FEMP

Federal Energy Management Program

Leading by example, saving energy and taxpayer dollars in federal facilities

Procurement of Architectural and Engineering Services for Sustainable Buildings

A Guide for Federal Project Managers

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Cover photos and credits (clockwise from lower left): Break room at Sandia's Process and Environmental Technology Laboratory (PETL), Sandia National Laboratories, PIX10230; PETL exterior, Sandia National Laboratories, PIX10231; daylit lab space at the Nidus Center for Scientific Enterprise, Steve Hall (Hedrick-Blessing), PIX12660; solar electric (PV) system on roof of Zion National Park Visitor Center, Robb Williamson, PIX09227; Thermal Test Facility, Warren Gretz, NREL, PIX04116; Simulation Research Group, Lawrence Berkeley National Laboratory, PIX08746.

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In order to continuously improve the recommendations we have made here, please participate in this collaboration. You may forward your comments or contributions to your local FEMP representative or to any of the FEMP contacts listed at the end of this report.

Introduction

What usually comes first is the contract.
Benjamin Disraeli, 1804–1881

Many federal agencies have developed and embraced principles of sustainable design. These principles strike a balance between the need to fulfill an agency's mission in cost-effective buildings and the need to protect workers, the environment, and other resources. Agencies have the leverage to convert these principles into effective design practices through the procurement of architectural and engineering (A/E) services for energy-efficient, sustainable new construction.

The two most important elements in the procurement process are the selection criteria and the statement of work. A capable, enthusiastic design team and the right work plan virtually assure a successful, energy-efficient, sustainable design. The result would be compromised if principles of sustainability were not made enforceable ("given teeth") in each A/E contract. Therefore, this guide was prepared to be a resource for federal construction project managers and others who want to integrate the principles of sustainable design into the procurement of professional building design and consulting services.

To economize on energy costs and improve the safety, comfort and health of building occupants, you can incorporate daylighting, energy efficiency, renewable energy, and passive solar design into all projects in which these elements are technically and economically feasible. But how do you do that? The information presented here will help you to begin and to manage the inclusion of sustainable design in the procurement process.

The section on establishing selection criteria contains key elements to consider before you actually select an A/E firm.The section on preparing the statement of work discusses the broad spectrum of sustainable design services that an A/E firm can provide for your federal project.

The Federal Context

As the world's largest consumer of energy, the federal government has a tremendous opportunity to save some of the money spent on energy every year. In fiscal year (FY) 2000, for example, the government spent $3.39 billion on energy for buildings and facilities, or $1.11 per square foot (ft^2) per year. Data show that about 1.39 quadrillion British thermal units (Btu) of primary energy were consumed in FY 2000: 0.63 for buildings and 0.76 for vehicles and equipment.

Randy Montoya, Sandia National Laboratories/PIX10231

The Process and Environmental Technology building at Sandia National Laboratories in Albuquerque, New Mexico, was designed with energy efficiency as well as attractiveness in mind; using efficiency measures, the design team reduced the building's estimated energy consumption by 40%.

However, the federal government has made considerable progress in reducing this energy use and cost. Building energy use fell from 139 kBtu/ft^2/year in 1985 to 121 kBtu/ft^2/year in 1995—less than the National Energy Conservation Policy Act goal of 126 kBtu/year. Energy use was reduced further by the year 2000 to 106.7 kBtu/ft^2/year. But according to the Department of Energy's (DOE's) Federal Energy Management Program (FEMP), more progress is needed if the government is to meet the goals of Executive Order 13123 and reach 97.6 kBtu/ft^2/year by 2005 and 90.6 kBtu/ft^2/year by 2010.

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 old ones they replace. For example, some new military housing in temperate Hawaii includes air-conditioning, while older housing relies on natural ventilation. Similarly, office automation and space-conditioning needs can increase the amount of energy consumed in new commercial buildings. But in general, the superior energy efficiency of new buildings contributes to federal energy reduction goals. Improvements in equipment efficiency and material properties usually result in new buildings that consume less energy than older ones.

Dozens of federal agencies construct, renovate, and maintain thousands of buildings in a wide range of climates and conditions. Thus, construction and maintenance costs are considerable. The federal government spent $130 million in FY 2002 on energy conservation retrofits, but more than $16.5 *billion* on all new construction the same year—$5.4 billion for defense-related buildings and the remainder for civilian agencies, as shown in Table 1. Clearly, it is very important to leverage this investment toward better energy efficiency and sustainability. "Doing it right the first time" is much more cost-effective than retrofitting a building for greater efficiency later.

Table 1. Value of New Federal Construction (FY 2002)

Type of Federal Construction	Value Put in Place (in millions)
Residential	$1,493
Office	2,422
Commercial	903
Health Care	1,391
Educational	1,403
Public Safety	1,601
Amusement and Recreation	655
Transportation	1,796
Power	259
Highway and Street	685
Conservation and Development	2,576
Manufacturing	140
Total Federal Construction	**$16,563**

Source: U.S. Census, Construction Expenditures Branch of the Manufacturing and Construction Division, 2003, Value of New Construction Put in Place; see *http://www.census.gov/prod/2002pubs/c30-0208.pdf.*

Achieving superior building performance requires a comprehensive approach. It begins during the selection of A/E professionals and continues through programming and the development of schematics, design, and construction documents. It culminates in building construction and commissioning. Superior building performance must then be sustained by conscientious maintenance and confirmed by monitoring.

Jim Yost Photography/PIX05126

To achieve a design ensuring superior energy performance, it is important to start by selecting a dynamic team of A/E professionals.

The Value of Integrated Design

Buildings have always been designed to achieve their functional mission. Good building design has also addressed aesthetics, cost and durability issues. Today, however, designers of federal buildings are realizing the importance of addressing other considerations as well, including accessibility for the disabled, historic preservation, environmental impacts, regulations and code requirements, and, more recently, sustainability.

Treating such additional requirements as "add-ons" to the basic mission can increase the cost and compromise the effectiveness of a design. But considering them early in the design process—in an integrated manner—allows designers to meet multiple objectives at little or no additional cost. For example, specifying a wheel chair ramp *in addition* to stairs can increase total costs, but specifying a ramp *instead* of stairs can reduce costs.

Designers have also demonstrated that features intended to improve the sustainability of a building can enhance its mission in other ways. For example, daylighting is sometimes considered an added sustainability feature. But studies show that integrating daylighting into a design actually reduces operating costs, improves occupants' morale and productivity, and augments safety and security by providing light during power outages.

Incorporating low-energy and climate-responsive strategies requires a unique perspective—that of whole-building performance. This means balancing particular heating, cooling, ventilation, lighting, and other energy-flow requirements with preferences for energy efficiency and renewable energy. It also means understanding the interactions among architectural features such as orientation, the amount and location of glazing, and the 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, and evaluation tools in the past have been cumbersome and expensive. However, a new generation of software (for example, *ENERGY-10* or *eQUEST*®) makes this process both easier and more accurate.

Because the purposes and locations of federal building projects are diverse, it is not possible to define a single set of procurement specifications that apply to all projects or all agencies. Nevertheless, by considering the process in which these specifications are developed, agencies can optimize their resources in new construction and renovation projects, saving themselves—and U.S. taxpayers—millions of dollars. By making use of the 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) to keep it all on track, more federal building projects can benefit from integrated, low-energy, sustainable design practices.

Design Guidelines

> *When one has finished a building, one suddenly realizes that in the process one has learned something that one really needed to know in the worst way—before one began.*
> Friedrich Nietzsche, 1844–1900

Executive Order 13123 directs federal agencies "to apply sustainable design principles to the siting, design, and construction of new facilities." An agency's sustainable design guidelines are especially important in 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 already established such guidelines.

Sustainable design guidelines are sometimes given their own section in project specifications. This has both advantages and disadvantages. One advantage is that an agency's sustainability considerations can be included in specifications rapidly by inserting a separate section. The primary disadvantage 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 that they are really interested in. (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 (for example, the Bureau of Prisons) have identified all areas in their specifications where sustainability requirements should be added. And some private publishers have issued detailed guides to preparing specifications using "green" building products (see, for example, *http://www.buildinggreen.com/menus/index.cfm*).

The Department of Defense (DoD) and the military services have established the Unified Facilities Criteria (UFC) program to unify technical criteria and standards (see *www.ccb.org/ufgs/ufgs.htm*). 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 agency-specific documents except when required by unique circumstances. In its early form, however, it consists mostly of documents applicable to a single military service. These offices administer the UFC program for the military services:

- Headquarters, U.S. Army Corps of Engineers (*www.hq.usace.army.mil/hqhome/*)

National Institutes of Health/PIX09136

The design and planning team for energy-efficient Building 50 at the National Institutes of Health campus in Bethesda, Maryland, included both public-sector and private-sector experts.

- Naval Facilities Engineering Command (NAVFAC), Engineering Innovation and Criteria Office (*www.navfac.navy.mil/*)
- Headquarters, Air Force Civil Engineer Support Agency (*www.afcesa.af.mil/*).

Many agencies have adopted the Construction Criteria Base (CCB) information system as the distribution method for facilities criteria (see *www.ccb.org/*). 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 (GSA); 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* (see *www.wbdg.org*), which provides one-stop shopping for 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, the 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. Tasks and tools are constantly evolving, however, so 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 prominently called out 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 (see *www.gsa.gov*).

It is important to note that no single design process is "sustainable" while others are "not sustainable." Rather, continuous improvement in all processes will result in better and better buildings. Instead of simply replicating "what worked last time," we need to continually evaluate new products and methods. Design team members must also have a common understanding of what constitutes an improvement, so defining the evaluation metrics is an important task for the team.

Establishing Selection Criteria

Never contract with a man that is not better than thyself.
Confucius, 551–479 BC

Selecting capable, experienced, enthusiastic individuals to be on the design team could be the most important step in the sustainable design process. Some A/E firms have a strong commitment to sustainability and view it as a leading design consideration. Others, however, while acknowledging that sustainability is desirable, do not see sustainability as central to determining the design and form of a building. To achieve a successful partnership between your agency and your selected A/E team, you must first clarify your agency's values and priorities and then hire a firm whose values are closely aligned.

How do you select the right A/E firm? As a first step, your agency will want to choose a project manager and other key members of the team to oversee the project. It is a good idea to ensure that at least one member will be an advocate for sustainable design features throughout the process.

The second step is for the team to define the selection criteria that will be in the request for proposals (RFP) for the A/E. Because team members have different interests and values regarding the most important criteria for selecting an A/E, they will want to discuss them and come to an agreement about how much emphasis they want to place on sustainability in the selection process. In other words, where should sustainability rank in relation to other important design considerations? Selection criteria reflect the priorities and values of an organization, and these priorities determine how funds are spent. So, it is important to achieve some internal consistency before you develop selection criteria and the scope of work.

Once you develop a set of criteria (generally in four to eight topic areas), the next step is to assign a weight to each criterion, to establish its relative importance. Here is an example of the selection criteria one agency used to hire an A/E firm to design a new federal laboratory building:

- *Safety*: Does the offeror clearly demonstrate the ability to design laboratories that incorporate Uniform Building Code H-6 requirements 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)
- *Green Building Technologies*: Does the offeror clearly demonstrate the ability to incorporate green building technologies, as defined in the U.S. Green Buildings Council's Leadership in Energy and Environmental Design™ (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)

In addition to meeting criteria like the ones already described, A/E firms should also respond enthusiastically to your 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. And they should clearly describe a design process in which the energy implications of design decisions will be evaluated at each phase of the process with appropriate tools.

The design team must have demonstrable expertise and experience with design 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 by partnering with recognized energy and sustainable design experts. The consideration for energy efficiency and environmental quality should begin at the earliest stages of planning and continue through construction and operation. There should also be scheduled reviews of energy and environmental strategies throughout the design process.

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

Team Building

Too often in practice, an architect hands a completed architectural design to a mechanical engineer and says, "Make this work." The mechanical engineer then sizes a mechanical system to meet the building's peak load.

By that time, decisions regarding building orientation, massing, and fenestration—which all affect energy use—have already been made. This late in the process, there is little or no opportunity to optimize the building as a whole system. The mechanical engineer can optimize only the heating, ventilating, and air-conditioning (HVAC) subsystem—which is usually the assigned task.

In fact, the mechanical engineer should have been analyzing mechanical system options as the architectural design was developing, to inform the architect about the energy use and cost implications of design decisions. Similarly, in order to have proper daylighting, the lighting designer should be consulted when the building plan is being laid out on the site.

Everyone involved in a building project might want to coordinate closely at the outset. But because of the way competitive design fees are conventionally structured and procured, there is no financial incentive to participate in meetings and correspondence, evaluate alternatives, and reach a consensus—which are essential to achieving a successfully integrated, sustainable design.

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. Teamwork involves collaboration and cooperation, as well as making a shared goal a priority. Team members work together better if they are all involved in setting project goals early in the process. Deliberate, planned efforts to communicate at each step help to ensure success.

Susan Galentine-Ketcham/PIX12724

The 2800-square-foot Fort Carson Green Building in Colorado is a sustainable training facility incorporating natural daylighting and high-efficiency windows to reduce heating and cooling loads; a natural cooling cupola is a conspicuous part of the design.

Several trends promise to enable better design integration, including a growing emphasis on coordination and the use of new communication tools. Agency project managers realize that time spent on coordination early in the design process is likely to be returned several times over in lower construction and operating costs, so they budget and schedule ample time for coordination meetings.

Information Sharing

Several powerful new communication technologies are making this coordination easier and less costly. They enable design team members in different locations to share information, analyze data, and generate results efficiently. Many design and construction professionals make use of "collaborative Internet sites" to share drawings and coordinate schedules. And efforts are under way in industry and in the national laboratories to integrate computer-aided design (CAD) drawings, energy analysis computer programs, cost-estimating procedures, and all processes in which information is shared.

Security is of prime importance, of course. So, some agencies use private networks such as the project extranet system developed by the GSA for multi-billion-dollar capital construction programs in the Washington, DC, area. Experience with these new tools, or a willingness to try them, can also be part of the selection criteria for your A/E firm.

Checklist of Project Manager Considerations: Selecting Design Professionals

You can use the following criteria to enhance sustainability in your solicitations for design services.

To be successful, applicants should—

- ❑ State their commitment to sustainable design in their cover letter or introduction to their proposal.
- ❑ Demonstrate their ability to respond to sustainability goals and targets set in program documents.
- ❑ Demonstrate competence with the life-cycle cost (or 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.
- ❑ 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.
- ❑ Demonstrate familiarity with sustainability principles and sustainability rating criteria (such as LEED).
- ❑ Include a sustainability expert (such as a LEED Accredited Professional) in a position of decision-making authority on the design team, or demonstrate familiarity with the applicable rating system and its design implications.
- ❑ Describe actual experience achieving LEED ratings for completed building projects.
- ❑ 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, *ENERGY-10*).
- ❑ 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 prison or foreign embassy.
- ❑ Demonstrate an understanding of the most recent federal code, 10 CFR 434/435 (Code of Federal Regulations), or the comparable commercial code, American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1.

(Continued on next page)

- ❑ 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; electric 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 glazings; 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 an understanding of renewable energy technologies, such as solar water heating and photovoltaics, and past experience with them.
- ❑ Demonstrate an understanding of site design to provide or restore habitat and promote biodiversity and past experience with this.
- ❑ Demonstrate an awareness of new measurement technology and past experience with metering and monitoring of energy and water utilities.
- ❑ Demonstrate an awareness of the issues involved in operable windows and natural ventilation and past experience with them.
- ❑ Demonstrate familiarity with techniques to minimize and recycle construction waste and past use of them.
- ❑ Demonstrate a method to identify and use materials with recycled content or materials from rapidly renewable resources, such as certified wood products; demonstrate an awareness of the use of salvaged or refurbished materials rather than new ones.
- ❑ Demonstrate knowledge of the generation and distribution of indoor air pollutants such as volatile organic compounds (VOCs) and demonstrate past measures taken to minimize emissions from building materials and to control the passage of pollutants between rooms; demonstrate familiarity with air quality monitoring technology.
- ❑ Demonstrate an awareness of designing systems for the collection of recyclable materials and past experience with this.
- ❑ Demonstrate knowledge of the availability and use of locally manufactured products.
- ❑ Demonstrate knowledge and use of water-conserving fixtures and appliances; demonstrate an awareness and past use of wastewater recovery systems and rainwater collection systems.
- ❑ Demonstrate an understanding of indigenous landscaping and strategies to use less water, fewer chemicals, and less labor for maintenance.
- ❑ Demonstrate an understanding of specifying and implementing enhanced “whole-building” commissioning and quality assurance processes and past experience with them.

Preparing the Statement of Work

The most difficult things in the world must be done while they are still easy, the greatest things in the world must be done while they are still small.
Sun Tzu, circa 500 B.C.E.

A statement of work that includes all tasks to be performed is essential in the procurement of an A/E contractor for an energy-efficient, sustainable federal construction project. Schematic design, design development, construction documents, bidding and negotiating with contractors, and construction contract administration are considered an architect's basic services and are specified in the statement of work. A more comprehensive suite of services can include predesign planning such as project analysis, feasibility studies, programming, land-use studies, and analysis of financing options.

Other services can include attending or facilitating meetings to set goals and monitor progress, managing construction, performing an energy analysis, and conducting surveys of the sustainability attributes of various materials. Special language is included to enhance the consideration of sustainability in each phase of the design, emphasizing early ones in which key decisions are made.

To continuously improve sustainability, the design team must research new technologies and be able to rank many alternatives, as well as employ sophisticated methods of evaluating performance. These tasks should also be included in the statement of work to ensure that they are completed and that the designer has budgeted enough hours for analysis and design team meetings.

Performance goals from the building program should be written into the statement of work 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. It should also specify the involvement of mechanical and lighting designers as early as possible in the process.

Green design can take 40% to 100% more effort on the part of a mechanical engineer or energy analyst than simply sizing the mechanical system. To optimize the process, the mechanical engineer can use a "shoebox" model analysis (see *Setting Goals* in the Building Program section) to investigate mechanical system strategies early in the design. The engineer then continues the energy analysis as the design evolves, to keep the team informed about energy-use and cost implications of design decisions.


Nella Hobson/PIX09704

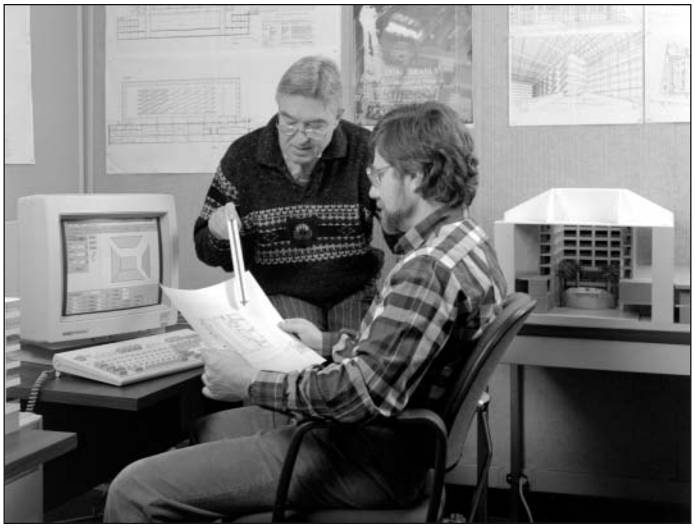
Daylighting and exterior shading are featured in the design of the U.S. Army Chaplain Center and School at Fort Jackson, South Carolina, to reduce electrical and cooling loads.

The design project schedule must include time to conduct regular meetings of the project designers to communicate energy-use and cost implications and recommend alternatives. Time for investigating utility rates and programs should also be included, and results for utility rates should be incorporated into the energy simulation to estimate the annual energy cost of alternatives. The statement of work for the energy analyst should include assistance with compiling the commissioning handbook, including the design basis and performance criteria.

For the energy analysis, a whole-building approach is needed to account for interactions between systems. Exploiting these interactions is a key strategy in green building design. For example, energy-efficient lighting reduces heat gain and allows a smaller chiller and much less energy for cooling to be specified. However, multiple measures must be considered in light of the fact that you cannot save the same kilowatt-hour twice. For example, a light sensor that turns off electric lights as more daylight comes in the building through the windows won't save any more energy or money if an occupancy sensor has already turned the lights off when people left the room.

Most of these interactions are well-represented by hourly simulation computer programs such as EnergyPlus, DOE-2, *Energy-10*, and BLAST. These programs are based on first principles laws of physics rather than correlation, so they can evaluate an infinite variety of design configurations. The hourly simulation consists of an equation balancing the energy in and out of each building component; 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 among the building envelope; heating, cooling, and lighting systems; solar heat gain; heat gain from occupants; and other energy flows specified by users.

The energy analysis will be discussed in detail in the section on the schematic design. But it may be helpful to



Lawrence Berkeley National Laboratory/PIX08746

Researchers at Lawrence Berkeley National Laboratory developed a new user interface for the DOE-2 simulation program, which can predict the hourly energy use and related costs of a building given its location, size, utility rate structure, and proposed heating and cooling equipment.

present here an overview of the role of energy analysis in the stages of building design: predesign and preliminary design, schematic design, design development, and design completion.

During predesign, 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 analyst evaluates schemes and the sensitivity of results to variable inputs, such as utility rates, and selects strategies for further development. In the schematic design, rough sizes of components are determined. During design development, the analyst assists in determining precise sizes and complete design descriptions.

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.

The statement of work for these services must also include work needed to arrive at a sustainable design. It specifies all the tasks required of the A/E firm and the following sustainability requirements:

- Specific research as to the client's needs and the most effective ways to meet them
- Detailed energy modeling
- Life-cycle-cost analysis
- Evaluation of alternative systems and materials
- Research and specification of energy-efficient (e.g., Energy Star-rated) equipment and materials that meet certification criteria for health or sustainability
- Development of documentation relating to sustainability rating criteria.

The statement of work for A/E services addresses sustainability in the following areas: 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 sections that follow.

Warren Gretz, NREL/PIX04116

The team that designed the Thermal Test Facility at the National Renewable Energy Laboratory in Colorado incorporated passive solar features, daylighting, advanced equipment controls, and other energy efficiency measures to ensure a sustainable, effective, comfortable testing facility.

The Building Program

The building program is a document conveying 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 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 the desired LEED rating (see Setting Goals) 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 agency's architectural guidelines regarding sustainability are referred to in the building program. The building program also documents the energy-related needs of users, which is a critical first step in designing systems to meet those needs efficiently as well as an indicator of the suitability of renewable energy systems.

The healthier environment and lower operating cost of a green building enhances the feasibility of a project, providing more desirable space. Some agencies have discovered that potential partners (e.g., funding sources, local community stakeholders) are more enthusiastic about supporting projects involving superior-performing buildings than those resulting in business-as-usual buildings.

Setting Goals

If you don't know where you're going, you'll end up somewhere else.
Yogi Berra, b. 1925

Goals for sustainability that are clearly and quantitatively stated at the beginning of design and construction are more likely to be factored into all the decisions made throughout the process. Sustainability goals require clear definitions and criteria that can be used to determine whether we have succeeded in meeting them. An agency often sets goals before issuing a solicitation. However, making goal setting a task of the entire design team after the A/E firm is on board can result in greater understanding and buy-in among team members.


Steve Hall, Hedrick-Blessing/PIX12660

The Nidus Center for Scientific Enterprise in St. Louis, Missouri, features daylighting, an efficient mechanical system with energy recovery, sustainable landscaping, and the use of local and recycled materials in construction.

A good general goal for most federal projects is to produce a beautiful, sustainable, cost-effective building that meets its program, encourages productivity, and consumes as few nonrenewable resources as possible through the use of passive solar design, energy efficiency, and renewable resources. However, unless quantitative aspects are included and can be measured later, it will be difficult to determine whether this goal was met. Using sustainability rating criteria such as Energy Star, LEED, and others is one effective means of doing this.

Energy Star-rated buildings are those that demonstrate energy performance among the top 25% nationwide, and Executive Order 13123 urges federal agencies to use Energy Star building tools. These tools 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 buildings pages on the FEMP Web site (*www.eere.energy.gov/femp/*).

Leadership in Energy and Environmental Design, or LEED, promulgated by the U.S. Green Buildings Council, is the most popular sustainability rating system in the United States. LEED tallies points for prescriptive criteria and designates levels of performance: Certified, Silver, Gold, or Platinum. For example, achieving a Silver LEED rating has implications for site selection, water use, wastewater handling, energy use, and materials selection.

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.

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.

Team members are more likely to proceed with a keen awareness of, and commitment to, project goals if they share in setting goals and determining metrics. Sometimes goal setting occurs before all design team members are on board, however. 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 previously set goals.


Steve Hall, Hedrick-Blessing/PIX12661

The Nidus Center for Scientific Enterprise received a Silver LEED rating for its numerous energy-efficient, sustainable features.

Energy performance goals can have different objectives. Annual energy use per gross square foot (Btu/ft^2/year) is a common metric in federal projects because that is how progress is tracked toward goals in the Energy Policy Act (EPAct) of 1992 and 1998 amendments, as well as those in Executive Order 13123. The shortcoming 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 option is to specify an energy-use goal as a certain percentage less than that 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 25% less energy than that allowed by 10 CFR 434/435 for federal projects, by ASHRAE 90.1 for commercial buildings, or by California Title 24 for buildings in that state.

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

Whichever metrics you select, it is important to use the same yardstick to measure performance as the one used in setting the goal. 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 the building's performance will be determined ultimately by actual use of resources (as evident 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.

How do you set an energy goal before you know what the building looks like? 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 selected because a cube shape would minimize surface area and would thus be an extreme selection for the base case.

First, a base case is defined to serve as a benchmark with which to compare 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.

Second, a suite of energy-efficiency measures is modeled, using the shoebox 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 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. For example, a reference case might be 100 Btu/ft^2/year, the shoebox with all cost-effective measures implemented might be 30 Btu/ft^2/year, and the goal for the project might be set at 40 Btu/ft^2/year. The *Energy-10* computer program has been developed to implement this predesign analysis and to assist design teams in setting energy-use goals.

Establishing 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 viable 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.

This task can be difficult, 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. But 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 thus desirable for the 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, you will probably want to retain the same base case definition throughout the project.

Decisions made regarding the definition of the base case will have implications in decisions about cost-effective interventions in the final design. Consequently, establishing the specifications of an appropriate base case building design is important, and the project manager and design professional or energy consultant should do this early in the design process.

Defining Performance Targets

After choosing sustainability rating criteria that will be a yardstick for measuring performance, we then need to specify what level of performance (what tick mark on the yardstick) we aspire to. 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 (projects of 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 *ENERGY-10*, Building Design Advisor, 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, into their program documents. Incorporating this kind of information in a program statement provides criteria against which to evaluate subsequent design performance.

Robb Williamson/PIX09256

The Zion National Park Visitor Center in southern Utah was designed to be a model of sustainability, incorporating the area's beautiful natural features as well as numerous elements that save energy and reduce operating expenses; the center also features a photovoltaic system for on-site power generation and a Trombe wall for solar heating.

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, BLAST, 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 the Energy Information Administration in DOE) as a reference and cite a target as a percentage reduction from the data. For example, in the year 2000, federal building energy costs averaged \$1.11/ft^2/year, which provides 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 could 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/ft^2 of office building is a reasonable estimate of the maximum cost savings possible using energy-efficient design. However, if you compare energy consumption in your new design to a hypothetical base case building rather than to the national mean for existing structures, the savings could be more modest. In that 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 absolute project criteria. The great variety of building types, programs, and conditions makes it challenging to set goals that do not involve uncertainty and are not difficult to achieve. Nevertheless, incorporating target goals into a programming document conveys the seriousness of energy consumption as a design issue. By asking potential design contractors to comment on this information in their proposal submissions, you can more readily evaluate their experience and insights.

Checklist of Project Manager Considerations: Programming

- ❑ List sustainability as a core value along with other requirements in the program.
- ❑ Stress the goal of employing a sustainable design alternative whenever economically and technically feasible in program documents.
- ❑ Highlight 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 building in the shape of a 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 suite of measures that are suitable for the base case shoebox (percent reduction in energy use from the requirements of ASHRAE 90.1).
- ❑ Specify which energy analysis software will be acceptable (DOE-2, *Energy-10*, or the equivalent).
- ❑ Indicate a target LEED rating in the building program:
    - ❍ LEED Certified, 26-32 points
    - ❍ LEED Silver Level, 33-38 points
    - ❍ LEED Gold Level, 39-51 points
    - ❍ LEED Platinum Level, 52+ points
- ❑ 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 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.

(Continued on next page)

- ❑ 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.
- ❑ Include in the building program any requirements of access to daylight or lines of sight to vision glazing (percent of space). Note any types of space in the program that would be enhanced by direct penetration of daylight, as well as any spaces that could not tolerate such direct penetration.
- ❑ 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, and temperature as determinants of human comfort.
- ❑ Establish in the building program the intention to continuously monitor building energy performance, indoor air quality, and comfort conditions.
- ❑ Indicate in the building program any requirements for accessing systems for mechanical, electrical, and communications distribution needs.

Schematic Design

We shape our buildings; thereafter they shape us.
Sir Winston Churchill, 1874–1966

The statement of work must describe all schematic design studies, showing the scale and relationship of project components. Submittals 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. Clearly, any suitable sustainability measure must be included in the schematic design, because in subsequent phases, these concepts are developed further but new ones are rarely added.

Sometimes an agency requires a design team to develop several schematic design alternatives. The work required to compare them—such as energy modeling for all options in order to compare energy use—must be accommodated 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 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. It 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.

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, you 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.
- *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).


Warren Gretz, NREL/PIX04715

Daylighting through high, stacked windows and clerestories, and indoor metal "trees" that disperse warm or cooled air evenly are just two of several sustainable and energy-efficient features of the award-winning Solar Energy Research Facility in Golden, Colorado.

- *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.

Energy Analysis and Software

The energy analysis includes an hourly simulation to evaluate different schematic designs and interactions between measures. Measures can be considered independently (single measure included), and elimination parametrics can also be used (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. New strategies or technologies cannot be added to a fully developed design. Thus, it is important that all information needed for decision making be obtained before the schematic design is completed (e.g., in a design charrette or from consultants).

Energy modeling with hourly computer simulation programs is essential for green design. But energy modeling is a specialized field, and the programs are very detailed. Someday, CAD software for creating designs will link directly to an energy analysis program. In the meantime, the tedious task of doing *takeoffs* (reading dimensions off plans and entering them into the energy program) falls on the mechanical engineer or energy consultant.

The energy analysis requires several iterations to analyze multiple design alternatives, including these:

- 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.

EPA/PIX12663

The Environmental Protection Agency's new facility at Research Triangle Park, North Carolina, was designed to be energy efficient and to produce electricity on site by means of a rooftop photovoltaic (solar electric) system.

> *Get the habit of analysis—analysis will in time enable synthesis to become your habit of mind.*
> Frank Lloyd Wright, 1869–1959

There are many kinds of analysis techniques. These include calculations (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. Although hand-based methods remain valid and can be used, today most designers and consultants use computer-based methods. These software programs have varying levels of accuracy, 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.

Tools such as *Energy-10* and *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, DOE-2.1E, and BLAST require input detailing a developed design. Consequently, they 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. Calculations are made of 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, they tend to be isolated. An energy analysis should determine both peak loads (sizing requirements) and annual energy consumption. The cost of an efficiency measure is partially offset 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 geared to calculating peak hourly load conditions independently during the heating season and during the cooling season to size mechanical equipment. For almost all buildings, a sizing analysis of some kind is run by an architect, 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 pollution avoidance. The most accurate software packages calculate building loads on an hourly basis; they assume that the structure uses a mechanical system of some defined 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. Annual performance is calculated 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.

Who Should Perform the Analysis? 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 be taken seriously and be given sufficient weight in the course of the design.

Checklist of Project Manager Considerations: Determining Energy Analysis Techniques

- ❏ Direct the contractor to propose design tools or software that match the project phase.
- ❏ Establish a reasonable budget for project energy analysis and consulting services.
- ❏ Determine whether there is a reasonable correlation between potential energy savings and an investment in energy analysis and consulting services; that is, are potential cost savings sufficient to justify the proposed cost of the energy analysis?
- ❏ Ensure a process in which the information that is generated from a quantitative energy analysis has an impact on the design process.
- ❏ 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 RFP 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).

Energy Analysis Software. Descriptions of energy analysis software can be found on the DOE Energy Efficiency and Renewable Energy Web site (see *www.eere.energy.gov/buildings/energy_tools*). Some programs are proven to be effective for goal setting and design evaluation. They include the following:

BLAST (Building Loads and System Thermodynamics)
BLAST Support Office
1206 West Green Street
Urbana, IL 61801
217-333-3977

Building Design Advisor
Energy and Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720
510-486-4000

DOE-2
Building Energy Simulation Group
Energy and Environmental Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720
510-486-4000

ENERGY-10
Sustainable Buildings Industry Council
1112 16th Street NW, Suite 240
Washington, D.C. 20036
202-628-7400

EnergyPlus
www.eere.energy.gov/buildings/energyplus/

Energy Scheming
Energy Studies in Buildings
Laboratory Department of Architecture
University of Oregon
Eugene, OR 97403
503-346-3656

HAP (Hourly Analysis Program)
Carrier Corporation
P.O. Box 4808
Syracuse, NY 13221
315-432-7072

TRACE®
The Trane Company
3600 Pammel Creek Road
La Crosse, WI 54601-7599

Visual DOE 3.1
www.eley.com/gdt/visualdoe/

Design Charrette

> *An idea is salvation by imagination.*
> Frank Lloyd Wright, 1869–1959

"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 urgent nature of a charrette). A design charrette today is an intense, collaborative effort among diverse professionals to complete a building design in a short period of time.

Because charrettes can generate so many good design considerations and ideas, the scope of work for a sustainable design should include time for team members in all disciplines to participate in one charrette either before or early in the schematic design phase. Ideally, there should be one more near the end of that phase. But 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 costliness might suggest limiting charrette participants. However, since each aspect of a design affects all other aspects, it is best to involve as wide a range of stakeholders in the charrette as possible. In addition to the project's 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, which usually consists of a plenary session and specific breakout sessions. The breakout sessions might address such topics 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 to select topics. Project managers often describe the program objectives early in a charrette.

During plenary sessions, participants identify and exploit the interactions between topics discussed in the breakout sessions and then bring the discussion back to a whole-building perspective. Charrette participants first listen, in order to understand the goals, needs, and limitations of a project. Then, participants envision and discuss creative but realistic solutions.

The scope of work for the architect could include facilitating the charrette, or this responsibility could fall to the sustainability consultant. A professional, dedicated recorder should also be included, to record ideas as they are mentioned 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. A recorder with experience in graphic arts could make the charrette report colorful and engaging.

Documentation

It is important to document the decision-making process. Documentation records how the design progressed and keeps the owner and new team members informed, thus avoiding the need to revisit decisions that have already been made. The statement of work must include the development of a design narrative (in addition to specifications and drawings) and documentation of the basis of the design.

The dual needs of weighting criteria and documentation can be satisfied by setting up a bookkeeping system for priorities, numerical values of various weighting criteria, and a convenient format for reporting the rationale of design decisions. The LEED rating criteria system provides a method for quantifying green building design measures, and it can be useful as a system of weighting the team's criteria.

The task of collecting and presenting documentation for a LEED rating should not be underestimated and should be accounted for explicitly in the statement of work. Documentation costs an average of about $20,000 to $50,000, depending on the complexity of the project and how effectively the team shares documents. Efforts are currently under way to simplify project documentation requirements and thus reduce costs to some degree.

Objective parties who have not been involved in the design could be recruited 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.

Reviewers usually point out strengths as well as weaknesses, and they try to be constructive with solutions to perceived problem areas. Putting the designer on the defensive would disrupt the team approach and make information-sharing problematic in subsequent reviews. A reviewer might take a questioning approach, however, to lead a designer to new thinking.

Checklist of Project Manager Considerations: Additions to the Statement of Work

The statement of work and budget must accommodate both additional work needed to evaluate alternatives and the greater communication needed for effective teamwork and sustainable design. Integrating otherwise disparate activities requires more than communication, however. It also requires that sustainability goals established in early program documents be shared across the team, and that the tasks required to integrate them with the work of others be included in contractual documents. Additional work includes, but is not limited to, the following items:

- **Architect**

❏ Ascertain the owner's requirements regarding sustainability.
❏ Lead the process of setting goals for the design team.
❏ 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 recycled, salvaged, or reused building materials.

- **Landscape architect**

❏ Evaluate and optimize measures to reduce water use in the landscape.
❏ Optimize the efficiency of the irrigation system.
❏ Evaluate and optimize measures to reduce requirements for chemical use (insecticide, fertilizer).
❏ Consider the landscape's impacts on building energy use by siting and planting to provide shade and wind breaks.
❏ Provide for stockpiling of topsoil for reuse.
❏ Participate in the development of an erosion control plan.
❏ Minimize paved areas and preserve or restore native vegetation.
❏ Participate in the design of rainwater catchment and greywater use systems.

- **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 members that do not block the distribution of daylight, and the storage of heat in structural mass.

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❑ In the selection of structural materials, consider recycled content, environmental impacts of extraction and delivery, and embodied energy.
❑ Inspect and evaluate the reuse of any existing structures 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 or energy analyst**

❑ Establish a base case model for energy-use calculations.
❑ Implement a suite of measures to optimize the goal set in the building program (minimize life-cycle cost or minimize energy use) in order to set a quantitative energy-use goal.
❑ Frequently calculate the energy use of evolving design alternatives and inform all other 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 more carefully ascertaining requirements and taking measures to mitigate the risk of discomfort.
❑ Consider innovative methods such as displacement ventilation, solar, or geothermal heat 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 systems to contain and remove tobacco smoke from designated areas.
❑ Design occupant-based control (e.g., CO_2 monitor) of mechanical systems.
❑ Design individual personal control of temperature, humidity, and airflow.
❑ Design mechanical system controls that respond to open windows (e.g., turn off).

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• **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.

• **Plumbing engineer**

❏ Establish baseline water use and lead in setting reduction goals.
❏ Select fixture and pipe layouts to conserve materials.
❏ Include recycled content and environmental impacts in material selection.
❏ Evaluate and specify low-flow fixtures.
❏ 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 a solar water heating system.

• **Interior designer**

❏ Specify recycled and recyclable furniture, furnishings, and fixtures.
❏ Specify colors (contrast) that allow lower lighting levels.
❏ 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.

• **Lighting designer**

❏ Minimize installed lighting capacity through architectural design of the lighting system.
❏ Consider a task-and-ambient lighting strategy.
❏ 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 direct illumination leaving the site.

• **Environmental 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).

(Continued on next page)

- **Indoor air quality consultant**

- ❏ Study room-to-room airflow and recommend measures to prevent contamination from spreading from pollution sources.

- **Waste management consultant**

- ❏ Recommend ways to minimize construction waste and maximize recycling of it.
- ❏ Recommend ways to enhance recycling over the building's life.
- ❏ Recommend ways to enhance on-site recycling (design and siting of collection stations).

- **Contractor** (trades)

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

- **Operation and maintenance** (O&M staff)

- ❏ 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** (predesign to post-occupancy)

- ❏ Be involved from the predesign phase to add commissioning-related requirements.
- ❏ Prepare commissioning-related requirements for construction documents.
- ❏ Include commissioning in the design review.
- ❏ Prepare recommissioning manual.
- ❏ Review at the end of the warranty period.

- **Owner** (Although not contracted for, the owner's role is a key determinate of sustainability.)

- ❏ 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.

Design Development

Daylighting provides most of the light in perimeter areas of Sandia's Process and Environmental Technology Laboratory.

During design development, drawings and documents are prepared 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, which includes determining the cost and performance trade-offs between alternative systems. The architect, mechanical engineer, and electrical engineer work together to place renewable energy sources (e.g., solar water heating, solar ventilation preheating, photovoltaics) in such a way that they do not look like afterthoughts or add-ons. Mechanical system options (e.g., thermal storage, economizer, night cooling, HVAC controls, evaporative cooling, ground-exchange) are specified at the component level. Lighting system design development integrates daylighting, equipment, fixtures, and controls.

Communication during the design development phase is key. A change in any system, such as lighting power, could affect all other systems, such as cooling load on the mechanical system. It is wise to conduct design reviews that are both internal and external to the project team. The focus of design review efforts should be on the early schematic design submittals. 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.

Design reviews can be accomplished by marking up plans and specifications and by supplying product literature and other information to facilitate implementation of the recommendations. It is also useful to call a meeting to convey to the design team some of the more complicated concepts from reviewers.

Objective parties who have not been involved in the design could be recruited 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.

Reviewers usually point out strengths as well as weaknesses, and they try to be constructive with solutions to perceived problem areas. Putting the designer on the defensive would disrupt the team approach and make information-sharing problematic in subsequent reviews. A reviewer might take a questioning approach, however, to lead a designer to new thinking.

Value Engineering

During value engineering, the design is scrutinized 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 first cost.

Energy analysis should be incorporated into the value engineering process in order to inform the value engineer of the consequences of deleting 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 analysis and computer simulations as needed to determine the effects of proposed cost cuts and to defend justified measures.

The value engineering professional is not always the "enemy" of the sustainability advocate. In fact, this phase sometimes provides a final opportunity to include a sustainability measure that reduces first costs or has other compelling benefits.

Construction Documents

During this phase of the project, the design team prepares working drawings and specifications. These were 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 now try to ensure that sustainability measures developed in the design phase are being carried out.

In this phase, 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 cost the 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.

The project team must plan and budget for collecting documentation to evaluate environmental performance criteria and for preparing "green" specifications. The green attributes of a specified material or method must be described, and information should be included to assist the installation subcontractors in adopting some new material or technique. Special sustainability measures can include specifications or materials that are non-standard and difficult to estimate in terms of cost. In that 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. Forms certifying that the construction documents comply with all applicable codes and standards (including those related to energy and environmental requirements) are signed, and the plans are stamped by the architect and professional engineer. Contract documents are often organized according to the structure in Table 2.

Table 2. Elements of a Construction Contract

Bidding Requirements	Invitation Instructions Information Bid Form Bid Bond
Contract Forms	Agreement Performance Bond Payment Bond Certificates
Contract Conditions	General Supplementary
Specifications (in numbered divisions)	General Site Work Concrete Masonry Metals Wood and Plastics Thermal and Moisture Doors and Windows Finishes Specialties Equipment Furnishings Special Construction Conveying Systems Mechanical Electrical Sustainability (?)
Drawings	Site Architectural Electrical Mechanical

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

Assistance with Bid Solicitation and Contract Award

During the bidding 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, as well as other direct construction costs. Bids do not include design team fees, 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.

The statement of work for the design team should include supporting the owner in bid solicitation and negotiation. This way, the team has an opportunity to maintain sustainability goals if any costs have to be cut. The statement of work for the energy analyst should include studies to evaluate trade-offs or substitutions. Since the contractor is providing all the labor and materials to complete construction, bidders may want to substitute materials they are familiar with or have ready access to for those specified for their sustainability benefits. In such cases, a sustainability expert should remain involved to advise the owner and encourage a compromise that optimizes the benefits of the materials selected.

Assistance during Construction

Administration of the construction contract is often included in the architect's and design team's basic services. The scope of work should include specific monitoring of sustainability and energy-related aspects during construction. Many energy efficiency measures, such as insulation and vapor barriers, require special attention to details during installation. Special instructions from the design team will help to realize the benefits of these measures.

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 taken place. 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. Again, the design team maintains adherence to sustainability goals as change orders are issued and if cost-cutting is required. Additional analysis may also be required to evaluate cost and performance trade-offs.

Commissioning

Commissioning processes confirm that building systems are 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 entails the earlier involvement of the commissioning authority to develop a record of the design intent with respect to energy efficiency and sustainability. The commissioning authority's early design reviews and recommendations result in system designs that are not only easy to evaluate in field installations, they are also more reliable.

Checklist of Project Manager Considerations: 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; 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.

Measurement and Verification

The ancient Romans had a tradition: whenever one of their engineers constructed an arch, as the capstone was hoisted into place, the engineer assumed accountability for his work in the most profound way possible: he stood under the arch.

Michael Armstrong

Measurement and verification (M&V) provide diagnostic information so that systems continuously realize their intended benefits. The International Performance Measurement and Verification Protocol (www.IPMVP.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.

Warren Gretz, NREL/PIX05170

For measurement and verification, energy-saving features such as advanced lighting, heating, cooling, and water-heating equipment can be monitored to determine whether they are performing as designed.

DETERMINING COSTS AND FEES

How Much Should I Spend?

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. This means that it is important to be practical about the extent to which a project can support the cost of consulting and analysis services for sustainability.

It is equally important to be realistic about the extent of the benefits of applying these services. This is true whether the analysis is being conducted internally or by outside contractors or consultants. A rule of thumb is that federal building managers should expect to spend as much as one year's expected energy savings for new building energy analysis studies. For major renovations that include window replacements, insulation retrofits, and lighting changes, this rule of thumb is also valid. For minor renovations involving component changes such as fixture or ballast replacements, expenditures on energy studies should as a rule be limited to not more than half of one year's expected energy savings.

An additional fee is required for the design team to evaluate alternatives and optimize system designs. And additional time is required for meetings and correspondence. In addition to basic design fees, a project manager could use the range of costs in Table 3 to augment the design budget to provide for green design services.

Table 3. Typical Additional Expenditures in Green Building Projects
(In addition to basic fees for architectural and engineering design)

	Minimum	Maximum
Additional A/E fees for "greening" of building	0% of project costs	5% of project costs
Energy modeling	\$0.05/ft^2 to \$0.25/ft^2 for large, simple building	\$0.25/ ft^2 to \$0.45/ft^2 for small, complicated building
LEED facilitation	0.25% of project cost for large building	0.50% of project costs for small building
Enhanced commissioning	0.25% of project cost for large building	0.50% of project cost for small building

How Should I Estimate Energy Modeling Costs?

There is a clear relationship between the level of energy analysis you can afford and the deliverables and level of detail you can expect from the analysis. The following list can help you determine the level of effort you can expect from your energy design professional or your energy consultant.

Modest Effort: 3 to 15 Person-Days

At this level, your 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 by running a design-phase analysis tool such as *ENERGY-10* or Energy Scheming.
- With the project architect or manager, use similar tools to study schematic building envelope and massing alternatives, including such options 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 one- or two-zone 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 this level, your 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 DOE-2.2, BLAST, or an equivalent hour-by-hour simulation tool to study schematic building envelope and massing alternatives, including such options 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.

Large Effort: 2 to 6 Person-Months

At this level, your 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 DOE-2.1E, BLAST, or an equivalent hour-by-hour simulation tool to study schematic building envelope and massing alternatives, including such options 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 that at least three alternative HVAC systems be analyzed on a life-cycle basis.
- In some cases, help write or compile a building commissioning handbook.
- In major renovation projects, conduct physical tests of existing conditions 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.

Should I Consider Performance-Based Fees?

Although this practice is far from business-as-usual, several projects 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 these:

- A clear goal and a specification as to how performance relative to that goal is to 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.

Eckert and Eckert/PIX03055

The Fred Hutchinson Cancer Research Center in Seattle, Washington, was designed for energy efficiency; after construction, it was found to use about 26% less energy than a conventionally designed building, and later retrofits saved an additional 7%.

To mitigate the risk associated with this approach, some projects have retained a minimum fee and based a special incentive fee on documented performance of the design (Charles Eley, Eley and Associates, San Francisco, California). However, some efforts to develop performance-based fee contracts have been scuttled by contracting officers or legal advisors unfamiliar with the technology required to evaluate performance. To make this approach work, 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.

CONCLUSION

The procurement of architectural and engineering services is the best place to leverage the resources of a project toward increased efficiency. Designers respond to what the customer asks for, and careful statements of work and deliverables for A/E teams are the best places for owners to tell the design community that they want green buildings.

Requests for proposals that require green design services will enhance interest among design firms. However, that requirement must be reflected in detailed tasks and appropriate budgets. Owners will be disappointed if they say that they want a green building but do not include the additional tasks or budget required to allow the design team to pursue that goal. The statement of work, and its accompanying estimate of the budget, are necessary precursors to a successful green building project.

A low-energy building is not simply the product of new hardware; it is the product of better design. Creating a low-energy building requires great attention to detail throughout the design process. Even after the 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. Getting and staying involved, and taking a proactive stance, can accomplish a lot. The directives and criteria you set early in the programming and project development phases will have a crucial impact on your building's energy performance.

Oberlin College/PIX09678

The Adam Joseph Lewis Center at Oberlin College in Ohio was specifically designed to be a "green" building; its features include water-source heat pumps for heating, cooling, and ventilation; photovoltaics for electricity production; heat-radiating thermal mass for floors and walls; and energy-efficient lighting and glazing.

Glossary

ADELINE (includes SUPERLITE and RADIANCE)— A software tool for daylighting design that links daylighting and thermal performance.

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

ASEAM—A simplified energy analysis software tool based on the bin method of calculating annual performance. It is not set up to properly evaluate the interactive effects of many passive solar features, such as daylighting and thermal mass, however.

BLAST—A detailed, annual energy performance software tool that can model the interactive effects of passive solar design strategies such as daylighting, passive solar heating, and thermal mass.

consumption, energy—The actual energy consumed by a building—compare with "load."

correlation—An analysis technique whereby 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.

DOE-2.1E—An energy analysis software program that calculates the hour-by-hour energy use of a building, given detailed information on the building's location, construction, operation, and heating, ventilating, and air-conditioning systems. It was developed by Lawrence Berkeley National Laboratory in collaboration with Los Alamos National Laboratory and is supported by the U.S. Department of Energy.

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.

***ENERGY-10*—**An hour-by-hour, annual simulation program designed to analyze residential and commercial buildings of less than about 10,000 ft^2 (or two zones). It was conceived to be used during the earliest phases of design, and was developed by the National Renewable Energy Laboratory with support from the U.S. Department of Energy.

hour-by-hour simulation—An analysis approach that calculates the energy loads and consumption of a building for each hour of the year. Examples of hour-by-hour simulation software include DOE-2.1E and *ENERGY-10*.

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.

For More Information

EERE Information Center:
1-877-EERE-INF or 877-337-3463

FEMP's Web site: *www.eere.energy.gov/femp*

For your DOE Regional Office FEMP Representative, please see *http://www.eere.energy.gov/femp/about/regionalfemp.cfm* and the list below.

DOE Regional Office FEMP Representatives

Denver Regional Office (Central)
Sharon Gill
Alternative Financing
303-275-4846
sharon.gill@ee.doe.gov

Randy Jones
Technical Assistance
303-275-4814
randy.jones@ee.doe.gov

Golden Field Office
Lincoln Capstick
303-275-4796
lincoln.capstick@go.doe.gov

Joyce Ziesler
Contracting Officer
303-275-4725
joyce.ziesler@go.doe.gov

Chicago Regional Office (Midwest)
Gordon Drawer
Alternative Financing
312-886-8572
gordon.drawer@ee.doe.gov

Melinda Latimer
Outreach/Technical Assistance
312-886-8582
melinda.latimer@ee.doe.gov

Atlanta Regional Office (Southeast)
John Adams
Technical Assistance
404-562-0563
johnc.adams@ee.doe.gov

Doug Culbreth
Alternative Financing
919-870-0051
carson.culbreth@hq.doe.gov

Lisa Hollingsworth
Lead/Outreach/Technical Assistance
404-562-0569
lisa.hollingsworth@ee.doe.gov

Philadelphia Regional Office (Mid-Atlantic)
Tom Hattery
Alternative Financing
215-370-1362
thomas.hattery@ee.doe.gov

Claudia Marchione
Lead/Outreach/Technical Assistance
215-656-6967
claudia.marchione@ee.doe.gov

Boston Regional Office (Northeast)
Paul King
Outreach/Technical Assistance
617-565-9712
paul.king@ee.doe.gov

David Mark
617-565-9725
david.mark@ee.doe.gov

Seattle Regional Office (Western)
Arun Jhaveri
Technical Assistance
206-553-2152
arun.jhaveri@ee.doe.gov

Cheri Sayer
Outreach
206-553-7838
cheri.sayer@ee.doe.gov

Scott Wolf
Alternative Financing
206-553-2405
scott.wolf@ee.doe.gov

Pacific Liaison
Eileen Yoshinaka
808-541-2564
eileen.yoshinaka@ee.doe.gov

DISCLAIMER

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

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EERE Information Center
1-877-EERE-INF
(1-877-337-3463)
www.eere.energy.gov/femp/

Shawn Herrera
Federal Energy Management Program
U.S. Department of Energy
1000 Independence Ave., S.W., EE-2L
Washington, DC 20585
Phone: 202-586-1511
Fax: 202-586-3000
shawn.herrera@ee.doe.gov

Andy Walker, Ph.D., PE
National Renewable Energy Laboratory
1617 Cole. Blvd.
Golden, CO 80401
Phone: 303-384-7531
Fax: 303-384-7411
andy_walker@nrel.gov

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