department of Energy

Energy Efficiency and Renewable Energy

Federal Energy Management Program

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Procuring Architectural and Engineering Services for Energy Efficiency and Sustainability

A Resource Guide for Federal Construction Project Managers

Eliza Hotchkiss, Andy Walker, and Nancy Carlisle

National Renewable Energy Laboratory

October 2012

NOTE TO READER

This document is intended to provide Federal agencies with initial guidelines on how to enhance sustainability in the procurement of architectural and engineering services. It is not meant to replace agency-specific legal guidance. This document is based on best practices and the experience of agency personnel and laboratory and industry collaborators. Each agency, however, develops internal rules and regulations regarding procurement, therefore it is important to emphasize that the experiences and outcomes vary greatly. For example, there are substantial differences between statutes for military agencies as compared to those for most civilian agencies. Further, the procurement of architectural and engineering services in the Federal sector (as well as in U.S. market sectors) is a dynamic and rapidly evolving industry. As Federal agencies work to navigate their own procurement rules, many others in the energy efficiency and renewable energy industry also endeavor to understand how to incorporate sophisticated contracting models and legal agreements into the Federal procurement process. It therefore is vital to acknowledge that new lessons, information, and projects likely will develop in the future, and could provide new or different guidance not included in this document.

Acknowledgements

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This guide was produced as a collaborative effort of professionals in several Federal agencies. In order to continuously improve the recommendations we have made here, please participate in this collaboration and forward comments or contributions to the local FEMP representative or any of the FEMP contacts listed below.

Acronyms and Abbreviations

ASHRAE . . . . . American Society of Heating, Refrigerating, and Air-Conditioning Engineers

ASTM . . . . . American Society for Testing and Materials

BEPAC . . . . . Building Environmental Performance Assessment Criteria

BREEAM . . . . . Building Research Establishment Environmental Assessment Method

Btu . . . . . British thermal unit

CCB . . . . . construction criteria base

CFR . . . . . code of Federal regulations

CO_2e . . . . . carbon dioxide equivalents

CO_2 . . . . . carbon dioxide

DOD . . . . . U.S. Department of Defense

DOE . . . . . U.S. Department of Energy

EPAct . . . . . Energy Policy Act

FEMP . . . . . Federal Energy Management Program

GSA . . . . . General Services Administration

HVAC . . . . . heating, ventilating, and air conditioning

LEED . . . . . Leadership in Energy and Environmental Design

NAVFAC . . . . . Naval Facilities Engineering Command

NREL . . . . . National Renewable Energy Laboratory

O&M . . . . . operation and maintenance

PDS . . . . . prospectus development study

RFP . . . . . request for proposals

RFQ . . . . . request for qualifications

SBIC . . . . . Sustainable Buildings Industry Council

SOW . . . . . statement of work

UFC . . . . . Unified Facilities Criteria

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Executive Summary

Federal agency leaders are incorporating energy efficiency and renewable energy technologies and features on their sites, motivated by both Federal sustainability targets and a desire to lead by example in the transition to a clean energy economy.

Federal agencies have many reasons to implement energy efficiency and renewable energy on their sites, including legislation, Executive orders, and agency targets, among others. *Procuring Architectural and Engineering Services: A Resource Guide for Federal Construction Project Managers* provides Federal construction project managers with step-by-step guidance, resources, and checklists for each phase of procuring architectural and engineering (A/E) services, with special emphasis on the three most important phases: **establishing the selection criteria**, **establishing design criteria**, and **preparing the statement of work**.

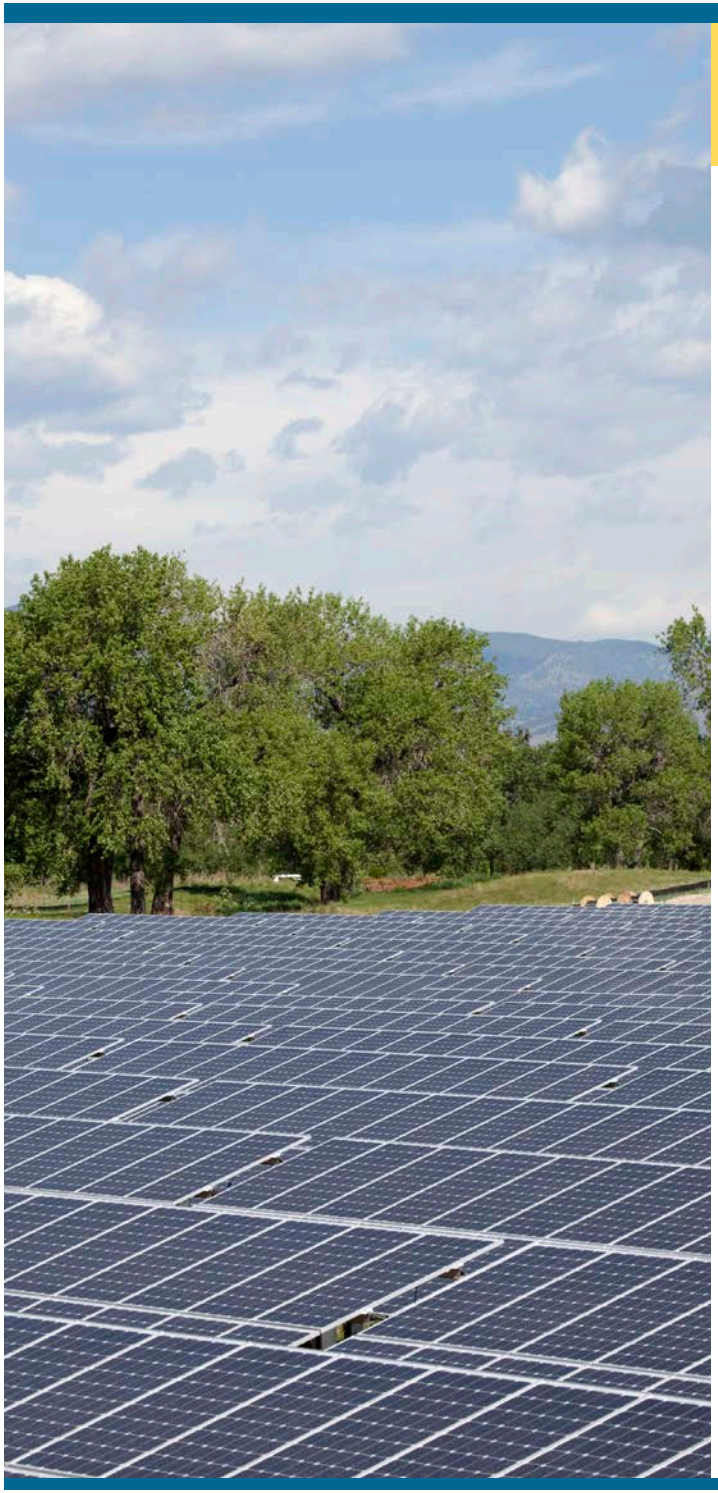
The Introduction to this guide provides background to the Federal context in which agencies are working, the value of an integrated, "whole building" approach to design, and the importance of creating and maintaining documentation throughout a project.

Pre-Design Considerations discusses important steps agencies should consider to prepare for a successful project, including building an internal project team and establishing effective communication.

The remaining sections discuss the major phases and steps for ensuring a successful project within the framework of the general timeline for these phases, which includes:

- **Establish Selection Criteria** – The design team must first define the selection criteria for the A/E firm that will be in the request for qualifications (RFQ) and request for proposals (RFP).
- **Establish Design Criteria** – In a design charrette, both internal and external team members should collaborate to establish design criteria that emphasize sustainability and represent a full range of knowledge and perspectives of key industry experts.
- **Select an Architectural and Engineering Firm** – In this phase, the team issues the RFP, evaluates the proposals, and selects the A/E team with the capability to deliver a sustainable building.
- **Create a Statement of Work** – The team creates a comprehensive statement of work that defines roles, responsibilities, and expectations for all aspects of the project, including the additional modeling, analysis, and product research needed to include sustainability features.
- **Develop the Building Program** – The team develops the Building Program, a document that defines clear and quantitative sustainability performance goals and targets for the project.
- **Design the Project** – The A/E team prepares drawings and documents to describe the project in detail, collaborating with the wider team to create the schematic design, perform further energy analysis, and create the construction documents.

Finally, the Post Design/Construction section reviews additional critical elements of a project, including Commissioning, Operation and Maintenance, and Measurement and Verification.



Introduction

Many Federal agencies have embraced the principles of sustainable design. These principles enable agencies to find a balance between their goals for cost-effective buildings and the need to protect workers, the environment, and other resources. Agencies can leverage these principles for design practices by procuring architectural and engineering (A/E) services for energy-efficient and sustainable new construction and major renovation projects.

The three most important elements in the procurement process are establishing the selection criteria, establishing design criteria, and preparing the statement of work. A capable, informed design team and solid planning set the foundation for a successful, energy-efficient, sustainable building design. The results can be compromised if provisions of sustainability are not made enforceable in each A/E contract.

This guide was created as a resource for Federal energy managers and others who want to integrate sustainable design principles into the procurement of professional building design and consulting services for Federal construction projects.

To save energy and improve the safety, comfort and health of building occupants, designs should incorporate daylighting, energy efficiency, renewable energy, and passive solar design into all projects in which they are technically and economically feasible.

The Establishing Selection Criteria section contains key elements to consider before selecting an A/E firm. The Establishing Design Criteria discusses the issues that internal and external team members should discuss collaboratively. The Preparing the Statement of Work section discusses the broad spectrum of sustainable design services that an A/E firm must provide for a successful Federal project.

1.1 The Federal Context

As the nation's largest consumer of energy, the Federal government has a tremendous opportunity to save money spent on energy every year. In fiscal year (FY) 2008, for example, the government spent $7 billion on energy for Federal buildings and facilities. Data show that about 1.6 quadrillion British thermal units (Btu) of primary energy were consumed in FY 2008[1].

The Federal government has made considerable progress in reducing energy use and cost. Building energy use fell from 139 kBtu/ft^2 in 1985 to 121 kBtu/ft^2 in 1995—less than the National

[1] Kidd, Richard. (January 2010). Statement Before the Subcommittee on Federal Financial Management, Government Information, Federal Services and International Security Committee of Homeland Security and Government Affairs, U.S. Senate. *http://energy.gov/oe/information-center/congressional-testimony*. Accessed July, 2011.

Energy Conservation Policy Act goal of 126 kBtu. The government further reduced its energy use by the year 2000 to 106.7 kBtu/ft²/year. Based strictly on total site energy use per gross square foot (excluding renewable energy purchases and primary energy savings from improved generating efficiency), the government reduced its energy intensity by 7.5 percent between 2003 and 2007[2].

Much of the reduction in energy use can be attributed to retrofit projects in existing Federal buildings. In some instances, new buildings use more energy than the ones they replace due to the evolution of building technologies. For example, new military housing in temperate Hawaii includes air-conditioning, while older housing relies on natural ventilation. Similarly, office automation and space-conditioning needs due to server rooms can increase the amount of energy consumed in new commercial buildings. In general, however, the energy efficient construction and improvements in equipment efficiency and building systems result in new buildings that consume less energy than older ones, making progress toward Federal energy reduction goals.

Because dozens of Federal agencies construct, renovate, and maintain thousands of buildings in a wide range of climates and conditions, Federal construction and maintenance costs are considerable. The Federal government spent $57 billion in FY 2010 on energy conservation retrofits, but over six times as much ($360 billion) on all new construction the same year, as shown in Table 1.

Table 1. Value of New Federal Construction (FY 2010)

Type of Federal Construction	Value Put in Place* (in millions)
Residential	$28,369
Office	58,809
Commercial	15,657
Health Care	40,362
Educational	38,335
Public Safety	48,049
Amusement and Recreation	10,388
Transportation	22,792
Power	12,964
Highway and Street	12,654
Conservation and Development	56,866
Other	23,073
Total Federal Construction	$368,318

* Value put in place refers to the dollar value of construction work done in the U.S. For additional information from U.S. Census Bureau, see *www.census.gov/construction/c30/c30index.html*. Accessed July, 2011.

Source: U.S. Census, Construction Expenditures Branch of the Manufacturing and Construction Division (2010). "Value of New Construction Put in Place." *www.census.gov/const/C30/pubsahist.pdf*. Accessed July, 2011.

The government can leverage investments for better energy efficiency and sustainability during new construction to avoid the need for energy efficiency retrofits in the future. Integrating energy efficiency into building design is much more cost-effective than retrofitting a building for greater efficiency after construction is complete. Achieving optimal building performance requires a comprehensive approach. The approach begins during the selection of A/E professionals and continues through programming and the development of schematics, design, and construction documents, and finally, building construction and commissioning. Superior building performance must then be sustained by conscientious maintenance and confirmed by monitoring.

1.2 The Value of Integrated Design

Good building design integrates function with aesthetics, cost and durability. Federal building designers are increasingly aware of the importance of addressing considerations such as accessibility for the disabled, historic preservation, environmental impacts, regulations and code requirements, and sustainability targets, in an integrated approach.

Treating efficiency and sustainability practices as "add ons" to the basic mission can increase the cost and compromise the effectiveness of a design. Considering these requirements early in the design process—with an integrated approach—allows designers to meet multiple objectives at little or no additional cost. For example, specifying a high-efficiency chiller can increase first costs, but reduce annual costs through energy savings.

[2] Annual Report to Congress on Federal Government Energy Management and Conservation Programs Fiscal Year 2007. *www.eere.energy.gov/femp/pdfs/annrep07.pdf*. Accessed July, 2011.

Features intended to improve the sustainability of a building often provide benefits beyond sustainability. For example, daylighting is a sustainability feature; however, studies show that integrating daylighting into a design reduces operating costs, improves occupants' morale and productivity and enhances safety and security by providing light during power outages.

To incorporate climate action and energy saving strategies, a perspective toward whole-building performance is critical. A whole building approach considers energy flows, such as heating, cooling, ventilation and lighting requirements, and a goal to incorporate energy efficiency and renewable energy. It requires understanding the interactions among architectural decisions such as the orientation, amount, type, and location of glazing, and placement of thermal mass and insulation, as well as their combined effect on heating, cooling, and lighting.

Evaluating complex interactions and selecting among options requires some type of analysis. This can be done using evaluation tools and software, such as eQuest®, which are discussed in Section 8.3, Energy Analysis and Software.

1.3 Developing Procurement Specifications

Federal building projects have diverse purposes and locations, making it impossible to define a single set of procurement specifications that apply to all projects or all agencies. Still, by considering the *process* in which these specifications are developed and considering the costs of failing to integrate sustainability principles into the architecture and energy procurement process, agencies can optimize their resources in new construction and major renovation projects, potentially saving millions of dollars. Guided by an agency's guidelines and policies, the advocacy and resources of other Federal agencies (such as FEMP), and a project champion (often, the construction project manager), Federal building projects can benefit from integrated, low-energy, sustainable design practices.

1.4 Importance of Documentation

Throughout design, construction, and post-design/construction phases of a project, it is important to document the decision-making process. Documentation creates records of the design progress and keeps owners and new team members informed, reducing the need to revisit decisions that have already been made. The development of a design narrative, in addition to specifications, drawings, and documentation of the basis of the design, should be included in the statement of work, which is discussed in Section 6, Create a Statement of Work. Some building owners may also choose to require a building log book, which describes the process undertaken to create a more sustainable building and details the HVAC and mechanical systems for the building occupants. The log book aids in a smooth transition between construction and occupancy, assisting with operations and maintenance (O&M).

Documentation should include the design team's decisions, along with weighting criteria to enable these decisions to be prioritized. Agencies can weight criteria and develop documentation by using a bookkeeping system for priorities and

U.S Marine Corps Camp Pendleton's temporary lodging facility was constructed from 20% recycled materials and will be 100% recyclable upon its distant demolition. The four-story South Mesa Lodge also received one of the U.S. Green Building Council's highest energy efficiency ratings, saving more than 30% percent of water, lighting, and overall utility usage. *Photo from Pfc. Daniel Boothe, U.S. Marine Corps*

numerical values of various weighting criteria, providing a convenient format for reporting the rationale of design decisions. Depending on the program, specific documentation may be required. The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system,™ and the Green Building Initiative's Green Globes Building Certification system, provide methods for quantifying green building design measures and systems for weighting the team's criteria. Green Globes is a Web-enabled, fully interactive building assessment tool that allows building professionals to augment their design (in new construction) or incorporate sustainable features (in existing buildings) and rate the building's proposed or actual sustainability performance. For more information on Green Globes, see the Green Building Initiative: *www.thegbi.org/green-globes/.* For information on LEED, see the U.S. Green Building Council: *www.usgbc.org/DisplayPage.aspx?CategoryID=19.*

Agencies should be sure to allocate budget for the task of collecting and presenting documentation for a LEED rating, accounting for this explicitly in the statement of work. The importance of documentation is reflected in its cost, averaging about $20,000 to $50,000, depending on the complexity of the project and how effectively the team shares documents. Experience has shown that having a LEED-certified professional capture the required information can be an easy and cost effective approach to providing documentation.

2 Pre-Design Considerations

2.1 Build an Internal Team

Selecting capable, experienced, enthusiastic individuals to be on the design team is an important step in the sustainable design process. Everyone involved in a building project should coordinate closely from the beginning to create an integrated team.

The first step is to select an internal team or an "ownership team" that takes responsibility for identifying construction performance metrics and selecting the project design team. The internal team may include the building/site owner, project manager, contracting staff, operations and maintenance staff, and building occupants. All who are chosen should be engaged and enthusiastic about their role in the process.

2.2 Establish Effective Communication

Once a team is in place, communicating goals throughout the process is essential. Due to the conventional structure and procurement of competitive design fees, there are few financial incentives to participate in meetings and correspondence, evaluate alternatives, and reach a consensus—which are all essential to achieving a successfully integrated, sustainable design. Communication can be improved, however, by holding charrettes at various stages of the design process.

Creating a working environment in which the project manager, architect, engineers, lighting designer, building owner, and occupants work together and communicate openly is an important part of the design process. Establishing positive relationships can also result in fewer change orders, and reduced operating expenses through reduced energy costs and on-going maintenance costs. For example, by taking a team approach to the design process, a mechanical engineer can inform an architect's understanding of the mechanical systems and the building orientation, massing, and fenestration's impacts on the peak load to optimize the building as a whole system, with input from the energy analyst and lighting designer. Additionally, because designers may not want to take risks that do not meet owners' expectations, strong communication between the owner and designer can support more innovative sustainable designs.

Sustainable design requires an integrated process in which the members of a project design team (who are usually from different disciplines) cooperate to exploit the interactions between building elements or systems. Team members collaborate best when they are all involved in setting project goals early in the process, making deliberate, planned efforts to communicate at every step.

3 Establish Criteria for Selecting Architectural and Engineering Services

The selection criteria are among the most important components of a sustainable design project. Selecting an A/E team with the capability, passion, and reputation almost ensures that a sustainable building project will be successful. In contrast, a team without the right capabilities will almost certainly fail to meet the sustainability goals. Depending on the resources in the agency, this team of professionals could be comprised of internal and/or external members. The project team must define the selection criteria for the A/E firm that it will use in the request for qualifications (RFQ) and request for proposals (RFP). Because Federal stakeholders may have different interests and values regarding the most important criteria for selecting an A/E firm, they should prioritize the criteria and establish agreement regarding the role of sustainability in relation to other considerations. The selection criteria reflect the organization's priorities and values, and these priorities determine how funds are spent. It is important to achieve internal agreement before establishing selection criteria and preparing the scope of work. Depending on the agency's priorities, the budget may be set before the design phase or the requirements of the design may dictate the budget.

Some A/E firms have a strong commitment to sustainability and view it as a leading design consideration. Others, however, may acknowledge that sustainability is desirable, but do not see it as central to determining the design and form of a building. An agency should clarify its own values and priorities before selecting an A/E firm, as a partnership between parties whose values are closely aligned will be most successful.

After establishing its priorities and developing criteria (generally in four to eight topic areas) for selecting the A/E firm, the design team should assign a weight to each of the criteria, and to establish relative importance. Example selection criteria that one agency used to hire an A/E (referred to as the "offeror") to design the Science and Technology Facility (S&TF) at U.S. Department of Energy's National Renewable Energy Laboratory (NREL) include:

- **Safety:** Does the offeror clearly demonstrate the ability to design laboratories that incorporate ASHRAE 62.1 (relating to mechanical exhaust for appropriate air changes per hour) while meeting the end user's functional requirements? (Weight: 25 points)
- **Technical Requirements:** Does the offeror clearly demonstrate the ability to design to technical requirements? (Weight: 25 points)
- **Budget:** (a) Has the offeror shown, in past projects, the ability to design to budget? (Weight: 12.5 points) (b) What is the result of the team's evaluation of the proposed cost of the design services? (Weight: 12.5 points)

Early photos show the first few reclaimed gas pipes being erected at the RSF construction site. Using these recycled pipes helped the building attain LEED platinum status. *Photo from Carl Cox, NREL/PIX 18235*

- **High Performance and Green Building Technologies:** Does the offeror clearly demonstrate the ability to incorporate energy efficiency and green building technologies, as defined in the U.S. Green Buildings Council's LEED rating system? (Weight: 12.5 points)
- **Architectural Image:** Does the offeror's proposal demonstrate the ability to develop an architectural image consistent with the project site and the owner's image? (Weight: 12.5 points)

The design team must have expertise as demonstrated with strategies and techniques for incorporating energy efficiency and sustainable design practices that meet life-cycle economic criteria. This expertise can be demonstrated by previously documented projects and through partnerships with recognized energy and sustainable design experts. Consideration for energy efficiency and environmental quality should begin at the earliest stages of planning and follow through to construction and operation. There should also be scheduled reviews of energy and environmental strategies throughout the design process. Architects should be flexible in their designs to allow for energy analyses to influence design strategies to create a high performance building.

To maximize energy performance, the entire A/E team should be supportive and knowledgeable. An architect unconcerned with energy performance—even if coupled with an engineering firm with excellent energy credentials—is unlikely to produce an optimal building design. The same would be true for an energy-conscious architect paired with an unconcerned engineering firm. It is critical to select a team that is prepared to work together to achieve superior building performance.

Checklist: Internal Project Team

An internal ownership team should be comprised of the following agency staff:

- ☐ Owner (agency leadership)
- ☐ Project manager
- ☐ Contracting staff
- ☐ Operations and maintenance staff
- ☐ Building occupants (engaged and informed about sustainability)

Checklist: External Professionals

External professionals who will be important to engage early in the process include:

- ☐ Architect
- ☐ Engineers (structural, mechanical, electrical, plumbing and civil)
- ☐ Energy analyst
- ☐ Landscape architect
- ☐ Lighting designer
- ☐ Interior designer
- ☐ Safety experts (security, fire, blast, force protection experts)
- ☐ LEED AP consultant
- ☐ NEPA consultant
- ☐ Indoor air quality consultant
- ☐ Waste management consultant
- ☐ Contractor
- ☐ Commissioning agent

Checklist: Ownership Team Considerations

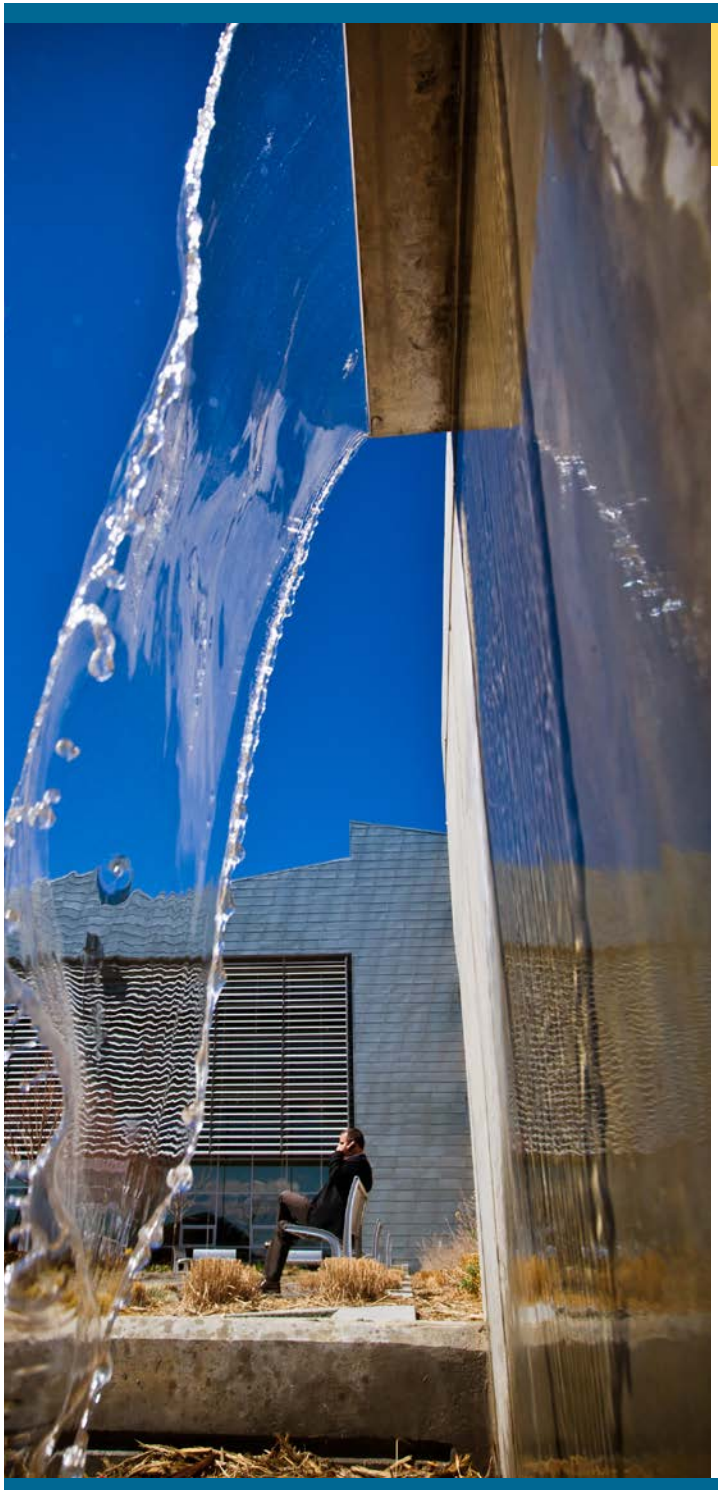
The following criteria can be used to enhance sustainability in solicitations for design services. The items under each criterion are additional considerations to support high performance buildings.

Request for Qualifications

The internal ownership team should request that applicants demonstrate their understanding of, commitment to, and experience in designing to high performance buildings standards. Additionally, the applicants should:

- ☐ State their commitment to sustainable design in their cover letter or introduction to their proposal.
- ☐ Demonstrate their ability to meet sustainability goals and targets set in program documents.
- ☐ Demonstrate competence with the life-cycle cost (LCC) procedures and criteria of 10 CFR 436 and current economic parameters (discount rate, inflation rate) specified for Federal projects. Demonstrate competence with estimating the costs and benefits of energy efficiency and sustainability measures.
- ☐ Demonstrate familiarity with sustainability principles and sustainability rating criteria (such as LEED). Describe actual experience achieving LEED ratings for completed building projects.
- ☐ Propose a team organization that can respond with a combination of communication channels and decision-making authority to the results of energy analysis and sustainability evaluations, such as a Leadership in Energy and Environmental Design (LEED) rating; successful teams should work together on a cross-disciplinary basis.
- ☐ Experience in designing to meet the ENERGY STAR® label or 2030 Challenge.*
- ☐ Follow up on actual performance of facilities the team has designed at least one year after occupancy, compared to design modeling (Btu/ft^2).
- ☐ Demonstrate experience in planning, facilitating, and reporting on design charrettes.
- ☐ Demonstrate proficiency with employing, and using the results of, analysis tools (such as EnergyPlus, DOE-2, eQuest).
- ☐ Be able to cite completed projects that feature workable, cost-effective, energy-efficient, and low-energy design principles.
- ☐ Demonstrate awareness and sensitivity with requirements specific to an agency or a project, such as heightened security at a courthouse, prison or foreign embassy.
- ☐ Demonstrate an understanding of requirements and guiding principles for Federal leadership in high performance and sustainable buildings and how to meet them, for example: 10 CFR 434/435 (Code of Federal Regulations), or the comparable commercial code, EISA, EO 13423 and 13514, American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1, AEDG for energy efficiency, or ASHRAE Standard 189.1, EPAct 2005, etc.
- ☐ Demonstrate expertise and experience integrating energy-efficient design strategies for all major systems and components: HVAC, building envelope, orientation, thermal mass, shading, daylighting analysis and simulation; electrical lighting design, control and integration with daylighting; energy-management control systems; commissioning of energy systems; indoor air quality; efficient operation and maintenance of energy systems; and documentation of design intent for energy systems performance.
- ☐ Demonstrate familiarity with new emerging energy technologies such as high-performance glazing; waste energy recovery; new thermal comfort standards (and associated temperature and humidity monitoring requirements); non-CFC (chlorofluorocarbons) refrigeration options; ENERGY STAR-compliant equipment; HVAC under-floor systems; and HVAC controls to improve personal control.
- ☐ Demonstrate both an understanding of and past experience with renewable energy technologies such as solar water heating and photovoltaics.
- ☐ Demonstrate both an understanding of and past experience with site design to provide or restore habitat and promote biodiversity.
- ☐ Demonstrate awareness of low impact development strategies for storm water management and retention of rainwater on site.
- ☐ Demonstrate an awareness of new measurement technology and past experience with metering, advanced metering, and monitoring of energy and water utilities.

* Architecture 2030 is a non-profit, independent organization that has issued a "2030 Challenge" asking the global architecture and construction industry to adopt aggressive targets by implementing innovative sustainable design strategies, generating on-site renewable power and/or purchasing (20% maximum) renewable energy. See *www.architecture2030.org/*.



4 Establish Design Criteria

Executive Order 13423 directs Federal agencies to apply sustainable design principles to the siting, design, and construction of new facilities. Executive Order 13514 requires agencies to ensure all new Federal buildings that enter the planning process in 2020 and thereafter are designed to reduce fossil fuel-generated energy use by: 55% in 2010; 65% in 2015; 80% in 2020; 90% in 2025; and 100% in 2030 to achieve zero-net-energy standards by 2030.

In addition to this guidance, the Energy Independence and Security Act of 2007 (EISA 2007) requires that 30% of the hot water demand in of new Federal buildings (and for major renovations) be met with solar hot water equipment, provided that it is life-cycle cost effective. Sustainable design can also help meet targets regarding water, waste, construction and demolition material, stormwater management, and renewable energy established in EO 13514.

An agency's sustainable design guidelines are especially important when contracting for A/E services because language promoting sustainable design can be leveraged across all agency projects. Often, individual agencies—and individual organizations within agencies—have established such guidelines.

It is important to note that no design process alone is "sustainable." Rather, continuous improvement in all processes is necessary for better buildings. Instead of simply replicating processes used in the past, projects need to be evaluated continually with regard to new products and methods. Design team members must also have a common understanding of what constitutes an improvement, so it is important for the team to define the metrics for evaluation.

Sustainability topics are sometimes given their own section in project specifications. This has both advantages and disadvantages. One advantage to this approach is that an agency's sustainability considerations can be included in specifications quickly by inserting a separate section. The primary disadvantage to this approach is that all members of the project design team will have to refer to and interpret the sustainable design section in regard to the other sections. For example, a person specifying plumbing vent pipe would be expected to read the sustainability section and consider recycled content, even though that requirement does not appear in the plumbing section.

To address this problem, some agencies, such as the Bureau of Prisons, have identified all areas in their specifications where sustainability requirements should be added. Some private publishers have issued detailed guides to preparing specifications using "green" building products (for examples, see *www.buildinggreen.com/*). Los Alamos National Laboratory published a Sustainable Design Guide[3] that outlines the Laboratory's specific planning and design process

[3] Los Alamos National Laboratory. (December 2002). LANL Sustainable Design Guide. *http://engstandards.lanl.gov/esm/architectural/Sustainable.pdf*. Accessed July, 2011.

The historic General Services Administration Federal Office Building in Seattle, Washington is one of the most efficient in the Federal government's inventory. Building upgrades included the installation of highly efficient lighting, improved elevator controls, and new building control system panels. *Photo from Federal Energy Management Program, NREL/PIX 17250*

to meet its sustainability goals, guide the planning and design teams and provide a process for evaluating sustainability progress.

4.1 Hold a Design Charrette

"Charrette" is a French word that in the 19th Century referred to the "little cart" that was rolled down the aisle to take up art and design students' completed work for a competition. Only the work on the cart would be considered, which explains, in part, the central role of a charrette. A design charrette today is an intense, collaborative effort among diverse professionals to discuss design alternatives in a short period of time.

A design charrette is a collaboration process for integrating various design concepts from different perspectives. Charrettes should be conducted with internal and external team members early in the process and throughout the design process. The procuring agency should write the scope of work for the sustainable design to allow for team members from all disciplines to participate in one charrette either before or early in the schematic design phase. The charrette may be a meeting with all members together in one room, followed by breakout sessions for individual focus areas. Ideally, there should be an additional charrette near the end of that phase. Because numerous professionals are asked to participate, charrettes can be costly; some run as much as $40,000 for the participants' time, travel, and other expenses.

The expense of a design charrette might suggest it is necessary to limit the number of charrette participants. However, because each aspect of a design affects all other aspects, it is best to involve the widest possible range of stakeholders in the charrette. In addition to the project owner and representatives of all agencies, disciplines, and firms on the design team, a charrette can include representatives of electric, gas, and water utilities; surrounding community associations; water quality and air quality management districts; industrial partners and technology experts; financial institutions; and environmental organizations.

The project manager often describes the program objectives early in the charrette in a session with all participants. The breakout sessions may address topics such as lighting, mechanical systems, material use, water and wastewater, site and landscape, and other specific areas of interest to charrette participants. It can be very useful to use LEED criteria to select topics.

During the initial sessions, participants identify and assess the interactions between topics discussed in the breakout sessions and then bring the discussion back to a whole-building perspective. Charrette participants listen to a description of the goals, needs, and limitations of a project, then envision and discuss solutions that are both creative and realistic.

The architect may facilitate the charrette (as sometimes indicated by the scope of work), or this responsibility could fall to a sustainability consultant or a hired facilitator. The facilitator should ensure that all participants express their ideas and concerns. The charrette should also include a minute keeper to record ideas and compile them in a charrette report. An independent recorder ensures that the record includes not just the views of the most vocal participants or the facilitator, but those of everyone who presents a concept.

Case Studies

Unified Facilities Criteria program

Federal agencies have developed the following systems and programs, which provide replicable criteria that agencies can incorporate into their own building projects:

The Department of Defense (DoD) and the military services established the Unified Facilities Criteria (UFC) program to unify the many technical criteria and standards[4] from each separate agency. The UFC provides a single criteria publishing system with a uniform format for all agencies. The goal is to reduce duplication of information and provide unified documents, limiting the need for agency-specific documents unless required by unique circumstances. The UFC program for the military services is administered by the following offices:

- Headquarters, U.S. Army Corps of Engineers (available at *www.usace.army.mil*).
- Naval Facilities Engineering Command (NAVFAC), Engineering Innovation and Criteria Office (available at *www.navfac.navy.mil*).
- Headquarters, Air Force Civil Engineer Support Agency (available at *www.afcesa.af.mil*)

[4] National Institute of Building Sciences. Unified Facilities Criteria." Whole Building Design Guide. *www.wbdg.org/ccb/browse_cat.php?o=29&c=4*. Accessed July, 2011.

Construction Criteria Base information system

Many agencies have adopted the Construction Criteria Base (CCB) information system as the distribution method for facilities criteria (available at *www.wbdg.org/ccb/ccb.php*). These agencies include DoD, especially the U.S. Air Force and Army Corps of Engineers; DOE; the Department of Housing and Urban Development; the Veterans Administration; the Environmental Protection Agency; the Federal Emergency Management Agency; the Federal Highway Administration; the General Services Administration; National Aeronautics and Space Administration; the National Institutes of Health; the National Institute of Occupational Safety and Health; the National Institute of Standards and Technology; and the Occupational Safety and Health Administration.

The CCB is connected to the *Whole Building Design Guide* (available at *www.wbdg.org*), which is a single source for comprehensive design guidance, Federal mandates (Executive Orders and Federal Regulations), technical information, project management tools, and links to CCB data and other codes and standards. The *Whole Building Design Guide* is maintained by the National Institute of Building Sciences (*www.nibs.org*) through funding from the NAVFAC Engineering Innovation and Criteria Office, GSA, and DOE (including FEMP), with assistance from the Sustainable Buildings Industry Council (SBIC).

Many Federal agencies, such as the GSA and DoD, include language in their contracts that encourages the use of sustainable design in all new construction and major renovations, wherever technically and economically feasible.

A complete renovation of the Annex Building at the Social Security Administration avoided $25 million in new construction costs, while recycling and salvaging of materials from the original interior led to 76% of the original building's interior materials being reused. Daylighting and updated lighting led to a 32% reduction in lighting. *Photo from Kevin Reals, NREL/PIX 12722*

Because tasks and tools are constantly evolving, this language must be updated frequently to provide useful direction to contractors and other design professionals. Therefore, it is necessary to first review existing agency documents and determine how their directives can be used to encourage sustainable design. For example, the GSA prospectus development study (PDS) process allows energy and passive solar performance to be highlighted as a fundamental design criterion, or "functional objective," in the Building Systems Matrix that summarizes project goals. GSA procedures for design and construction projects are outlined in the Design and Construction pages of the Public Buildings portion of GSA's Web site (available at *www.gsa.gov/portal/content/104549*).

5 Select an Architectural and Engineering Services Firm

5.1 Issue a Request for Proposal

Requests for Proposals (RFPs) are standard practice for contracting external services in the Federal sector. Issuing a request for qualifications (RFQ) allows an agency to select design teams that demonstrate past experience to help ensure a successful, sustainable project. From the RFQ stage, an agency can determine which teams are qualified to submit proposals. Before issuing an RFP, it is important to establish design criteria and priorities for completing a project. In an RFP, the agency should clearly define the selection criteria and scope of work for the A/E firm and the requirements that apply to the agency or project that the bidder is expected to meet.

Once the RFPs have been issued, firms can bid on the request by submitting proposals to demonstrate their capability to complete the project. In one example, a national laboratory used the RFP process to establish key energy performance metrics and specify the goal of achieving LEED Platinum certification. The RFP is available online.[5]

5.2 Evaluate Proposals and Award the Contract

During the bid solicitation and contract award phase of a project, bidders submit offers to perform the work described in the construction documents at a specified cost. Offers include proposed costs for all construction described in the documents, other direct construction costs, as well as design team fees. Bids do not include the cost of the land, rights of way or easements, or other costs that are the responsibility of the owner (or otherwise outside of the scope of the construction contract).

In addition to meeting all of the required criteria, A/E firms should respond thoroughly and specifically to inquiries about energy and resource efficiency. In their formal written and verbal presentations, they should address challenges and opportunities specific to sustainable design. The principal-in-charge and the project architect should demonstrate a familiarity with energy-efficient building design, material selection, and other key elements. The architect should clearly describe a design process in which the energy implications of design decisions will be evaluated at each phase of the process using appropriate tools.

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[5] National Renewable Energy Laboratory (February 2008) Research Support Facilities, Solicitation No. RFJ-8-77550. *www.nrel.gov/sustainable_nrel/pdfs/rsf_rfp_conceptual_docs.pdf*. Accessed July 2011.

An overhead PV skylight system is integrated into the main entry of the Thoreau Center at the Presidio National Park, in California. It is the first integrated overhead glazing system at a Federal facility. The modules are installed in a conventional skylight structure. *Photo from Lawrence Berkeley National Laboratory, NREL/PIX 01057*

The design team should support the owner in bid solicitation and negotiation. This support should be included in the design team's statement of work. The team then has an opportunity to maintain sustainability goals if any costs must be cut. Additionally, because contractors provide all the labor and materials to complete construction, and bidders may want to substitute materials they are familiar with or have ready access to for those that had been specified for their sustainability benefits, the statement of work for the energy analyst should include studies to evaluate trade-offs or substitutions. In such cases, a sustainability expert (typically a sustainability manager, facility manager, LEED-accredited professional, or sustainability consultant) should also remain involved to advise the owner and encourage a compromise that optimizes the benefits of the selected materials. See section 6 for additional information on the Statement of Work.

5.3 Administer the Construction Contract

The basic services of both the architect and design team include construction contract administration. The statement of work (further discussed in section 6), should include specific monitoring of sustainability and energy-related aspects during construction. Note that during installation, many energy efficiency measures, such as insulation and vapor barriers, require special attention. The design team should provide special instructions in the construction contract to help ensure proper installation, ensuring the agency can realize the benefits of these measures.

The design team should remain heavily involved throughout the administration of the construction contract. The design team often provides important cost-saving assistance during construction. Problems cannot be corrected easily or inexpensively if they are discovered by the commissioning authority after installations have occurred. For example, it is much more expensive to correct sagging or missing insulation after the drywall and interior finish are installed than before these installations. The design team should maintain adherence to its sustainability goals as change orders are issued and in cases when cost-cutting is required. Additional analysis may be required to evaluate cost and performance tradeoffs.

5.4 Determine the Costs and Fees

Sustainable design and consulting services, like the actual buildings, should be cost effective. For Federal buildings, cost effectiveness is defined in 10 CFR 436 as a savings-to-investment ratio greater than 1 during a 40-year analysis period for building measures, as opposed to the shorter 25-year analysis period for mechanical equipment measures. Some rules of thumb are helpful in determining the extent to which a project can support consulting and analyses.

Whether the analysis is being conducted internally or by outside contractors or consultants, it is also important to realistically consider the extent of the benefits when purchasing consulting and analysis services. A rule of thumb is that Federal building managers should spend the equivalent of one year's expected energy savings on energy analyses. This rule of thumb is also valid for major renovations that include window replacements, insulation retrofits, and lighting changes. Although A/E firms would not be hired for minor renovations,

a general rule of thumb for energy studies may be helpful. Energy studies relating to minor renovations involving component changes (such as fixture or ballast replacements) should generally be limited to six months' expected energy savings.

Sustainable design projects typically have other expenses in addition to basic fees for architectural and engineering services. An additional fee is required for the design team to evaluate alternatives and optimize mechanical system designs, and additional time is required for meetings and correspondence. In addition to basic design fees, project managers can use the range of costs in Table 2 to estimate the additional expenses for green design services. The additional expenses can be offset through energy savings associated with sustainable design.

5.4.1 Energy Modeling

There is a clear relationship between the affordable level of energy analysis and the deliverables and level of detail that can be expected from the analysis. The following descriptions can help clarify the expectations of an energy design professional or energy consultant, at each level of effort.

Modest effort (3 to 15 person-days)

At a modest level of effort, the energy analyst might be expected to:

- Attend a preliminary meeting and present results at a second meeting.
- Help define energy targets (in both dollars and Btu/ft^2) during programming using a design-phase analysis tool such as eQuest, Energy Scheming, eQ, e+, or other industry program, such as Trane Trace or Carrier HAP.
- With the project architect or manager, use similar tools to study schematic building envelope and massing alternatives, including options such as daylighting, night cooling, passive solar heating, and glazing optimization during the early phases of design.
- Be available to the project architect or manager throughout the design process to answer questions.
- In simplified buildings, analyze a limited number of simplified HVAC configurations.
- Provide a brief, written final report summarizing recommendations.

Intermediate effort (3 to 12 person-weeks)

At an intermediate level of effort, the energy analyst might be expected to:

- Attend regular meetings during the design and design development phases.
- Help define energy targets (in both dollars and Btu/ft^2) during programming.
- With the project architect or manager, run hourly simulations using eQuest, Energy Plus or an equivalent hour-by-hour simulation tool to study schematic building envelope and massing alternatives, including options such as daylighting, shading, lighting controls, and glazing optimization, during the early phases of design.
- Be available to the project architect or manager throughout the design process to answer questions.
- Analyze a significant number of alternative HVAC configurations, including controls and distribution options, during design development.
- Conduct an economic analysis of building design and systems alternatives, including life-cycle costs or discounted paybacks.
- Provide a comprehensive, written final report summarizing recommendations.

Table 2: Typical Additional Expenses in Sustainable Design Projects

	Minimum	Maximum
Additional A/E fees for "greening" of building	0% of project costs	5% of project costs
Energy modeling	Approximately $10,000 for a simple building	$20,000 to $50,000 for a complex building
LEED facilitation	0.25% of project cost for large building	0.50% of project cost for small building
Enhanced commissioning*	0.25% of project cost for large building	0.50% of project cost for small building

* Enhanced commissioning is a set of best practices that go beyond basic commissioning to further ensure proper building function for energy optimization.

Large effort (2 to 6 person-months)

At a large level of effort, the energy analyst might be expected to:

- Attend regular meetings throughout the project
- Help define energy targets (in both dollars and Btu/ft^2) during programming
- With the project architect or manager, run hourly simulations to study schematic building envelope and massing alternatives, including options such as daylighting, shading, lighting controls, and glazing optimization, during the early phases of design
- Be available to the project architect or manager throughout the design process to answer questions
- Maintain an ongoing energy analysis of the evolving design to inform the designers of the energy implications of design alternatives
- Analyze a significant number of alternative HVAC configurations, including controls and distribution options
- Conduct a comprehensive economic analysis of building design and systems alternatives, including life-cycle costs or discounted paybacks. Many Federal agencies require at least three alternative HVAC systems to be analyzed on a life-cycle basis
- In major renovation projects, assess existing conditions with physical tests such as infiltration studies, thermography, and equipment efficiency studies
- Undertake higher-order prediction studies such as physical daylight study models of prototypical office spaces or computational fluid dynamic models of convective flows in atria
- Team with a utility to analyze utility interface issues such as off-peak ice thermal storage and other peak-shaving and peak-shifting strategies
- Monitor actual building performance
- Produce comprehensive intermediate and final reports, as appropriate.

5.4.2 Performance-Based Fees

Although not a "one size fits all" approach, several projects, including NREL's Research Support Facility (RSF), have piloted the concept of basing professional fees on the level of performance as designed. Such performance-based fees reward efforts to minimize a project's life-cycle cost and reward designers for not oversizing equipment. The elements of a performance-based fee include:

- A clear goal and a specification for how performance relative to that goal will be measured
- A schedule of how the fee is a function of success in meeting the goal
- A method of evaluating the design
- A protocol for resolving disputes without expensive litigation.

Some projects have retained a minimum fee and based a special incentive fee on documented performance of the design, as a cautionary measure. However, some efforts to develop performance-based fee contracts have been halted by contracting officers or legal advisors unfamiliar with the technology required to evaluate performance. Therefore, it is essential to include legal counsel in the earliest stages of contract development. In multiple cases, Federal legal staff have determined that it is not possible to alter the fee structure described in the original solicitation to a performance-based fee through a contract modification. For this reason, consider a performance-based approach only at the beginning of a project.

6 Create a Statement of Work

A thorough and specific statement of work (SOW) is essential to the procurement of an A/E firm for an energy-efficient, sustainable Federal construction project. It should include all tasks to be performed by the different members of the project.

Roles and Responsibilities

The SOW should specify the architect's basic services to include schematic design, design development, construction documents, bidding and negotiating with contractors, and construction contract administration. A more comprehensive set of services also includes predesign planning, such as project identification and analysis, feasibility studies, programming, land-use studies, and analysis of financing options.

The architect's services can also include attending or facilitating meetings to set goals and monitor progress, managing construction, performing an energy analysis, conducting surveys of the sustainability attributes of various materials, and other consulting services. The SOW should include special language to emphasize the importance of sustainability in each phase of the design, with emphasis on the early phases in which key decisions are made.

To improve sustainability continuously, the design team must research new technologies and be able to rank many alternatives, as well as employ sophisticated methods for evaluating performance. The SOW should also include the tasks to ensure this is done and that the designers have budgeted enough hours for analysis and design team meetings.

The SOW also should include performance goals from the building program for all subsequent A/E services. This establishes the contractual obligation to create a sustainable project. It also ensures that all parties understand what that means in terms of specific tasks. The SOW should also specify the involvement of the energy analyst and the mechanical and lighting designers as early as possible in the design process.

According to one mechanical engineer familiar with the work, high-performance design takes 40% to 100% more effort on the part of a mechanical engineer or an energy analyst than simply sizing the mechanical system. The mechanical engineer can use a "shoebox" model analysis (described in "Base Case Modeling," Section 7.2) to investigate various mechanical system strategies very early in the design. Then, the engineer continues the energy analysis as the design evolves, to keep the team informed about the energy-use and cost implications of design decisions.

Timing and Schedule

The design project schedule must include time to hold regular meetings with project designers to communicate energy-use and cost implications and recommend alternatives. The schedule should include time for investigating utility rates and programs. The results of utility rate investigation should be incorporated into the energy computer simulation in order to estimate the annual energy cost of alternatives. The SOW for the energy analyst should include assistance with compiling the building commissioning handbook, including the design basis and performance criteria.

Energy Analysis

It is essential to involve the energy analyst at the beginning of the design phase to enable the analyst to have the largest possible impact on the project. The analyst has the most input before the design is 35% complete. By the time it is 90% complete, the analyst's role has been reduced to confirming that performance goals have been met, sometimes in cooperation with the commissioning agent.

For the energy analysis, a whole building approach is needed to account for the interactions between systems. Leveraging these interactions is a key strategy in green building design. For example, energy-efficient lighting reduces the heat gain from lights, which allows a smaller chiller and significantly less energy for cooling to be specified. However, the analyst must consider multiple measures with understanding that the same kilowatt-hour (kWh) cannot be saved twice. For example, a daylight sensor, which turns off electric lights in a room when sufficient daylight comes in through the windows, will not save any more energy or money if an occupancy sensor has already turned the lights off because nobody is in the room.

Most of these interactions can be well represented by hourly simulation computer programs such as EnergyPlus, eQuest and IES-VE. These programs are based on first principles (laws of physics) rather than correlation, enabling them to evaluate an wide variety of design configurations. The hourly simulation consists of an equation balancing the energy in and out of each building component, and these equations are solved simultaneously for each of the 8,760 hours of a typical year. Solving the system of equations at each hour accounts for the interactions between the building envelope, heating, cooling, and lighting systems, as well as solar heat gain, heat gain from occupants in the space, and other energy flows specified by the user.

During pre-design, the energy analyst develops the code-compliant reference case, identifies and evaluates energy efficiency and renewable energy strategies, and sets performance goals with the owner based on a case in which all cost-effective strategies are implemented. During preliminary design, the task is to evaluate schemes and the sensitivity of results to variable inputs, such as utility rates, and then select strategies for further development. In the schematic design, rough sizes of components can be determined. Design development is when the analyst assists in determining precise sizes and complete descriptions of the design.

The SOW describing these services must include measures needed to arrive at a sustainable design. The statement of work specifies all the tasks required of the A/E firm and the following sustainability requirements may be considerations to include:

- Specific research addressing the owner's needs and the most effective ways to meet them
- Detailed energy modeling to inform the design process
- Life-cycle cost analysis
- Evaluation of alternative systems and materials and their impact on building performance
- Research and specification of energy-efficient (e.g., ENERGY STAR® and WaterSense®-labeled) equipment and materials that meet rating or certification criteria for health or sustainability
- Development of documentation relating to sustainability rating criteria.

The SOW for A/E services should address sustainability topics in each of the following: the building program, the schematic design, documentation, design development, value engineering, construction documents, assistance with bid solicitation and contract award, assistance during construction, commissioning, and measurement and verification. Each of these elements is described in greater detail in the following sections.

For additional information on energy modeling and analysis, see Section, 8.1 Schematic Design.

Checklist: Statement of Work

The following considerations for the statement of work are not a complete list, but rather a starting point for the ownership team to use. These considerations should be discussed among the team before and after the charrette to determine roles and responsibilities of the entire team:

Architect

- ☐ Incorporate results from energy analyses to improve design efficiency.
- ☐ Incorporate energy efficient factors through design features such as building orientation, layout, fenestration, thermal mass, passive features and design, daylighting, climate appropriate/vernacular architecture, etc.
- ☐ Review details for high performance thermal envelope (e.g., thermal bridging, wall systems, etc).
- ☐ Clarify and understand the owner's requirements regarding sustainability. Lead the process of setting goals for the design team with owner input/involvement.
- ☐ Evaluate progress toward sustainability goals and coordinate the creation of a building design that meets the goals.
- ☐ Integrate the work of all disciplines to achieve effective daylighting and any other goals requiring interdisciplinary cooperation.
- ☐ Administer the construction contract to ensure the proper implementation and integration of sustainability measures.
- ☐ Inspect and evaluate the reuse of any existing structures on site.
- ☐ Investigate availability and then specify low VOC, recycled, salvaged, or reused building materials. Develop a solution that meets the goals of the owner. All goals should be substantiated in some way (quantified, modeled) so that the owner has confidence that the design solution meets their goals.
- ☐ Consider adaptability of the design for future use or deconstruction.

Landscape architect

- ☐ Evaluate and optimize measures to eliminate or reduce water use in the landscape.
- ☐ Optimize the efficiency of the irrigation system, if one is needed. Use WaterSense contractors and equipment.
- ☐ Evaluate and optimize measures to reduce requirements for using chemicals such as insecticide and fertilizer. Include integrated pest management systems.
- ☐ Optimize the landscape's impacts on building energy use by siting and planting to provide shade and wind breaks.
- ☐ Evaluate and optimize measures to reduce maintenance and energy use during maintenance.
- ☐ Provide for stockpiling of topsoil for reuse.
- ☐ Participate in the development of an erosion control plan.
- ☐ Minimize paved areas and where paved areas are essential, use porous pavement systems.
- ☐ Preserve or restore native vegetation.
- ☐ Participate in the design of rainwater catchment and greywater use systems, including low-energy use systems such as gravity fed irrigation systems.
- ☐ For hardscapes, consider solar reflectance impacts on heat island effects and permeability of surfaces.

Structural engineer

- ☐ Integrate the need to withstand physical forces with sustainability design requirements; including the size and location of window openings, required clear spans, structural elements that do not block the distribution of daylight, and the storage of heat in structural mass.
- ☐ In the selection of structural materials, consider durability, recycled content, environmental impacts of extraction and delivery, and embodied energy.
- ☐ Inspect and evaluate the reuse of any existing structures and materials on site.

Civil engineer

- ☐ Address issues of site sustainability, including surface water runoff.
- ☐ Prevent sedimentation of streams.
- ☐ Design structural control measures to retain sediment.
- ☐ Participate in the development of an erosion control plan.
- ☐ Design the treatment system to remove suspended solids and phosphorus from storm water.
- ☐ Work with the landscape architect to evaluate options for detaining surface runoff with landscape features where water is needed for landscape.

Mechanical engineer and energy analyst

- ☐ Assist the team in establishing an energy use intensity target.
- ☐ Establish a base case model for energy use calculations.
- ☐ Implement a set of measures to optimize the goals in the building program (minimize life-cycle cost or minimize energy use) to set a quantitative energy use goal.
- ☐ Frequently calculate the energy use of evolving design alternatives and inform team members of the life-cycle energy use implications of major design decisions and progress toward the stated goal.
- ☐ Evaluate alternative system types and design an HVAC system that optimizes efficiency.
- ☐ Right-size (rather than oversize) the system by carefully clarifying requirements and taking measures to mitigate the risk of discomfort.
- ☐ Consider innovative methods such as displacement or natural ventilation, chilled beams, solar or geothermal heat, radiant or hydronic systems, heat recovery, and avoiding re-heat and air conditioning, to save energy and improve indoor environmental quality.
- ☐ Evaluate the environmental impacts of materials (refrigerants) used in the mechanical system and consider them in the selection process.
- ☐ Prepare or assist in the preparation of special drawings and specifications to describe energy features of the design.
- ☐ Participate in the design of a solar water heating system with the plumbing engineer.
- ☐ Design instrumentation systems to monitor the long-term performance of major building systems (with the electrical engineer).
- ☐ Design occupant-based control (e.g., CO^2 monitor) of mechanical systems.
- ☐ Consider the appropriateness of individual personal control of temperature, humidity, and airflow.
- ☐ Design mechanical system controls that respond to open windows (e.g., turn off).

Energy modeler

- ☐ Prepare a shoebox model to set early goals and help identify issues.
- ☐ Prepare models for each schematic design alternative.
- ☐ Prepare a model of the final design.
- ☐ Prepare the LEED submittal regarding energy points.
- ☐ Provide a reference case for building system commissioning.
- ☐ Inform the project team of the energy use implications of value engineering recommendations.

Electrical engineer

- ☐ Integrate the use of innovative sources of power, such as cogeneration or solar energy.
- ☐ Optimize the efficiency of distribution system hardware (transformers).
- ☐ Optimize the efficiency of any other specified electrical equipment.
- ☐ Design instrumentation systems to monitor the long-term performance of major building systems, including temperature and humidity.
- ☐ Ensure that all the controls (lighting controls, etc.) are designed properly and work as expected.

Plumbing engineer

- ☐ Establish baseline water use and lead the development of reduction goals.
- ☐ Select fixture and pipe layouts to conserve materials.
- ☐ Include durability, recycled content and environmental impacts in material selection.
- ☐ Evaluate and specify high-efficiency fixtures (e.g., WaterSense).
- ☐ Optimize pumping power through pipe sizing for recirculation loops.
- ☐ Optimize warm-up time through pipe sizing for buildings without recirculation loops.
- ☐ Participate in the design of rainwater catchment and greywater use systems.
- ☐ Participate in the design of solar water heating systems.

Interior designer

- ☐ Specify certified wood products, low-VOC, recycled and recyclable furniture, furnishings, and fixtures.
- ☐ Specify lighter or contrasting colors so that less lighting power is needed to achieve energy savings.

- ☐ Select furniture upholstery options that are durable and comfortable over a wide range of temperatures.
- ☐ Investigate the emission of volatile organic compounds from paints, composite products, and carpets and specify low-VOC alternatives.
- ☐ Plan furniture systems that are compatible with daylighting and natural ventilation strategies
- ☐ Work with architect and lighting controller to design an integrated daylighting system.
- ☐ Work with lighting engineers to select low-energy lighting fixtures and task lighting.

Lighting designer

- ☐ Communicate with the interior designer to determine where coloring of fixtures can be optimized to require less power for lighting.
- ☐ Minimize installed lighting capacity through architectural design of the lighting system.
- ☐ Consider a lighting strategy for task specific lighting and for ambient lighting (e.g., overall office lighting).
- ☐ Design a system to admit, distribute, and control daylight.
- ☐ Design controls to integrate daylight and artificial light.
- ☐ Include measures to increase personal control of lighting.
- ☐ Design measures to control the direct illumination leaving the site.
- ☐ Design systems that are flexible for daylighting levels, occupancy patterns, and multiple functionalities of a building over its lifetime.

LEED building consultant (e.g., a LEED-accredited professional)

- ☐ Make recommendations regarding the impact of building materials as they are produced and the waste they generate in the construction process and over their product life cycle.
- ☐ Organize and facilitate coordination meetings or charrettes.
- ☐ Maintain a record of progress toward stated sustainability goals (for example, maintain a LEED checklist and documentation).

Environmental Consultant

- ☐ Ensure the project management team is aware of NEPA requirements and complies with regulations.
- ☐ Complete any paperwork required to meet NEPA requirements.

Indoor Air Quality Consultant

- ☐ Assess room-to-room airflow and recommend measures to prevent contamination from spreading from pollution sources.
- ☐ Recommend air flow that is both energy efficient and maintains high levels of air quality.

Waste management consultant

- ☐ Recommend ways to minimize construction waste and maximize construction recycling.
- ☐ Recommend ways to enhance recycling over the building's life.
- ☐ Recommend ways to enhance on-site recycling (for example, using design and siting of collection stations).

Construction Manager/Tradesmen

- ☐ Recruit early to review and ensure the constructability of the design.
- ☐ Recommend innovative improvements regarding installation.

Operation and maintenance staff

- ☐ Include the O&M team in the design process as part of the integrated team to advise the design team about the O&M implications of design options.
- ☐ Participate in early meetings to understand and support the sustainability goals of a project.

Commissioning agent (pre-design to post-occupancy)

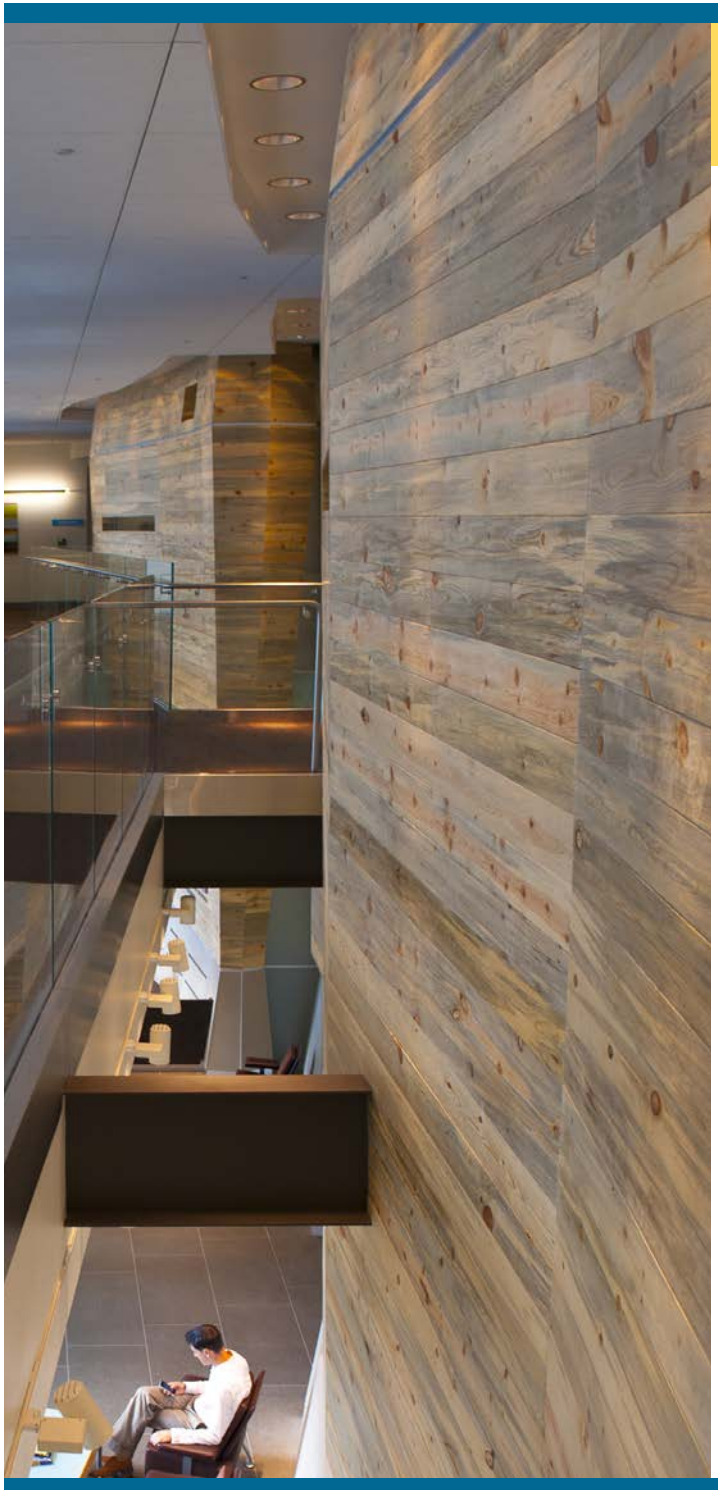
- ☐ Be involved from the pre-design phase through the post-occupancy phase to add commissioning-related requirements.
- ☐ Prepare commissioning-related requirements for construction documents.
- ☐ Include commissioning in the design review.
- ☐ Prepare the recommissioning manual.
- ☐ Review at the end of the warranty period.
- ☐ In some cases, help write or compile a building commissioning handbook

Owner

Note: Although the owner's role is not contracted, it is key to achieving sustainability goals.

- ☐ Declare sustainability as a requirement and functional objective in the preamble to the statement of work (reiterating requirements already established in the building program).

- ☐ Avoid building on farmland, habitat of threatened or endangered species, flood plains, wetlands, or parkland.
- ☐ Consider redevelopment of urban areas over greenfields.
- ☐ Consider rehabilitation and development of brownfields.
- ☐ Request daylighting and energy modeling results at schematic design, design development, construction documentation and post-construction phases.
- ☐ Identify plug load opportunities and ENERGY STAR products.
- ☐ Clarify how to prioritize sustainability in relation to other design goals.
- ☐ State a desire to exceed Federal mandates.
- ☐ Consider the full life cycle of the building and future energy and environmental impacts.



7 Develop the Building Program

The building program is a document describing the conditions and requirements for a project, including the owner's project requirements and performance criteria. The building program contains the project's overall goals, specific goals for resource use and costs, and specific system performance targets.

The program specifies the number of square feet of different types of building space (office, assembly, laboratory, etc.) and the relationships between those spaces. The program should also state clear, quantitative sustainability performance goals. For example, it might specify a desired rating from a third-party building certification program (such as the Green Globes system, LEED, etc.) or a maximum annual operating cost in dollars per square foot.

Other goals often include achieving a facility that is beautiful, safe, reliable, secure, and comfortable, or one in which the quality of air and light is superior. For some facilities, such as prisons, security might be central to the building program. The program may also put limits on the style and materials to be considered by dictating the intended "look and feel" of the building.

The building program should refer to the agency's criteria regarding sustainability. The building program should also document the energy-related needs of building occupants, which is a critical first step in designing systems to meet those needs efficiently and an indicator of whether renewable energy systems are appropriate.

Typically, healthier indoor environments and lower operating costs are byproducts of a green building, and can enhance the feasibility of a project because of the demand for more desirable space. Some agencies have discovered that potential partners (e.g., funding sources, local community stakeholders) are more prepared to support projects involving superior-performing buildings than those resulting in conventional building types.

7.1 Establish Goals

When a building program clearly and quantitatively states the goals for sustainability at the beginning of design and construction, it is more likely to factor them into all decisions throughout the process. To ensure the program is meeting sustainability goals, it must define the goals with clear criteria. Agencies often set the goals before issuing the solicitations. However, including the entire design team in goal setting after the A/E firm is on board usually results in greater understanding and buy-in among the team members.

Creating quantitative metrics, such as LEED ratings, ENERGY STAR, and other sustainability criteria will assist with measuring whether the goals were met.

An air intake structure outside the west wing of NREL's Research Support Facility—nicknamed "the football" takes in cool outside air to cool the data center. Such air-intake structures are key to lowering energy costs in the new building. *Photo by Dennis Schroeder, NREL/PIX 18836*

A good general goal for Federal projects is to produce an aesthetic, sustainable, cost-effective building that meets its program's needs, encourages productivity, and consumes as few nonrenewable resources as possible through the use of intelligent building design, passive solar design, energy efficiency, and renewable resources.

ENERGY STAR-rated buildings are those that achieve an EPA energy performance rating of at least 75 on a scale of 1 to 100. Building energy consumption data is entered into EPA Portfolio Manager and must meet specific criteria before receiving an ENERGY STAR label. Programs such as LEED and ENERGY STAR can help design teams set goals, develop and implement a plan, and assess performance. The ENERGY STAR rating is maintained over time rather than just during construction. For more information, see the ENERGY STAR website (*www.energystar.gov/*) and ENERGY STAR buildings pages on the FEMP website (*www.eere.energy.gov/femp/*).

The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification system is a popular sustainability rating system for buildings in the United States. LEED tallies points for prescriptive criteria and designates levels of performance by category: Certified, Silver, Gold, or Platinum. For example, if a building program includes achieving a Platinum LEED rating, this has implications for site selection, water use, wastewater handling, energy use, transportation options and access, and materials selection. For more information, see *www.usgbc.org/LEED*.

Green Building Initiative's Green Globes® Building Certification system is a green building guidance and assessment program that provides a way to advance the overall environmental performance and sustainability of commercial buildings. It provides a rating/certification system, comprehensive environmental assessment protocol, software tools for online assessments, best practices for green construction and operations, and qualified assessors with green building expertise. For more information, see: *www.thegbi.org/green-globes/*.

Other sustainability criteria include the Building Research Establishment Environmental Assessment Method (BREEAM)/New Offices; Building Environmental Performance Assessment Criteria (BEPAC); and International Standards Organization (ISO) 14000, ISO 14001, *Environmental Management Standard*. For more information, see *www.breeam.org*.

The International Living Future Institute also provides useful standards, resources, a certification program, and case studies. For more information, see: *http://living-future.org/lbc*.

The American Society for Testing and Materials (ASTM) International's Subcommittee E6.71 has compiled more than 100 standards that address sustainability in buildings. They include E1991, *Guide for Environmental Life Cycle Assessment of Building Materials/Products*; E2114, *Terminology for Sustainability Relative to the Performance of Buildings*; E2129, *Practice for Data Collection for Sustainability Assessment of Building Products*; and E917, *Practice for Measuring Life-Cycle Costs of Buildings and Building Systems*. For more information, see the ASTM website: *www.astm.org/COMMIT/COMMITTEE/E35.htm*.

When possible, goal setting should be a team activity. Team members are more likely to proceed with awareness of and commitment to project goals when they contribute to setting the goals and determining metrics. Sometimes, however, goals are established before all design team

members are present. In such cases, general goals that were set early can be made more specific with new team members, or a meeting can be held with new members to discuss and reaffirm the goals already determined.

7.2 Establish Metrics

Energy performance goals can be measured in different ways. Annual energy use per gross square foot (Btu/ft^2/year) is a common metric for Federal projects because that is how progress is tracked toward energy reduction goals required by Energy Policy Act (EPAct), Executive Order 13423, and Executive Order 13514. The disadvantage of using Btu/ft^2/year as a metric is that energy in Btu supplied by different fuels has different costs, and there is no differentiation between time-of-use or demand rates.

One good metric is to specify an energy-use goal as a certain percentage less than the minimum required by code, without sacrificing any performance in the habitability of the building or the comfort and health of its occupants. For example, a goal might be to use 35% less energy than that allowed by 10 CFR 434/435 for Federal projects, by ASHRAE 90.1 for commercial buildings, 90.2 for residential low-rise buildings, and 189 for green buildings, or by California Title 24 for buildings in that state.

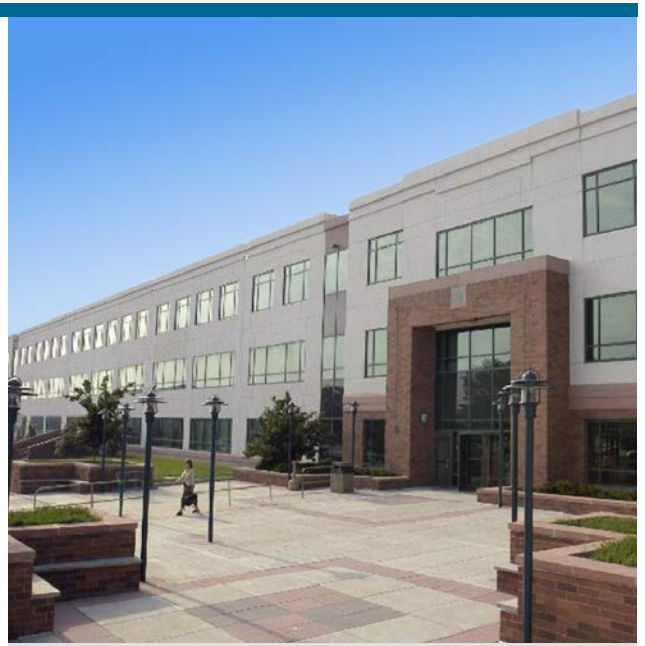
Another useful metric is annual operating cost, which accounts for the cost of different fuels, as well as various time-of-use and demand savings. More detailed data tracking provides a more detailed view of performance. Annual operating cost can also be integrated as a figure of merit with all other annual costs, such as operation, maintenance, water, and disposal.

Another option is to set performance metrics in terms of greenhouse gas emissions, or carbon dioxide equivalents (CO_2e). Greenhouse gas emissions reporting is required as part of Executive Order 13514 and enables an easy comparison between resource areas: waste, water, energy and transportation.

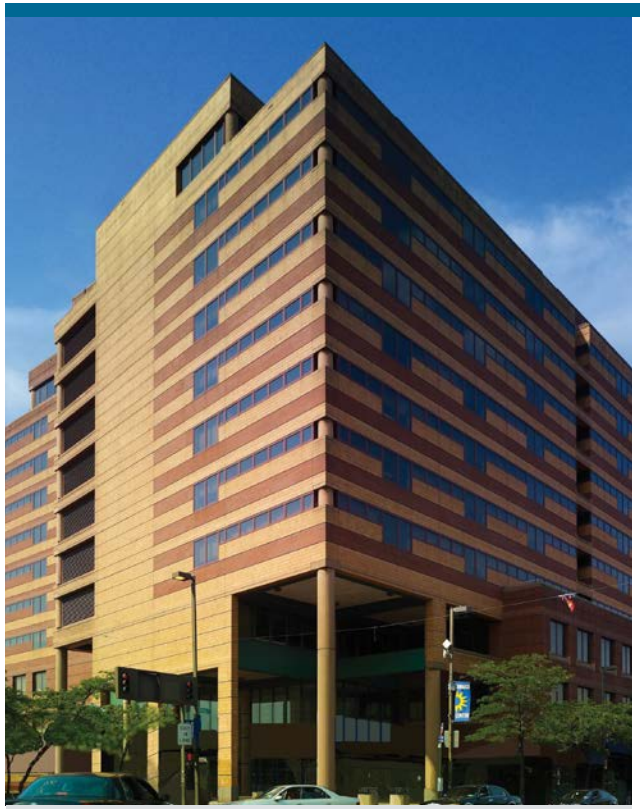
Regardless of which metric(s) are selected, it is important to measure performance consistently with the metric used when the goal was set. Goals set using a computer model are often hard to compare with actual utility bills, for example, because of variables outside the designer's control that affect energy use after the building is occupied. Although a building's performance is ultimately determined by actual use of resources (as shown in utility bills, for example), the performance of the design team should be evaluated by simulating the final design with the same computer program and uncontrolled parameters (weather data, utility rates, occupancy, schedules, plug loads) that were used to set the goal.

Base case modeling

It is ideal for the designers to know the physical characteristics of a building before setting energy goals. However, it is possible to set energy goals before knowing the building characteristics. One approach is to model a default building in the shape of a shoebox with the same floor area and number of floors, the same occupancy schedules, and the same kinds of space (office, circulation, kitchen, meeting rooms, storage, etc.) called for in the building program. A shoebox shape, with a length about twice its width, is suggested because a cube shape would minimize surface area and would thus be an unlikely selection for the base case.



A complete renovation of the Annex Building at the Social Security Administration avoided $25 Million in new construction costs, while recycling and salvaging of materials from the original interior led to 76% of the original building's interior materials being reused. Daylighting and updated lighting led to a 32% reduction in lighting. *Photo from Kevin Reals, NREL/PIX 12721*



The Joseph P. Addabbo Federal Building in Jamaica, NY improved energy efficiency 12 percent annually by replacing its entire chiller plant and upgrading building control systems. The result saves nearly 1.5 million kWh per year. *Photo from Federal Energy Management Program, NREL/PIX 17280*

In this approach, a base case is first defined to serve as a benchmark for comparing the performance of the evolving design. For the base case shoebox model, the properties of walls, roofs, windows, and mechanical systems are the minimum required by applicable codes. The annual energy performance of the base case shoebox model is evaluated using climate data and utility rates for the site.

Next, a set of energy efficiency measures is modeled, using the shoebox model to determine which strategies are most effective. For example, if evaporative cooling is effective for the shoebox model, it is likely to be effective for the actual design. Measures are also evaluated in combination with each other to account for interactions.

The shoebox model with the most cost-effective package of measures provides an estimate of what should be achievable in the design, but the goal is usually set above this level. In one example, a reference case is 100 Btu/ft^2/year, the shoebox with all cost-effective measures implemented is 30 Btu/ft^2/year, and the goal for the project might is set at 40 Btu/ft^2/year. NREL's ENERGY-10™ software tool was developed to implement this predesign analysis and to assist design teams in setting energy use goals.

7.3 Establish the Base Case

Establishing an appropriate base case building is the first step in evaluating low-energy design and other sustainability investments during the design process. Goals for resource use and costs are set relative to the base case. Establishing a base case is also an essential step in pursuing a performance compliance path under 10 CFR 434/435 or the comparable commercial code, ASHRAE 90.1, 90.2, and 189.

Establishing a base case can be a difficult task because there is no universal approach. Early in the programming phase, the base case may be the minimum, code-complying structure in a generic shoebox form. However, some codes or rating systems (e.g., ASHRAE 90.1 and LEED) specify that the shape of the base case building must be the same as that of the evaluated design. The problem with this requirement is that it does not reward the architect for innovations in building aspect ratio or orientation that improve energy use or reduce materials and costs. For example, designers of the Zion National Park Visitor Center achieved considerable savings by moving some program space (educational display boards) outside the building envelope.

It is therefore desirable for a base case to be defined to help identify related savings and reward the design team for improvements. It is often necessary, however, to define a base case building during the programming phase, to establish aggressive energy performance or material use targets. If this is the case, the agency will want to retain the same base case definition throughout the project.

The definition of the base case will have implications for cost-effective corrections in the final design. Consequently, establishing the specifications of an appropriate base case building design is important, and the project manager and designer or energy consultant should do this early in the design process.

7.4 Define Energy Performance Targets

After choosing sustainability rating *criteria* that will serve as a "yardstick" for measuring performance, it is important to specify the desired

performance target, which serves as a "tick mark" on the yardstick. An energy performance target is a subset of the general sustainability target—a quantitative goal, or measure of the maximum expected energy consumption for a structure, based on accepted calculation procedures.

In smaller projects (those in buildings approximately 10,000 ft^2 or less with only one or two thermal zones, such as warehouses, small offices, or individual residences), it can be helpful to use quick, design-based, climate- and program-specific energy software such as eQuest, Building Design Advisor, BREEAM, or Energy Scheming during programming. Using these software packages, Federal managers or their subcontractors can incorporate numerical energy targets, including breakdowns of estimated energy consumption for heating, cooling, ventilation, plug loads, and lighting to consider their impacts on design Incorporating this type of information in a program statement provides criteria for evaluating subsequent design performance.

For larger, multizone projects, such as laboratories and high-rise office buildings, it is necessary to run more complex software packages, such as EnergyPlus, DOE-2.2, eQuest, IES-VE, or the equivalent, to generate similar estimates of energy consumption. These tools estimate annual energy consumption by accounting for a wide range of factors, including building size, local climate, mechanical system control strategies, utility rates, maintenance practices, and occupancy schedules. However, energy modeling can be time consuming and expensive, as detailed below. An alternative is to use national average energy consumption data by building type, available through DOE's Energy Information Administration (*www.eia.gov/*) as a reference and cite a target percentage reduction from the data. For example, in the year 2000, Federal building energy costs averaged $\$1.11/ft^2$/year, which is a useful point of reference.

In designing new office space, a realistic goal is to reduce energy costs from 30% to 50% below national averages by applying an optimum mix of low-energy design strategies to the building design. The strategies might include optimized glazing and insulation, daylighting, shading, and passive solar heating. Even greater savings are feasible when advanced technologies and techniques are employed. This suggests that an annual savings of between \$0.45 and \$0.75 per ft^2 of office building is a reasonable estimate of the maximum cost savings possible using energy-efficient design. However, if the energy consumption in the new design is compared to a hypothetical base case building rather than to the national mean for existing structures, the savings could be more modest. In this case, savings might be expected to range from $\$0.20$ to $\$0.30/ft^2$/year, depending on the definition of the base case building.

These numerical goals are often established as targets, rather than as absolute project criteria. The great variety of building types, programs, and conditions makes it challenging to set goals that do not involve uncertainty. Still, incorporating target goals into a programming document conveys the fundamental nature of energy consumption as a design issue. If potential design contractors to discuss this information in their proposal submissions, agencies can evaluate their experience and insights.

FEMP provides information on building programming in the Guide for Integrating Renewable Energy in Federal Construction (available at *www.eere.energy.gov/femp/reconstructionguide/programming.html*).

FEMP assisted U.S. Army Fort Bliss with prioritizing the investment of appropriated funds to build renewable power plants for Army energy security, with the goal of generating enough energy to supply the Fort's current expansion. *Photo from Federal Energy Management Program, NREL/PIX 17255*

A barracks building at U.S Marine Corps Camp Pendleton was recently renovated, extending its life for at least 30 years. The project was self-certified to meet the Leadership in Energy and Environmental Design Silver standard. A few environmentally friendly features the project has to offer include a dryscape, a bio swell to collect water runoff before entering the storm drain, and solar paneled lights to illuminate the parking lot. *Photo from Cpl. Damien Guiterrez, U.S. Marine Corps*

Checklist: Programming Considerations

The following considerations may be defined by the owner's requirements or by the entire ownership team:

- ☐ Identify and prioritize space requirements and perceived limitations of building design as defined by building occupants, stakeholders and culture.
- ☐ Layout space types according to condition requirements to be able to select optimal mechanical systems for each space type.
- ☐ List sustainability or high-performance green buildings as a core value along with other requirements in the program.
- ☐ State desire to exceed performance goals, for example, a desire for a net zero energy facility.
- ☐ Emphasize the goal of employing a sustainable design alternative whenever economically and technically feasible in program documents.
- ☐ Perform a climate study to identify climate-specific strategies (e.g., using Climate Consultants or Hands Down Psychometrics Program Version 6 as modeling software for climate implications).
- ☐ Emphasize achieving superior whole-building performance as a written project goal, and select criteria to evaluate performance.
- ☐ Conduct a project programming workshop with key agency personnel.
- ☐ Establish a base case defined by minimum code requirements. The base case is often a simulated building shoebox with the same square footage, climate, and code-compliant assumptions as those called for in the building program.
- ☐ Establish quantitative energy targets in the program based on a set of measures that are suitable for the base case shoebox (e.g., percent reduction in energy use from the requirements of ASHRAE 90.1 minimum of 30% improvement).
- ☐ Specify which energy analysis software will be acceptable (DOE-2, eQuest or equivalent).
- ☐ Indicate a target LEED rating in the building program. See *www.usgbc.org*.
- ☐ Include considerations for stormwater runoff, on-site infiltration, or on-site treatment to limit disruption to natural water flows on site.
- ☐ Include considerations for minimizing building and parking energy intensity and footprints and moving appropriate program spaces outdoors; consider redevelopment of developed areas instead of greenfield development.
- ☐ Include language in the program mandating the use of renewable energy or cogeneration applications determined to be cost effective.
- ☐ Establish aggressive targets for lighting power density (W/ft^2); consider power densities 20% below standard practice where feasible.
- ☐ Include waste recovery and provisions for recycling (separation, collection, storage) in the building program.
- ☐ Require a waste management plan in the building program to divert demolition, construction, and land-clearing debris from the landfill through recycling or salvage.
- ☐ Require recycled or recyclable, rapidly renewable, locally available materials in material selection criteria.
- ☐ Ask for the use of native or drought-tolerant plants in the landscaping described in the building program.
- ☐ Establish indoor air quality requirements (ASHRAE 62), requirements for indoor pollution sources, and the location of outdoor air intakes.
- ☐ Identify required lighting levels and spaces that can use daylight, diffuse daylight, where direct sunlight is needed, etc. (e.g., conference rooms may need shades for presentations, while rooms with sensitive materials may need diffuse daylight). Include in the building program any requirements of access to daylight (by percent of space) or lines of sight to vision glazing.
- ☐ Include any requirements for permanent entryway systems to capture particulate matter.
- ☐ Establish comfort criteria in the building program (ASHRAE 55). Include humidity, radiant heat gain, lighting levels, and temperature as determinants of human comfort and minimize the impacts on energy consumption where possible.
- ☐ Establish the intention to continuously monitor building energy performance, indoor air quality, and comfort conditions for each space type and try to minimize energy consumption.
- ☐ Indicate any requirements for accessing and maintaining systems for mechanical, electrical, and communications distribution needs.
- ☐ Consider impacts of building layout on daylighting, natural ventilation, footprint, mechanical and electrical rooms, etc. to maximize natural resources with similar adjacent spaces.

8 Design the Project

In design development, the A/E team prepares drawings and documents to describe the entire project in detail. Drawings and specifications contain the architectural, structural, mechanical, electrical, materials, and site plans of the project. In design development, the team arrives at sustainability strategies and systems based on the brainstorming and selections that took place in the schematic design phase.

The energy analyst performs a more detailed analysis than the original analysis, and this includes determining the cost and performance trade-offs between alternative systems. The architect, mechanical engineer, and electrical engineer work together to integrate renewable energy sources (e.g., solar water heating, solar ventilation preheating, photovoltaics) with the existing building structure and aesthetics. The mechanical engineer and A/E firm specify the mechanical system options (e.g., thermal storage, economizer, night cooling, HVAC controls, evaporative cooling, ground-exchange) at the component level. Lighting system design development integrates daylighting, equipment, fixtures, and controls.

Communication during the design development phase is critical. A change in any system, such as lighting power, could affect other systems, such as cooling load on the mechanical system. It is best if both internal members and objective external parties perform design reviews. The focus of design review efforts should be on submitting and revising early schematic designs. After the design is 35% complete, it is usually too late to make major changes. Reviews should focus on preliminary and schematic designs and ensure that sustainability measures are included for subsequent development.

The internal team and external parties can perform the design reviews by marking up plans and specifications and by supplying product literature and other information to facilitate implementation of the recommendations. It is also useful for the project manager or lead to call a meeting to convey to the design team some of the more complicated concepts from reviewers.

The internal team should recruit external parties who have not been involved in the design to review it. These reviewers could include consultants, advocates from state and local governments or national laboratories, and experts on sustainability topics such as energy, materials, and indoor environmental conditions. A design review panel that meets periodically can provide an external review of design submittals. These reviews need to be factored into the construction timeline.

The statement of work must describe all schematic design studies, showing the scale and relationship of project components, whereas the design submittal should include drawings, specifications, and a cost estimate. This package provides the owner with a description of the design for review and approval and addresses project requirements and costs. The A/E firm must include all suitable

Alfred A. Arraj U.S. Courthouse; Denver Federal Courthouse; PV system supplied by Atlantis Energy Systems; rear view of structure; first federal courthouse to get PV glazing. The GSA worked with the project design team, the PV supplier, and the Federal Energy Management Program (FEMP) to design and monitor the PV system. *Photo from Atlantis Energy Systems, Inc., NREL/PIX 13998*

sustainability measures in the schematic design, because in subsequent phases, they can develop these concepts further.

Sometimes an agency requires a design team to develop several schematic design alternatives. The team must accommodate the work required to compare them—such as energy modeling for all options in order to compare energy use—in the statement of work and cost estimate of a project. This could stipulate that each alternative be scored according to sustainability rating criteria (e.g., a LEED score for each).

The RFP should include a requirement for a design report that explains how the design accomplishes the project's sustainability goals. The design report should describe the impact of the building's siting and footprint and discuss the form and orientation of major spaces as they relate to sustainable design. The report should also include the results of energy modeling, showing how the schematic design adheres to energy goals, and efficiency parameters for mechanical and lighting systems.

8.1 Schematic Design

The schematic design submittal required by the RFP should also include the size of major energy system components and how they interact with each other and other efficiency strategies. In addition to floor plans, elevations, and the types and sizes of mechanical system components, the project team can require that the following information be submitted:

- **The Building Plan:** Dimensions and a layout accommodating green building design strategies. For example, a double-loaded corridor is often suitable for daylighting and natural ventilation. The design team would describe any strategies that affect the shape of the building, such as open or private offices, perimeter circulation spaces, orientation, earth protection, an articulated or compact plan, atria, and sunspaces. A building floor plan should ideally stretch from east to west to minimize solar gain on west facades on summer afternoons and maximize solar heat on the south side during the winter.
- **Daylighting:** Size, number, and position of apertures (windows, roof monitors), relative dimensions of shading overhangs and light shelves, type of control (switching or dimming), number and location of light sensors, and requirements for room surface finishes (colors) and window glazing (visible transmittance and solar heat gain coefficient).
- **Passive Solar Heating:** Window areas and glazing properties (solar heat gain coefficient, U-value), amount of thermal storage material and relative position of glazing and mass, optimal levels of envelope insulation (R-values), and size and relative position of shading and overheat protection.
- **Natural Ventilation:** Size and relative position of apertures (operable windows, vents), controls, and interface requirements for the HVAC system.
- **Solar Water Heating Systems:** Solar collector area, location and orientation; amount of thermal storage (water tank volume); system schematic with heat exchangers and pumps; and control strategy.
- **Solar Photovoltaic System:** Area, location, orientation, and rated capacity of PV array; capacity of energy storage batteries (if any); and type and capacity of power-conditioning equipment (inverter).

- **Solar Cooling Load Avoidance:** Size, location, and orientation of window overhangs; reflectivity of roof surface; and glazing properties, such as solar heat gain coefficient and visible transmittance.
- **Solar Ventilation Air Preheating:** Size, location, and color (black is best but other dark colors are effective) of the perforated metal siding; connection to distribution ductwork; and any security concerns regarding ventilation air intake.

For each energy savings measure, and for the optimal combination of measures, the schematic design should include estimates of its energy use and operating cost, along with an estimate of probable construction costs. This information influences decisions about what should be included in the schematic design based on life-cycle cost effectiveness. Concepts included in the schematic design are carried over into design development.

FEMP provides information on project design in the Guide for Integrating Renewable Energy in Federal Construction (available at *www.eere.energy.gov/femp/reconstructionguide/building_design.html*)

8.2 Value Engineering

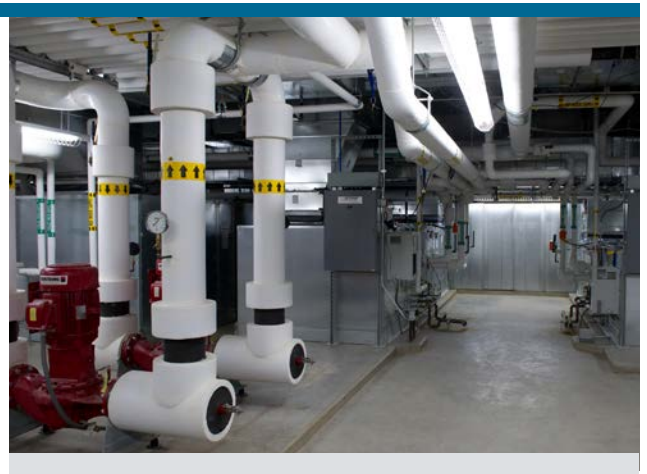
Value engineering is an effort that should be performed throughout a project. During value engineering, the team evaluates the design to determine how the same result or a better one can be achieved at a lower cost. Value engineering sometimes focuses on the functional mission of a building, but it is important that sustainability goals not be compromised as an important intent of the design. Value engineering should be based on life-cycle cost rather than just on capital costs.

Energy analysis should be part of the value engineering process to inform the value engineer of the consequences of removing important energy features. The analysis can also help to ensure that energy targets and goals are maintained through the value engineering process. The energy analyst performs computer simulations and analysis as needed to determine the effects of proposed cuts and to defend justified measures.

8.3 Energy Analysis and Software

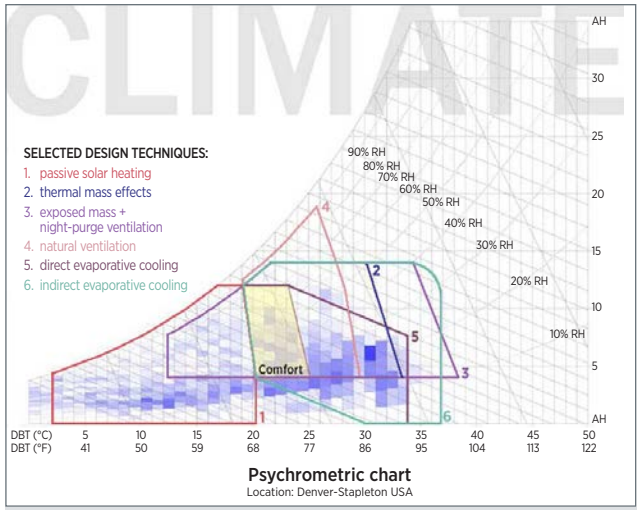
The energy analysis includes an hourly simulation to evaluate different schematic designs and interactions between measures. The design team can consider measures independently (single measure included), and also use elimination parametrics (single measure excluded) to evaluate the impact of a measure on the building as a whole system. The analyst can then rank strategies based on their performance and life-cycle cost. The objective is to select systems for design development. Incorporating new strategies or technologies into a fully developed design can be difficult. It is important to know as much project information, including project goals, early in the design process to inform the design moving forward.

Energy modeling with hourly computer simulation programs is essential for sustainable design, but energy modeling is a specialized field, and the effects of the inputs on simulation output can be complex.



Forty-two miles of radiant piping were installed in the ceilings of the Research Support Facility, allowing water to be used as a cooling and heating medium in the majority of workspaces instead of forced air. *Photo by Dennis Shroeder, NREL/PIX 19458*

Photovoltaic panels were installed on the Harold Washington Social Security Center in Chicago, Illinois as part of an energy savings performance contract (ESPC). *Photo from U.S. Social Security Administration, NREL/PIX 19006*



Psychometric chart. *Illustration by Shanti Pless, NREL*

The energy analysis requires several iterations to analyze multiple design alternatives such as:

- Climate specific strategies for the location of the building
- Building envelope and orientation
- Size and type of HVAC plant
- Type of distribution system
- Control set points
- Daylighting apertures and control
- Efficient lighting
- Renewable energy supplies.

There are many types of analysis techniques. Climate specific strategies can be analyzed using tools such as Climate Consultant and Hands Down Psychometrics Program Version 6, for example. These tools should be used at the start of the preliminary design to create psychometric charts* (as shown in the example) to understand the lighting, heating, cooling, and ventilation requirements to meet occupancy comfort levels.

Psychometric charts typically provide a "snapshot" of design conditions (such as loads and energy consumption programs), physical and computer modeling (such as daylight study models or light-tracing simulations), and testing (such as infiltration or HVAC equipment efficiency studies). Individual projects can benefit from some or all of these studies. Software programs have varying levels of complexity, are intended for different phases of the design, and require very different levels of effort and cost. The goal is to bring an appropriate level of analysis to the task at hand.

* A psychrometric chart is a graph of the thermodynamic parameters of moist air at a constant pressure, typically represented as an elevation point relative to sea level.

Tools such as eQUEST have been designed with intelligent defaults to provide immediate feedback to the designer or project manager during the earliest phases of a project. Computer simulations such as EnergyPlus, eQuest, and IES-VE require input detailing a developed design. Therefore, these are generally reserved for later in the design process, when many architectural decisions have already been finalized. Still other software packages—such as the proprietary program Trace—have been developed to assist in mechanical equipment selection and sizing and are often distributed by manufacturers. They are usually used only after all building envelope and massing decisions have been finalized.

Match the tool to the task

Analysts calculate building energy performance for two primary reasons: either to size mechanical equipment or to predict the annual energy consumption of a structure. Although these two tasks are not mutually exclusive and some programs can handle both, analysts tend to choose one or the other. However, the energy analyst should do both; evaluate the sizing requirements in terms of peak loads and determine the annual energy consumption. The cost of an efficiency measure is offset partially by the reduced size of the mechanical system serving the load, so it is important to include equipment sizing in the economic calculation.

Sizing programs are designed to calculate peak hourly load conditions independently during the heating and cooling seasons to size mechanical equipment. For almost all buildings, some kind of sizing analysis is run by an engineer or mechanical contractor in order to select equipment. Most sizing programs are based on consensus procedures and algorithms established by ASHRAE, but many are proprietary products distributed or sold by equipment manufacturers.

Annual consumption programs are designed primarily to analyze the total energy consumed by a structure in a typical year. Results are usually expressed in terms of Btu, dollars, or greenhouse gas emissions avoidance. The most accurate software packages calculate building loads on an hourly basis; they assume that the structure uses a mechanical system of some specified efficiency and a control strategy to meet this hourly load. Based on the inefficiencies of the mechanical system and the distribution system of the building (e.g., ductwork losses), the program can then estimate building energy consumption for that hour. The program calculates annual performance by summing hourly results for all 8,760 hours of the year. In many cases, annual energy consumption programs include provisions for inputting utility rate structures so that annual energy cost values (not just Btu consumption values) can be determined.

Plan the analysis early

Modeling adds no value to the process without early cooperation from the architects, engineers, and building owner to evaluate the potential to integrate the information that is generated from the models into the project design. Modeling should be conducted early enough to inform the conceptual design, preliminary design, the maintenance and verification stages and the final/post-occupancy model should be compared to the original design models. Integration of information is critical to a successful project.

Energy analyses can be performed in-house or by outside firms; they can be run by the primary design contractors (if they have adequate energy expertise) or by energy consultants. The most important thing to remember is that the results must influence the design process.

Checklist: Determining Energy Analysis Techniques

The energy analyst should bring expertise and ability to do the following:

- ☐ Perform a climate study to identify climate-specific strategies.
- ☐ Understand approved building energy computer program for calculating thermal performance of a building and its mechanical systems (e.g., following the list on the DOE website: *http://apps1.eere.energy.gov/buildings/tools_directory/doe_sponsored.cfm*).
- ☐ Work with the contractor to ensure that modeling results can be used throughout the project phase to influence the design efficiency.
- ☐ Clearly indicate which conceptual designs are being informed by the modeling.
- ☐ Ensure a process in which the results and level of detail that is generated from a quantitative energy analysis inform the design process, beginning in the concept stage.
- ☐ Specify the requirements of 10 CFR 436 (which specifies methods, discount rates, and fuel escalation rates) as the method by which the cost effectiveness of energy investments is to be determined.
- ☐ Specify in the SOW that the output of the energy analysis will meet the requirements of the LEED documentation (otherwise, the base cases could be different and may necessitate separate runs for LEED documentation).
- ☐ Define how the energy analysis tools are used in making design decisions.
- ☐ Integrate principles from the Whole Building Design Guide into modeling scenarios and the design process: *www.wbdg.org*

Resources

Descriptions of energy analysis software can be found on the DOE Energy Efficiency and Renewable Energy web site (available at *http://apps1.eere.energy.gov/buildings/tools_directory*), and the Whole Building Design Guide (see *www.wbdg.org/tools*). Some programs are proven to be effective for goal setting and design evaluation. A few examples organized by simulation area are listed below:

Whole-Building Energy Performance Simulation

Trane TRACE

(available at *http://www.trane.com/Commercial/Dna/View.aspx?i=899*)

A building energy simulation program that calculates peak heating and cooling loads, energy performance, ASHRAE 90.1 compliance, and conducts economic analysis.

Carrier HAP

(available at *http://www.commercial.carrier.com*)

An hourly building energy simulation program that aids in the sizing and design of HVAC systems and can demonstrate compliance with ASHRAE 90.1.

EnergyPlus

(available at *http://www.eere.energy.gov/buildings/energyplus/*)

A new-generation building energy simulation program that builds upon the capabilities of BLAST and DOE-2.

eQuest

(available at *http://doe2.com/equest/*)

An hourly, whole building energy analysis program that calculates energy performance and life-cycle cost of operation, including schematic design.

EnergyPro

(available at *http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=260/pagename=alpha_list*)

An energy simulation program that conducts HERS ratings for low-rise residential buildings; DOE-2 energy analysis and energy code compliance for California Title 24; and ASHRAE 90.1 for commercial buildings.

IES-VE

(available at *http://www.iesve.com/software*)

A building energy simulation program that can demonstrate compliance with a variety of energy codes, conduct lighting and daylighting analysis, and conduct computational fluid dynamics analysis.

Building Design Advisor

(available at *http://gaia.lbl.gov/BDA/*)

Provides building decision makers with the energy-related information they need from the initial, schematic phases of building design through the detailed specification of building components and systems.

Validation and Testing

BESTEST

(available at *http://apps1.eere.energy.gov/buildings/tools_directory/software.cfm/ID=85/pagename=alpha_list*)

A method for testing and diagnosing the simulation capabilities of the exterior envelope portions of building energy simulation programs. BESTEST (Building Energy Simulation TEST) evaluates design and analysis tools relative to their ability to adequately model the envelope dynamics of buildings. It has been adapted for certifying tools for Home Energy Rating Systems and by other organizations.

Through NREL, DOE has been working with the International Energy Agency Solar Cooling and Heating Programme Implementing Agreement (IEA SHC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) for more than the last 10 years to develop standard methods of test for building energy analysis computer software.

Standards Compliance

COMCheck-Plus

(available at *www.energycodes.gov/comcheck/*)

A resource designed to simplify the process of demonstrating compliance with commercial building energy codes using the whole building performance method.

Fenestration

WINDOW

(available at *http://windows.lbl.gov/software/window/window.html*)

A publicly available computer program for calculating total window thermal performance indices (i.e., U-values, solar heat gain coefficients, shading coefficients, and visible transmittances) using a method consistent with the National Fenestration Rating Council (NFRC) and ISO 15099 standards.

Therm

(available at *http://windows.lbl.gov/software/therm/therm.html*)

Performs analysis of two-dimensional heat-transfer effects in building components such as windows, walls, foundations, roofs, and doors; appliances; and other products where thermal bridges are of concern.

Assessment and Rating

BREEAM

(available at *www.breeam.org*)

BREEAM is a comprehensive and widely recognized assessment method and rating system for buildings. BREEAM assessments use recognized measures of performance, set against established benchmarks, to evaluate buildings' specification, design, construction and use. The measures used represent a broad range of categories and criteria from energy to ecology. They include aspects related to energy and water use, the internal environment (health and well-being), pollution, transport, materials, waste, ecology and management processes.

Sustainable Community Planning

AIA Sustainable Design Assessment Teams

(available at: *www.aia.org/about/initiatives/AIAS075425*)

The SDAT program is a community assistance program that focuses on the principles of sustainability. SDATs bring teams of volunteer professionals (such as architects, urban designers, landscape architects, planners, hydrologists, economists, attorneys, and others) to work with community decision makers and stakeholders to help them develop a vision and framework for a sustainable future.

NREL Life Cycle Inventory Database

(available at: *www.nrel.gov/lci/*)

NREL and its partners created the U.S. Life Cycle Inventory (LCI) Database to help life cycle assessment (LCA) practitioners answer questions about environmental impact. It provides individual gate-to-gate, cradle-to-gate and cradle-to-grave accounting of the energy and material flows into and out of the environment that are associated with producing a material, component, or assembly in the U.S.

8.4 Prepare the Construction Documents

The design team prepares working drawings and specifications generated during design development, approved by the owner, and confirmed as meeting the sustainability goals in the building program. At this point, it is too late to add new strategies or measures, so sustainability and energy experts try to ensure that sustainability measures developed in the design phase are being carried out.

The design team also prepares necessary bidding information, determines the form of the contract with the contractor, and specifies any special conditions of the contract. The construction documents contain all the information necessary for the bid solicitation. In other words, all the information that bidders need to accurately estimate labor and materials.

The team also ensures that architectural, mechanical, and lighting details and specifications, as well as commissioning specifications, meet energy goals. Team members then perform a final energy analysis to confirm that the energy goals will be met and to provide the documentation required for LEED certification or other purposes.

A data center manager reviews blueprints with an IT Project Manager and Data Center Coordinator in NREL's Research Support Facility data center. The building's cooling system, taking advantage of Colorado's cool nights, is key to achieving optimum energy performance. *Photo by Patrick Corkery, NREL/PIX 17289*

The project team must plan and budget for collecting documentation to evaluate environmental performance criteria and for preparing sustainable specifications. The sustainable attributes of a specified material or method must be described, and information should be included to assist the installation subcontractors in adopting an alternative material or technique. Special sustainability measures can include specifications or materials that are nonstandard and difficult to estimate in terms of cost. In this case, a consultant might be asked to provide information about specific products or processes. Careful specifications are key to keeping costs down while promoting change among suppliers and subcontractors.

The result of this final design effort is a package of drawings and specifications to be included in construction contract documents. The architect and professional engineer sign the forms certifying that the construction documents comply with all applicable codes and standards, including those related to energy and environmental requirements), and stamp the plans. Contract documents are often organized according to the structure in Table 2 with specifications defined by the Constructions Specification Institute (CSI). Some agencies have developed their own specification tools (such as NASA, NAVFAC and USACE) to standardize facility construction specifications.

FEMP provides information on project construction in the Guide for Integrating Renewable Energy in Federal Construction (available at *www.eere.energy.gov/femp/reconstructionguide/project_construction.html*).

Checklist: Elements of a Construction Contract

The following elements may comprise the construction contract:

Bidding Requirements

- ☐ Invitation
- ☐ Instructions
- ☐ Information
- ☐ Bid Form
- ☐ Bid Bond

Contract Forms

- ☐ Agreement
- ☐ Performance Bond
- ☐ Payment Bond Certificates

Contract Considerations

- ☐ General
- ☐ Supplementary

Specifications (in numbered divisions)

- ☐ General Requirements
- ☐ Existing Conditions
- ☐ Concrete
- ☐ Masonry
- ☐ Metals
- ☐ Wood, Plastics, and Composites
- ☐ Thermal and Moisture Protection
- ☐ Openings (e.g., doors, windows)
- ☐ Finishes
- ☐ Specialties
- ☐ Equipment
- ☐ Furnishings
- ☐ Special Construction
- ☐ Conveying Systems
- ☐ Fire Suppression
- ☐ Plumbing
- ☐ HVAC
- ☐ Integrated Automation
- ☐ Electrical
- ☐ Communications
- ☐ Electronic Safety and Security

Drawings

- ☐ Site
- ☐ Architectural
- ☐ Electrical
- ☐ Mechanical

Source: C.M. Harris, Ed. (1993). Dictionary of Architecture and Construction, 2nd Edition. ISBN 0-07-026888-6, New York: McGraw-Hill, Inc.

9 Post-Design/Construction

9.1 Commission the Project

Commissioning processes confirm that building systems were installed according to the intent of the design. Unlike testing and balancing, which are part of the construction contract, a third-party commissioning authority often performs commissioning on behalf of the owner.

In contrast to typical commissioning, commissioning that enhances sustainability requires the commissioning authority to be involved during the design and construction phases to develop a record of the design intent regarding energy efficiency and sustainability. The commissioning authority's early design reviews and recommendations ensure that the system designs are not only easy to evaluate in field installations, but are also more reliable.

FEMP provides additional guidance on project commissioning in the Guide for Integrating Renewable Energy in Federal Construction (available at *www.eere.energy.gov/femp/reconstructionguide/commissioning.html*).

Checklist: Commissioning

- ☐ Participate in goal setting and ensure that the owner's written requirements can be verified by the commissioning authority.
- ☐ Review and comment on preliminary design submittal and verify that schematic design features meet the owner's requirements regarding sustainability.
- ☐ Review and comment on the construction documents to ensure that the owner's requirements are met and that any special requirements related to commissioning are included.
- ☐ Review and comment on field construction reports or changes to the design.
- ☐ Conduct post-occupancy review one year after construction.
- ☐ Prepare written instructions for continuous commissioning of the building systems through the creation of a building log. Include photographs and documentation during the construction phase to increase knowledge of the building's structure and systems.

9.2 Operation and Maintenance

Operations and Maintenance (O&M) is critical to the success of a functional building. O&M should be a priority and included early in the A/E process. O&M staff should be included in the charrettes and discussions with architects, engineers, energy modelers, etc. to verify the predicted savings associated with smooth operation and regular maintenance, as well as serve as stewards of the building systems. Ideally, O&M staff will enhance the operation of a building through HVAC and lighting systems, which in turn, will result in optimum energy performance and energy savings. Safety and reliability of equipment are other benefits provided by a good O&M program. Proper maintenance of building systems also increases the life expectancy of equipment, which increases the value of the investment of equipment and into the O&M program itself.

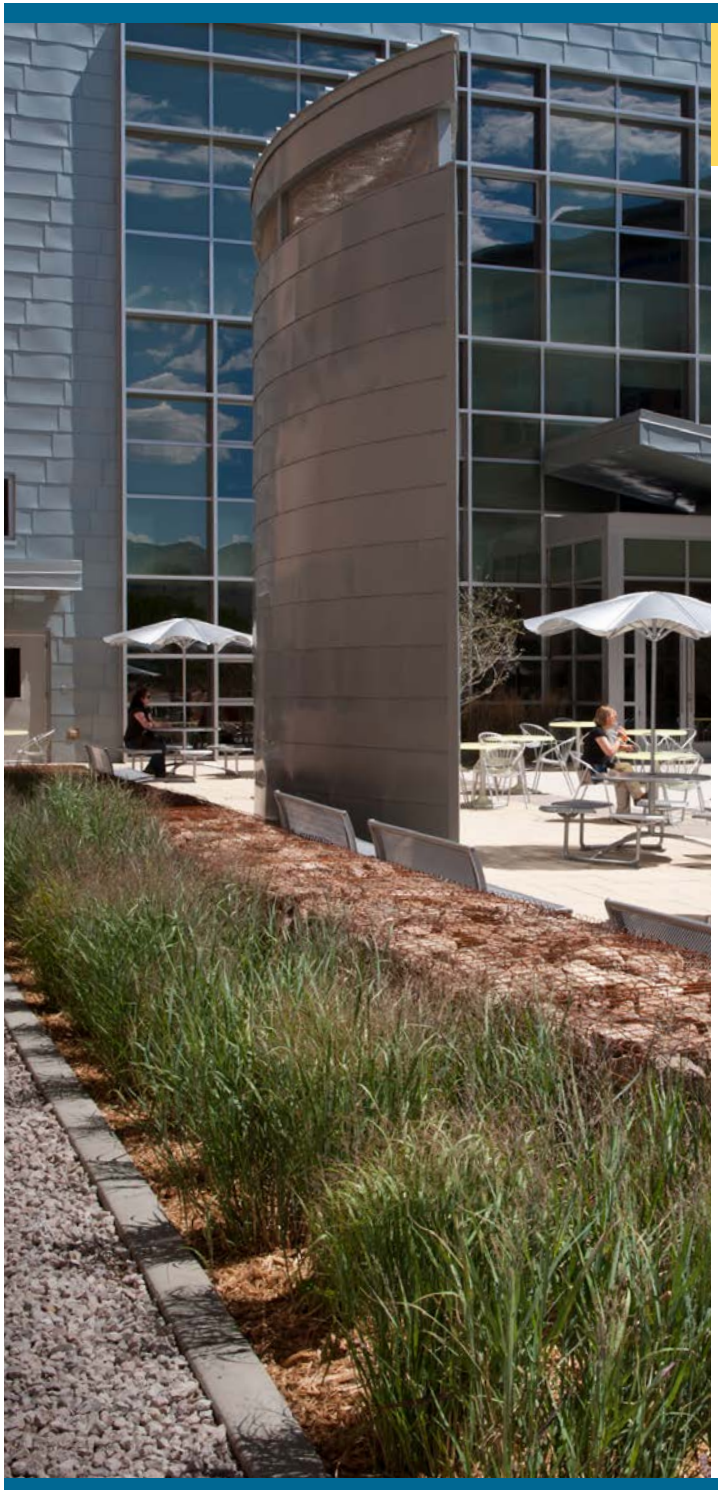
O&M staff should be trained in the operations of equipment, even if they have been previously trained. A/E staff should work with the staff involved in the O&M program to explain how each individual system operates and how the systems are integrated. A building log book or manual is useful to O&M staff, even if they have been trained in the specific building systems. A log book is a valuable tool for referencing issues that may arise, troubleshooting, or providing consistency when staff move on from an agency or organization. The logbook may include checklists for regular maintenance, instructions, certificates of inspection, safe operating procedures, maintenance schedules, etc. The A/E firm can train O&M staff and provide multiple copies of the log book, as well as an electronic file that can be updated as building systems change or are modified. The budget for the project should include the O&M considerations stated above, as well as continued education for O&M staff to attend trainings that might be offered or to bring specialized consultants to the facility for inspection or problem solving sessions.

FEMP provides additional resources on Operations and Maintenance (available at *www.eere.energy.gov/femp/program/operations_maintenance.html*).

9.3 Measurement and Verification

Measurement and verification (M&V) provide diagnostic information to enable systems to continuously realize their intended benefits. The International Performance Measurement and Verification Protocol (available at *www.evo-world.org/*) describes options for structuring and implementing such a program. The task of designing the M&V system should be included in the system design, so that measurement instruments can be installed along with the building's systems and adequate space and connections can be provided. This task is most often added to the mechanical or electrical requirements.

FEMP provides additional guidance on measurement and verification in the Guide for Integrating Renewable Energy in Federal Construction (available at *www.eere.energy.gov/femp/reconstructionguide/commissioning.html*).



10 Conclusion

The procurement of architectural and engineering services presents an opportunity to leverage the resources of a project toward increased efficiency. Designers respond to customers' needs, and clear and thorough statements of work for A/E teams are the best opportunities for owners to communicate their goals to the design community.

Requests for proposals that require green design services will generate interest among design firms. However, the requirement for green design must be reflected in detailed tasks and appropriate budgets. Even if owners indicate a desire for green buildings, but do not include the additional tasks or budget required to enable the design team to pursue that goal, the desired results will not be achieved. The statement of work and its accompanying estimate of the budget are prerequisites to a successful green building project.

Low-energy buildings are not achieved simply through new hardware; but require an integrated, whole building approach to their design. Creating a low-energy building requires great attention to detail throughout the design process. Even after a building is constructed and properly commissioned, an effective post-occupancy analysis is necessary to ensure that the expected performance has been achieved.

Studies show that buildings designed with energy consumption in mind—by knowledgeable design teams—significantly outperform average conventional buildings. Buildings designed with energy consumption in mind can also improve the indoor environment, enhancing the health and productivity of the building occupants. Proactive planning, collaboration among the key team members, and continual communication are key to successfully procuring architectural and engineering services. The scope of work and selection criteria the team sets early in the programming and project development phases will have a crucial impact on a building's energy performance and other sustainable design benefits.

Glossary

algorithm—A step-by-step procedure for solving a problem or accomplishing an action; the underlying equations that govern a calculation procedure.

consumption, energy—The actual energy consumed by a building, also referred to as "load."

correlation—An analysis technique in which building energy performance is calculated by comparing or correlating the performance of the building in question with prevalidated equations (or curves) based on key thermal characteristics and climate information.

daylighting—The intentional, controlled use of natural light to reduce the requirement for artificial lighting in a building.

elimination parametrics—An analysis procedure that involves zeroing out individual load components, such as artificial lighting, to evaluate the effects of that component on total building loads or energy consumption.

hour-by-hour simulation—An analysis approach that calculates the energy loads and consumption of a building for each hour of the year.

LEED—Leadership in Energy and Environmental Design, a sustainability rating system devised by the U.S. Green Buildings Council.

load—The net hourly heat loss or heat gain from a structure that must be met by a heating system to achieve interior comfort conditions.

passive solar design—A whole building, integrated approach to energy design that minimizes loads and uses standard elements of a building—such as windows, walls, and floors—to collect, store, and release the sun's energy for heating, cooling, and lighting.

Trace—A proprietary equipment sizing program developed by the Trane Corporation.

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For the DOE Regional Office FEMP Representatives, please see:
www1.eere.energy.gov/femp/about/regionalfemp.html

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