FEDERAL ENERGY MANAGEMENT PROGRAM

DOE/EE-0249

Low-Energy Building Design Guidelines

Energy-efficient design for new Federal facilities

Introduction

Incorporating energy efficiency, renewable energy, and sustainable green design features into all Federal buildings has become a top priority in recent years for facilities managers, designers, contracting officers, and others in government buildings procurement. These progressive design strategies have been formalized through Executive Order 13123 (known as *Greening the Government through Efficient Energy Management*), which was issued on June 3, 1999. There are significant opportunities to accomplish the goals set forth in the executive order, whether in new building design or in the context of renovations. This guidebook addresses the first category—the design process for new Federal facilities. Because energy-efficient buildings reduce both resource depletion and the adverse environmental impacts of pollution generated by energy production, it is often considered to be the cornerstone of sustainable design. In this publication, we will be looking at what low-energy design means, specific strategies to be considered, when and where to apply these strategies, and how to evaluate their cost effectiveness.

Low-energy building design is not just the result of applying one or more isolated technologies. Rather, it is an integrated whole-building process that requires advocacy and action on the part of the design team throughout the entire project development process. The whole-building approach is easily worth the time and effort, as it can save 30% or more in energy costs over a conventional building designed in accordance with Federal Standard 10 CFR 435. Moreover, low-energy design does not necessarily have to result in increased construction costs. Indeed, one of the key approaches to low-energy design is to invest in the building's form and enclosure (e.g., windows, walls) so that the heating, cooling, and lighting loads are reduced, and in turn, smaller, less costly heating, ventilating, and air conditioning systems are needed.

In designing low-energy buildings, it is important to appreciate that the underlying purpose of the building is neither to save—nor use—energy. Rather, the building is there to serve the occupants and their activities. An understanding of building occupancy and activities can lead to building designs that not only save energy and reduce costs, but also improve occupant comfort and workplace performance. As such, low-energy building design is a vital component of sustainable, green design that also helps Federal property managers meet the requirements of the Energy Policy Act of 1992, Executive Order 13123, and other climate change goals.

The low-energy design process begins when the occupants' needs are assessed and a project budget is established. The proposed building is carefully sited and its programmed spaces are carefully arranged to reduce energy use for heating, cooling, and lighting. Its heating and cooling loads are minimized by designing standard building elements—windows, walls, and roofs—so that they control, collect, and store the sun's energy to optimum advantage. These passive solar design strategies also require that particular attention be paid to building orientation and glazing. Taken together, they form the basis of integrated, whole-building design. Rounding out the whole-building picture is the efficient use of mechanical systems, equipment, and controls. Finally, by incorporating building-integrated photovoltaics into the facility, some conventional building envelope materials can be replaced by energy-producing technologies. For example, photovoltaics can be integrated into window, wall, or roof assemblies, and spandrel glass, skylights, and roof become both part of the building skin and a source of power generation.

This guidebook has been prepared primarily for Federal energy managers to provide practical information for applying the principles of low-energy, whole-building design in new Federal buildings. An important objective of this guidebook is to teach energy managers how to be advocates for renewable energy and energy-efficient technologies, and how to apply specific strategies during each phase of a given project's time line. These key action items are broken out by phase and appear in abbreviated form in this guidebook.

A guidebook of practical information on designing energy-efficient Federal buildings.

Prepared by the New Technology Demonstration Program

Internet: http://www.eren.doe.gov/femp/

Contents

This page left blank intentionally

About the Technology

Buildings consume roughly 37% of the primary energy and 67% of the total electricity used each year in the United States. They also produce 35% of U.S. and 9% of global carbon dioxide (CO_2) emissions. Preliminary figures indicate that in FY 1997, Federal government facilities used nearly 350.3 trillion British thermal units (Btus) of energy in approximately 500,000 buildings at a total cost of $3.6 billion.

By following a careful design process, it is possible to produce buildings that use substantially less energy without compromising occupant comfort or the building's functionality. Whole-building design considers the energy-related impacts and interactions of all building components, including the building site; its envelope (walls, windows, doors, and roof); its heating, ventilation, and air-conditioning (HVAC) system; and its lighting, controls, and equipment. This stands in marked contrast to the traditional design process, where there is generally no goal to minimize energy use and costs beyond what is required by codes and regulations.

Executive Order 13123 calls for a 30% reduction in energy use per gross square foot by 2005. To achieve this goal, the agency and design team must establish minimized energy use as a high priority goal at the *inception* of the design process. A balanced and appropriately funded team must be assembled that will work closely together, maintain open lines of communication, and remain responsive to key action items throughout the delivery of the project.

Continuing advocacy of low-energy design strategies is essential to realizing the goal. Therefore, it is important that at least one technically astute member of the design team be designated as the energy advocate. This team member performs many useful functions, such as:

- Introducing team members to design strategies that are appropriate to building type, size, and location.

- Maintaining enthusiasm for the integration of low-energy design strategies as central components of the overall design solution.

- Ensuring that these strategies are not abandoned or eliminated during the later phases.

- Overseeing construction to ensure that the strategies are not thwarted or compromised by field changes.

For most projects, it is also highly advisable to retain an experienced low-energy design consultant. Because low-energy design is not entirely intuitive, experience gained from a range of projects is vital. Indeed, the energy use and energy cost of a building depend on the complex interaction of many parameters and variables that require detailed analysis on a project-by-project basis. Some of the attributes that an energy consultant should bring to the project include:

- Sufficient background to identify potential strategies based on experience.

- Knowledge of Federal information sources (e.g., Federal Energy Management Program, national laboratories), Federal requirements (e.g., 10 CFR 435 and 436 Energy Star™ buildings and equipment, energy-savings performance contracting), the Energy Policy Act of 1992 (EPAct), and other relevant executive orders.

- Technical expertise that generates enthusiasm, cooperation, and respect among team members.

- The capacity to efficiently use detailed computerized energy simulation programs such as the latest version of Energy 10 or DOE 2.

- The ability to make informed design recommendations based on computer results and life-cycle economic analyses.

- A breadth of experience sufficient to consider design options that not only save energy, but are also integrated with other project needs, including aesthetic considerations.

In sum, the energy consultant should serve as a catalyst for eliciting innovative energy-conserving design ideas from the entire design team. In some cases, other members of the project team (such as the design architect and engineer) may, themselves, be quite pro-

Estimated Costs for Low-Energy Design Consulting Services

	Investment ($/ft^2)		
Energy Use Type	**Small buildings (0 to 20,000 ft^2)**	**Medium buildings (20,000 to 100,000 ft^2)**	**Large buildings (100,000 ft^2 and above)**
Moderate Energy Users Including single family residences, housing, and warehouses	**$0.35 to $0.25**	**$0.25 to $0.15**	**$0.15 to $0.05**
High Energy Users Including offices, factories, and service centers	**$0.40 to $0.30**	**$0.30 to $0.20**	**$0.20 to $0.10**
Very High Energy Users Including laboratories and hospitals	**$0.45 to $0.35**	**$0.35 to $0.25**	**$0.25 to $0.15**

Note: This table adjusts the rule of thumb for building size and energy use characteristics and provides a more precise guideline. Note that as buildings get larger, there is an economy of scale, so it is not necessary to expend as much on a square-foot basis.

U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP), March 1999. *Procuring Low-Energy Design and Consulting Services: A Guide for Federal Managers, Architects, and Engineers*, available at *www.nrel.gov or www.eren.doe.gov/femp*.

ficient in low-energy building design and will respond well to the challenge.

The only thing that may hold them back from advocating low-energy design on any particular project is the lack of a commitment and appropriate funding by the owner or agency. Estimated costs for this consulting service can be obtained from the table on the previous page.

Application Domain

The application domain for low-energy design is not so much a case of where the technology should be *installed*, but where it is *integrated* with the other elements of the project to produce an energy-efficient building that serves both the environmental and functional needs of its users. When thinking about whole buildings, it is important to consider not only the discrete components and materials but how the various parts can best work together to achieve the desired results. That is what is meant by the phrase “integrated, whole-building design.” Low-energy design strategies and renewable energy concepts can be applied to almost any type of new Federal building.

Energy-Saving Mechanisms

In Federal buildings, low-energy design mechanisms range from a few high-profile architectural features that are solar responsive to the application of more conventional, and often less conspicuous, energy conservation technologies. Many applications are reconfigurations of typical building components, such as a change from flat façades and roofs to those that are articulated and have surfaces designed to bounce or block direct solar rays.

The low-energy design process described in this guidebook combines a broad range of practical systems, devices, materials, and design concepts that should be considered simultaneously whenever possible to achieve significant reductions in energy use. For most non-residential buildings, an energy-use reduction of 30% below what is required by codes and standards can usually be achieved with little, if any, increase in construction cost. The figure is closer to a 50% reduction in residences. Savings of 70% or more are possible for exemplary buildings, although achieving such significant reductions can be challenging in light of the demands occasioned by budgeting constraints and cost-effectiveness criteria. For example, daylighting, coupled with dimmable lighting and light-level controls, is increasingly commonplace. An effective and highly recommended energy conservation strategy, this technology cluster is an important component of low-energy building design. (See Applications Screening and How to Apply)

Because energy-efficiency concepts and technologies must dovetail with all other building elements, one of the most important energy-saving tools is the use of computer modeling and design software. This strategy should be used early in the design process to analyze the efficiency and cost effectiveness of candidate strategies. Detailed computer simulation results are then referred to throughout the design process, and often through the value engineering (VE) phase, to ensure that the building will efficiently perform as intended, and that subsequent changes to the design in the interest of cost-cutting do not adversely affect performance. By using appropriate energy simulation tools in the context of a whole-building approach that emphasizes solar technologies and energy efficiency, design teams can achieve significant operating cost savings while still staying on budget. A list of design and analysis tools is provided later.

Advantages of Low-Energy Building Design

While basic techniques and concepts are important, of greater relevance to a given building project are the specific low-energy building design techniques themselves. One key element of low-energy building design is the inventive use of the basic form and enclosure of a building to save energy while enhancing occupant comfort. The section titled How to Apply describes a wide range of low-energy building design strategies that can be commonly applied to new Federal buildings. Low-energy building design combines energy-conservation strategies and energy-efficient technologies. Some of these are described in FEMP Federal Technology Alerts (FTAs), including high-efficiency lighting and lighting controls, spectrally selective glazing, and geothermal heat pumps.

Low-energy design represents both a load-reduction strategy and the incorporation of renewable energy sources. Many low-energy building design strategies result in an absolute reduction in the use of power produced from fossil fuels. Together these innovations can save energy, reduce costs, and preserve natural resources while reducing environmental pollution. Low-energy building design strategies (including various daylighting techniques) can also provide a renewed sense of connection with the outdoors for occupants of Federal facilities. Low-energy design can also inspire planning concepts, such as interior private offices that borrow light from open office spaces at the building’s perimeter.

Basic energy-saving techniques should be used to reduce building energy use.

- Siting and organizing the building configuration and massing to reduce loads.
- Reducing cooling loads by eliminating undesirable solar heat gain.
- Reducing heating loads by using desirable solar heat gain.
- Using natural light as a substitute for (or complement to) electrical lighting.
- Using natural ventilation whenever possible.
- Using more efficient heating and cooling equipment to satisfy reduced loads.
- Using computerized building control systems.

More difficult to measure are the increases in workplace performance and productivity that are often achieved through whole-building design and its resulting economic value. Nonetheless, organizations housed in low-energy buildings have reported that their indoor environments help retain employees, reduce tension, promote health, encourage communication, reduce absenteeism, and, in general, improve the work environment. Another potentially significant benefit is the public perception that, by its own example, the Federal government is helping to lead the construction industry toward a more responsible and sustainable future. Similarly, by using public funds for cost-effective measures that reduce operating costs, Federal agencies are performing these tasks in a responsible and frugal manner.

Application

Low-energy building design techniques are application specific. This section provides a practical method of determining the potential use of design techniques in different types of Federal buildings, in different climatic locations, and under various local energy cost scenarios. It also details the process and level of advocacy required to assure such strategies are considered and incorporated into the design process, beginning with the earliest project phases (see Needs Assessment and Site Selection) and continue through Construction and Building Occupancy. Refer to the time line on pages 22–23 for an illustration of the various phases and key action items to be addressed throughout the process.

For a particular project, the specific energy-saving techniques, strategies, and mechanisms to be deployed will vary greatly, depending on building and space type. Their selection and configuration will also be influenced by:

- Climate
- Internal heat gains from occupants and their activities, lights, and electrical equipment
- Building size and massing
- Illumination (lighting) requirements
- Hours of operation
- Costs for electricity and other energy sources.

In reviewing this list, one can quickly grasp that strategies specific to a particular building or space may not work nearly as well (or at all) in another application. Therefore, some general guidance about building and space types (provided in Applications Screening) will prove useful in understanding the factors that lead to significant energy use in buildings and in identifying the strategies that can yield optimum savings.

It is essential that the team appreciate that a successful design solution under one set of circumstances may not be appropriate or cost effective for a different building type, size, or configuration; the same building type constructed in a different climate; or where variable energy costs apply.

Applications Screening

The use characteristics discussed below are representative of the majority of Federal building projects. The first step toward assuring low-energy building design for a particular project is to understand the energy implications of the structure’s basic form, organization, and internal operations. These criteria will dictate the relative importance of strategies to be deployed for heating, heat rejection, lighting, and, in some cases, hot water. The term heat rejection is used (as opposed to cooling) based on the idea that a fundamental goal of low-energy building design is to greatly minimize the need for, and dependence on, mechanical cooling.

It is important for those involved in Federal design projects to know how and why office buildings, courthouses, laboratories, hospitals, visitor centers, border stations, warehouses, and various residential building types use energy. Each of these will be summarized later, but first, some background information should prove useful in forming a basis of understanding.

Perhaps the most basic division is that of houses and larger, non-residential buildings. Houses are the most common example of skin-load-dominated buildings, because their energy use is predicated by heat gain and loss through the building enclosure or skin (also known as the envelope, e.g., walls, windows, roof, floor). Houses and other skin-load-dominated buildings primarily require heat in cold climates, cooling in hot climates, and very little energy of any type (except hot water) in benign climates like San Diego. For low-energy performance, it is common for houses and other skin-load-dominated buildings to be well-insulated and to invite the low winter sun in while keeping it out (through shading and proper building orientation) during the summer.

Simplistically, larger non-residential or commercial buildings are often referred to as *internal-load-dominated* buildings because a large portion of their energy use is in response to the heat gains from building occupants, lights, and electrical equipment (e.g., plug loads for computers, copiers). As a result of these internal heat sources, internal-load-dominated buildings are often designed to turn their backs on the sun, and further reduce solar gain through the use of tinted and reflective glass. There is some logic to this, but such an approach is too universal and precludes some of the most beneficial low-energy design strategies. Moreover, it often is too simplistic to think of a building with offices as simply an office building. The structure is also likely to have a lobby and circulation spaces, a cafeteria, a computer room, meeting rooms, and other spaces that have environmental needs and thermal characteristics that are very different from those of offices. Ideally, design strategies should first satisfy the needs of each individual space or zone. This requires careful attention during the programming phase of the project.

Evaluating a specific project for selecting and integrating low-energy design strategies starts with an understanding of the following factors:

Climate

Not just is it hot or cold, but how humid is it? Is it predominantly clear or cloudy, and during what times of the year? Clear winter climates are well matched with spaces that incorporate passive solar heating strategies. In contrast, spaces (and buildings) in clear summer climates generally require a high degree of sun control. Clear climates also make the best use of light shelves—horizontal surfaces that bounce daylight deeper into buildings. Even the site-specific and seasonal nature of the wind needs to be understood if natural ventilation strategies are to be incorporated into a building design.

Internal Heat Gains

The heat gains from building occupants, lights, and electrical equipment can be thought of as the interior climate and should not be generalized. Instead, during the early programming of the project, the heat gains anticipated from these sources should be quantified for the various spaces where they apply. In some cases, such as in storage buildings and other areas with relatively few occupants and limited electrical equipment, these heat gains will be minor. In other instances, the presence of intensive and enduring internal heat gains may be a determining factor in HVAC system design. Examples of intensive and enduring influences include activity-based gains, such as those produced by cafeterias and laundry facilities (where increased humidity is also a factor), and technological or industrial gains, such as the heat produced by mainframe computers or heavy machinery. These factors should be identified early on, and appropriate design strategies investigated (such as heat recovery or using a closed-loop heat pump system).

Building Size and Massing

In a low-energy building, both the indoor and outdoor climates exert a powerful influence on all aspects of building design. Sometimes, they complement one another, such as the case of a building with a lot of internal heat gains sited in a very cold climate. At other times, however, the two climates are antagonistic, such as when there are a lot of internal heat gains in a very hot climate. Understanding the implications of these factors is fundamental to determining appropriate low-energy design strategies for a particular building project. Under hot/hot conditions, buildings with large footprints and a large amount of floor space far from the exterior of the building will require heat removal in the interior zones (generally by mechanical cooling) all or much of year.

The other basic planning approach is to position all spaces that can benefit from connection to the outdoors in proximity to exterior walls. To achieve this, buildings become much narrower, with a maximum width of about 70 feet. Such an approach to building massing must, by necessity, be introduced very early in the design process. Also, recognize that not all spaces need or want to be exposed to the exterior, including many areas of complex building types like hospitals and courthouses. These spaces often function better as interior placements within a wider and more compact building form.

Lighting Requirements

The lighting needs of a building's various spaces need to be identified, both quantitatively and qualitatively, as part of the environmental programming conducted early in the project. Many spaces, including lobbies and circulation areas, require general ambient lighting at relatively low foot-candle levels (10 foot-candles or less). Such spaces are ideal candidates for daylighting. In contrast, some spaces are used for demanding tasks that require high light levels (50 foot-candles or more) and a glare-free environment. Here the design team's attention may shift from daylighting to a very efficient electrical lighting system with integrated occupancy sensors and other controls.

Hours of Operation

Typically, on a per-square-foot basis, the most energy-intensive Federal building types are those in continuous use, such as hospitals and border stations. In these buildings, the balance of heating and heat removal (cooling) may be altered dramatically from that of an office building with typical work hours. For example, the around-the-clock generation of heat by lights, people, and equipment will greatly reduce the amount of heating energy used and may even warrant a change in the heating system. Intensive building use also increases the need for well-controlled, high-efficiency lighting systems. Hours of use can also enhance the cost effectiveness of low-energy design strategies, such as daylighting in a border station or weather station. In contrast, buildings scheduled for operations during abbreviated hours (including seasonal occupancy facilities, like some visitor centers), should be designed with limited use clearly in mind.

Energy Costs

The cost for energy, particularly electrical energy, for most non-residential buildings is a critical factor in determining which design strategies will not only conserve energy, but will also be cost effective. In most locations in the United States, electricity is three to four times more expensive than natural gas per Btu. This disparity can, at times, be capitalized upon by introducing design strategies that effect a trade-off in energy use. For example, increasing the glass area and the commensurate daylight entry can save expensive electrical use but, at the same time, occasion the purchase of additional (but relatively low-cost) heating energy. However, such an example should not be misconstrued as indicating that daylighting requires an excessive amount of glass, as that is just not the case. Daylighting primarily requires placing the glass carefully and selecting the appropriate glazing.

In many locations, utility deregulation imposes an uncertainty on future electrical and other energy prices. To the greatest extent possible, the life-cycle benefits of various design strategies should be investigated for the range of energy-cost scenarios deemed plausible. For some strategies—particularly those that affect the amount of heating energy used—

Natural Gas:
Typical Cost for One Million Btu

$$\frac{1{,}000{,}000 \text{ Btu}}{100{,}000 \text{ Btu/Therm* x } 0.75 \text{ (Heating System Eff.)}} \text{ X \$0.60/Therm = \$8 per million Btu}$$

Electricity:
Typical Cost for One Million Btu

$$\frac{1{,}000{,}000 \text{ Btu}}{3413 \text{ Btu/kWh x } 1.00 \text{ (Site Eff.)}} \text{ X \$0.08/kWh = \$23 per million Btu}$$

kWh = kilowatt-hour

deregulation may be of lesser importance. In other cases, however, rate structures, particularly those based on peak electrical demand, may significantly affect the economic impact of strategies such as daylighting.

As part of a whole-building design strategy, purchasing bulk green power resources complements many building-specific design measures. Through a holistic approach to building design and operation, incorporating green power resources can further decrease the environmental impacts already minimized through the specification of energy efficiency and renewable energy measures in the design process. Minimizing electrical load requirements, and then meeting these requirements with clean electricity resources, is at the core of a whole-building design strategy.

Green power refers to utility-scale electricity resources that are in some way environmentally preferable to conventional system power. The terms green and clean are often used interchangeably to describe this type of electricity. Green power supplied from the utility grid may be comprised of electricity from one or more types of renewable sources.

The term *renewable power* refers to electricity generated from one or more of the following types of resources:

- Wind—generated from wind-powered turbines, often grouped together into wind farms

- Solar—typically generated from photovoltaic (solar cell) arrays, often placed on rooftops

- Geothermal—generated from steam captured from below the earth’s surface when water contacts hot, underground rock

- Biomass—burning of agricultural, forestry, and other byproducts (including landfill gas, digester gas, and municipal solid waste)

- Small hydroelectric—generated from dams with a peak capacity of less than 30 megawatts (MW).

Building Types: Characteristics and Profiles

The following brief descriptions give broad categories of building types and some likely successful strategies for consideration.

Residential Buildings

In cold climates, the classic, skin-load-dominated building type really benefits from using high-performance, low emissivity (low-e) windows and high levels of insulation. In many cold climates, residential buildings can also significantly benefit from passive solar heating, so long as a reasonable amount of heat-absorbing thermal mass is incorporated into the design. In hot climates, solar control is paramount, based on the need to keep cooling loads and costs under control. It is also important to take advantage of the opportunity for passive or active solar water preheating. For remote structures that do not have easy access to the utility grid, photovoltaic systems should be considered as the primary, or sole, source of electricity.

Small Non-Residential Buildings

This profile describes buildings in which lighting and internal gains play a relatively small role in the building’s energy balance. Such buildings are the heart and soul of low-energy building design, as a multitude of low-energy building design strategies can be successfully applied to their construction. One common Federal building type that falls into this category is the visitor center.

Visitor centers are among the most advanced energy-conserving structures. They generally have a robust budget, allowing the purchase of durable materials. They are normally located in severe

Steven Sargent/PIX08889

An example of an energy-efficient home in a cold climate using direct-gain passive solar heating.

Robb Williamson/PIX09249

The Zion Visitor Center is designed to use 70% less energy than a typical building without costing more to build.

(either hot or cold) climates inaccessible to utilities; they have a natural connection with the outdoors; and the structures present an opportunity to interpret the resource-conservation mission of the agency to the visiting public. These structures typically combine a need for window area, massive construction, and a tolerance for temperature swings—all of which are highly compatible with low-energy building design. Daylighting is another key strategy for deployment in these building types.

Urban Office Buildings

This building type evinces characteristics commonly found in major urban centers, where Federal office buildings are often located. Land is often expensive and must be used at a high density. The building is typically dominated by one repetitive use—office space—although it may also contain a number of other uses, such as support facilities. These buildings are often landmarks or showpieces. In highly controlled areas like Washington, D.C., this translates into height limits and tight controls over façade treatment. In most cities, however, there are few controls on the style or height of downtown office buildings. As a result, many of these buildings include or consist of towers that shade and are shaded by neighboring buildings, a factor that may significantly affect the design and sizing of the mechanical cooling system.

Ascension Technology, Inc./PIX04478

Boston Edison joined Northwestern University to use solar electricity to power the Ell Student Center on the University's Boston campus. The rooftop PV system incorporates 90 285-W_p modules installed on innovative ballasted mounting trays that require no roof penetration.

Curtain walls are, by far, the most common enclosures for downtown office buildings, but most curtain walls are classic examples of a "building as a fortress against the environment" philosophy. The low-energy building design strategy for flat curtain walls is typically defensive in nature, limiting the boring and often unattractive result from the overuse of glass and by a lack of orientation-specific façades. Fortunately, there has been somewhat of a stylistic revolt against all-glass buildings, which has led to more articulated façades, variation in building façade treatments, and a resurgence in the use of masonry. All of these factors greatly enhance low-energy building design possibilities by creating opportunities to tune façades to suit their orientation and the activities taking place behind them. In most cases, thoughtful strategies will be needed to reduce solar gain. Exterior sunscreens or new glazing types (fritted, shaded) can both enliven the façade and provide substantial cooling load reduction.

An excellent way to take advantage of low-energy building design is to move as many private offices away from the façade as possible. In this way, more light can be directed further into the building, and more of the building's users can enjoy access to views and natural lighting. This scenario often yields increases in productivity and enables the adoption of more energy-efficient HVAC strategies.

If an atrium serves the program's needs, it should be located and designed to substitute natural lighting for artificial lighting, to minimize cooling loads, and to take advantage of solar heating, if it is needed. The location and shape of the atrium will be highly building-specific. In general, taking full advantage of the unique opportunities of each urban site requires considerable expertise, particularly because of shading from surrounding buildings and the complex interactions among lighting, HVAC, façade design, orientation, and climate.

Pamm McFadden/PIX02927

A courthouse in St. Paul, Minnesota.

Courthouses

This building type typically entails highly complex and interrelated space programming. Many diverse functions must be accommodated, sites are often constricted, and the professional occupants are demanding. In addition, courthouses often serve a ceremonial function. In many cities, they are the most prestigious and conspicuous of Federal buildings. Their typically urban location often requires a sensitivity to surrounding buildings with historical styles and value and most certainly will require careful integration into the existing urban plan. Oftentimes, the functional needs of courthouses (i.e., security requirements) must be fully satisfied before energy-based programming concerns can be addressed, and solar design strategies may not always apply to this building type. Still, low-energy design opportunities abound, especially in terms of efficient lighting, HVAC systems, equipment, and controls. It is also worthwhile to note that many of the design issues described for urban office buildings will also apply to courthouses.

Hospitals

These facilities tend to have a lot of small spaces, many of which need to be windowless. Offices and patient rooms can be thought of as small, mixed-use areas that incorporate both residential and commercial features. Cafeterias and public lobbies present special opportunities for daylighting. Overall, this building type has many spaces that require large quantities of outside ventilation air. Therefore, ventilation-air heat-recovery systems that are not prone to cross-contamination are particularly useful in these applications— especially in very cold climates. The around-the-clock nature of hospitals is a perfect opportunity to incorporate very efficient and well-controlled lighting and power systems.

Laboratories

Laboratories are an energy-intensive building type that often consumes more than 200,000 Btu per square foot, due to large ventilation requirements and in part to the long operating hours (two or three shifts) that are typical. The laboratory working environment normally requires enormous amounts of ventilation air to ensure good indoor-air quality, often making heat recovery systems cost effective.

If there is a considerable demand for hot water, preheating the water using solar energy is recommended, particularly for facilities located in clear climates. This building type can often benefit from daylighting, but because the walls tend to be occupied with equipment, it is appropriate to consider either high windows or toplighting by roof monitors on the upper floor. Either way, avoiding glare is crucial. Circulation corridors along southern façades can function as solar-heated sunspaces. Sunlight on south façades can be "bounced" through high glazing by way of light shelves. Depending on the regional climates, thermal mass walls for heat storage between labs and corridors may also make sense. The corridors can double as pleasant meeting and lounge spaces, while serving as a buffer to the south sun, thus permitting wider temperature swings than would be permissible in the main labs. On north-facing walls, small, well-spaced view windows can double as a source of diffuse daylight.

Incorporating atriums into laboratory buildings also makes sense, both as a means of bringing natural light into the labs and providing casual meeting spaces adjacent to the labs. West façades may serve as good locations for windowless lecture halls. Cafeterias can use direct gain, or in some temperate climates, might even have a fabric roof.

Warehousing/Shipping/Repairing

These activities are typically carried out in one-story buildings with high ceilings. Offices, supervisory booths, employee services, restrooms, and loading docks often complement a main unpartitioned space. For roof and wall assemblies, steps must be taken to counteract heat

Warren Gretz/PIX01137

The National Renewable Energy Laboratory's Solar Energy Research Facility.

Roch A. Ducey/PIX05184

An example of a multi-use building.

loss due to continuous metal contacts throughout the construction. Though not limited to metal components, this process is known as thermal bridging, which can significantly compromise the resistance value of insulation. In climates with hot summers, a white or reflective roof is advisable.

If lighting can be controlled electronically through light sensors and other devices, natural lighting strategies can be very useful. If the budget does not allow for proper roof monitors with vertical glass facing south or north, consider using high windows along the south and north walls with south-facing glass shaded by properly designed overhangs. Exercise care in using scattered skylights, as they can create glare and let in excessive amounts of solar heat.

If the building is subject to around-the-clock use, large high-intensity discharge (HID) lamps are appropriate when arranged in such a way as to light between inventory stacks when daylight is unavailable. Interior surfaces should be light-colored to reflect light. If the building is used intermittently, more and smaller HID or fluorescent lamps that easily switch on and off should be used. HVAC should be localized to work areas, with the overall building maintained at the maximum temperature range needed for its contents and the proper operation of machinery.

Campus Layout

This profile describes a wide variety of building types where space adjacency requirements are not crucial, and there is ample site area availability. Possible building types include rural or suburban office buildings, training and classroom facilities, some laboratories, barracks, and other multi-family housing.

If the buildings can be spread out, more of the interior space will be close to an outside wall. A campus plan makes the most sense in designing buildings for housing and classroom use, where deep interior spaces are inappropriate. Compared to a compact building form, the campus plan generally costs more at the outset, based on the need for a larger site, the cost of added building enclosures, and added lengths for service connections. When life-cycle economics are taken into account, these additional costs can be justified if the additional exposure is used to optimum advantage and daylighting and natural ventilation are brought into play.

For spaces that can benefit from passive solar heating, it is essential that south-facing solar glazing be clear of any shade during the heating season, even deciduous trees. The bare branches of trees can change a sunspace from one that provides useful heat into one that does not. In very cold climates, it is worth considering a partially earth-sheltered building, especially in the context of a sloping site.

Renovations

Renovating and reusing a building makes it low energy and sustainable in another very important way. Much less energy is needed to produce construction materials and deliver them to the site when the building's basic shell is being reused. Older buildings, in particular, often make excellent candidates for low-energy design that utilizes their mass, higher ceilings, and narrower building form. Many aspects of low-energy building design are applicable to many large-scale renovation projects. The only strategies that are clearly precluded are those based on siting, building form, or orientation. While these established features can limit a building's low-energy performance potential, renovations can still reduce energy costs by 20% to 30%.

Integrating Low-Energy Concepts into the Design Process

Feasibility Phase

The feasibility phase is normally when Federal building managers or other decision makers in the Federal sector determine that a project will be built to address a particular need. At this stage, the enabling premises of low-energy design and construction need to be defined and established. Think of this as the time when the seeds of the overall sustainable design and construction strategies are sown, and the framework is established for decisions to be made and actions to be taken throughout the design and construction process. Defining parameters; establishing general goals; and identifying policies, directives, and enabling legislation will guide and propel the process.

During the feasibility phase, architects and engineers develop a capital project scope and planning document that provides a design program, an implementation strategy, and a budget assessment. Identifying these elements early is essential to establish project feasibility, support project selection, and coordinate project execution. Community plans for major cities and surrounding areas identify long-term space needs for Federal agencies and propose appropriate actions to address those needs. Major projects involving renovation or construction of Federal buildings must be developed in accordance with applicable community plans. Agencies often conduct studies to support project planning or assess building conditions, some of which may take into account coordination with state and local authorities, community groups, and others who may have a stake in the development process.

Because Federal policy calls for cooperation with state and local authorities when planning Federal facilities, local government officials must be contacted to ensure that all documents impacting the project are discussed. These documents may include master plans, current and future land-use plans, zoning maps, traffic studies, and other documents that address the availability of essential support services (e.g., fire, police, utilities, telecommunications). Helpful information can also be obtained from your agency's local office, including documentation of current building conditions, maintenance concerns, site access, communication with other agencies, and other potential impacts on project scope and implementation.

Action Items

- Conduct all required feasibility analyses (including, but not limited, to those described above).

- Review all existing directives and policies to be sure of what your agency currently requires in the way of energy performance, materials usage (i.e., quality, durability, recycled content, energy saving features, impact on indoor environmental quality [IEQ]), daylighting, use of renewable energy sources, contracting issues, and other relevant concerns.

- Select an energy champion and give them the authority to make decisions relating to low-energy design and construction practices.

- Establish explicit energy-use targets that surpass those described in 10 CFR 435; specifically, reference Executive Order 13123. Factor in any additional criteria that may be specific to your agency or organization, facility location, or end use.

- Identify and list your agency's goals for other sustainable issues, such as site planning, materials use, water use, or IEQ.

Budgeting Phase

Some projects may be constructed using standard designs (those completed for similar projects or off-the-shelf, prefabricated structures). Be certain that your specific low-energy goals have been accounted for.

Action Items

- Program any special requirements into your budget submission.

- Submit a budget that allows for an energy champion (as well as the meetings and other resources required to accommodate a team process), the additional studies, analyses, and verifications that will be needed, and slightly higher design fees (generally 2%–4%).

- Include the requirement for an energy expert in your Request for Proposal/Architectural & Engineering (RFP/A&E) solicitation.

- Conduct a design charrette prior to concept development to ensure that low-energy building components and strategies will be adopted early in the planning and design stages, when these elements can be incorporated at the lowest possible cost.

- Identify the certification and testing measures required to ensure compliance with energy targets and sustainability goals.

Project Pre-Planning Phase

At inception, and during the early phases of a low-energy project's time line, a needs assessment is conducted (often with the assistance of a consultant). This process considers the long-term requirements of the building occupants and yields a program for the project that includes:

- User group needs and square footage requirements

- Location and site options

- Estimated costs and schedule.

For many Federal agencies, it is essential that the budget established at this time be based on all factors that will influence costs, including the incorporation of low-energy design strategies.

Action Items

- Select appropriate candidate low-energy design strategies.

- Associate these strategies with the particular project phase during which they must be considered and evaluated.

- Identify the team members who will be responsible for evaluating and incorporating the strategies at each phase.

- Identify the appropriate evaluation tools to use at each phase and who will use them.

- Identify the actions to be taken by various team members at each phase and carry them out.

- Establish low-energy design as a core project goal.

- Use case studies and passive solar performance maps to help determine appropriate strategies for the specific project type at hand.

- Establish energy-use targets that surpass applicable codes and standards. In general, energy-use reductions in nonresidential buildings should be targeted at 30% or better in comparison to a standard, code-compliant building.

- Ensure that the planned building configuration takes maximum advantage of the site and climate.

- In selecting consultants, consider their level of experience and expertise in low-energy design.

Strategies to Consider During This Phase

User Energy Needs Assessment

Description: This is a direct assessment of the energy-related needs of facility users. Whether it is in the form of an Environmental Programming Matrix or other, less formal, documentation, it is a fairly rigorous and thorough evaluation that considers occupancy, operating hours, and all aspects of the interior and exterior climates.

Goal: The needs assessment yields more precise energy use requirements, which, in turn, helps determine the applicability of low-energy building strategies.

Best Applied: The needs assessment is appropriate for use on all projects.

How to Do It: Classify users on the basis of specific needs that directly relate to specific low-energy building strategies. In addition to temperature, humidity, and general lighting standards, focus on other user needs such as the desire for exterior views and natural daylight; tolerance to moving air and temperature swings; and the type of automatic lighting control that is most appropriate for a given user.

Related Strategies: The needs assessment is considered a prerequisite to almost all other strategies.

Comments: This document may be seen as an expansion of the typical needs assessment procedure, and as such, may entail revision(s) to standard agency assessment protocols. Coming up with useful questions to ask in the needs assessment requires an understanding of the effects of various low-energy design strategies on user comfort.

Building-Appropriate Site Selection

Description: This process involves choosing a site that fully supports the energy reduction strategies contemplated for the project.

Goal: Proper siting increases the likelihood that many other low-energy building strategies can be implemented.

Best Applied: This strategy is appropriate for all new building projects.

How to Do It: During site selection, locate buildings that do not require extensive exterior exposure on shaded or confined urban sites. Buildings that will benefit from a greater degree of exterior exposure should be located on open sites.

Related Strategies: See Extended Plan.

Comments: For many projects, the site may have been selected before the manager's involvement.

Complementary Building Uses

Description: This process involves defining the nature of the facility and then matching the end use with complementary energy needs and minimizing the resulting wastes.

Goal: The design team takes advantage of the natural symbioses and commonalties that exist between building uses that might otherwise be overlooked.

Best Applied: When compatible projects are at similar points in their development; ideally, from the planning stages forward.

How to Do It: At the earliest stages of project conception and site selection, consider co-locating any types of facilities where the waste products of one can be used to provide needed energy for another, or where construction-based support services can be shared.

Related Strategies: Building-Appropriate Site Selection; User Energy Needs Assessment

Comments: Currently used in designing co-generation facilities, ecological industrial parks, district heating, and community-scale energy storage facilities; other applications may be identified on a case-by-case basis. Opportunities may also exist for co-locating non-polluting industrial and residential facilities. In all circumstances, action is required at the earliest stages of the project, before detailed plans for the various uses are fully developed.

Project Planning Phase

In close consultation with agency project personnel, the design consultants (e.g., architects and engineers) prepare initial and schematic design options. At this time, options for placing the proposed building(s) on the site and massing alternatives are evaluated. Fundamental low-energy design strategies (as detailed below) are also assessed for applicability to a specific project. Design consultants generally present their design options and analyses to agency project personnel for review and evaluation; this process is often repeated several times until the basic design is decided upon and approved. At the conclusion of this phase, the design should clearly indicate which low-energy design strategies have been incorporated in sufficient detail so that heating and cooling loads can be estimated and so HVAC system options can be examined.

Action Items

- Establish an interdisciplinary design team, including an energy professional, as early in the process as possible.
- Develop a preliminary layout that maximizes or minimizes solar gain. Consider atrium spaces, direct or indirect passive solar heating, earth-protected spaces, and natural and constructed shading.
- Develop landscape plans that contribute to the facility's energy performance. Consider shading options, wind breaks, and using existing site features.
- Develop a basic layout that maximizes the use of daylighting. Consider building orientation, the size and placement of windows, and toplighting.
- Investigate using renewable power sources as part of the facility's overall power supply. Consider using solar (domestic) hot water on building types with high hot water usage (such as laboratories) and building-integrated photovoltaics (BIPV) to reduce reliance on non-renewable power.
- Conduct a preliminary energy analysis (analysis tools depend on scale of project). Use ENERGY-10 and other user-friendly tools for smaller, simpler projects (those with two or fewer zones, and roughly 50,000 square feet or less). Use DOE 2.2 and other applicable tools for larger and more complex projects.

Strategies to Consider During This Phase

The following strategies need to be assessed during the project planning phase of the time line. Their incorporation will influence the overall siting and massing of the building, as well as the basic organization of spaces.

Perimeter Circulation Space

Description: This passive solar strategy uses circulation (corridors) and casual meeting spaces as buffers between the façade and the interior conditioned spaces.

Goal: To support several low-energy building strategies that are not compatible with certain uses (e.g., direct-gain sunspaces and office space).

Best Applied: The strategy is appropriate in buildings needing large areas for circulation, waiting, and casual meetings, such as a visitors' corridor in a hospital or casual meeting sunspaces outside laboratories or offices.

How to Do It: Because perimeter circulation plans generally require slightly more total floor area, it is necessary to examine user needs and evaluate the strategy in light of the overall budget. If the strategy is acceptable, look for buffer spaces that can be located along the building's exterior, particularly along the south façade.

Related Strategies: Atrium Spaces; Open Office Space at Perimeter; Direct-Gain Passive Solar Heating; Daylighting through Windows; Light Shelves; Selective Glazing; Shading Devices; Window Geometry; Natural Ventilation through Windows.

Comments: An accurate energy needs assessment is key to the effective integration of this strategy.

Extended Plan

Description: By extending the plan to produce a longer, narrower footprint, you can create more exterior wall surface. In most climates, elongating the building in an east-west direction makes the most sense from the standpoint of daylighting and passive solar heating.

Goal: To increase the amount of usable space that is close to an outside wall.

Best Applied: Building types that benefit most from exterior exposure include good candidates for daylighting and direct-gain passive solar heating.

How to Do It: This is best accomplished early in the design process, as modifying the basic building form may occasion a slight increase in the construction budget.

Related Strategies: Atrium Spaces; Open Office Space at Perimeter; Perimeter Circulation Space; Daylighting through Windows; all forms of Passive Solar Heating; Building-Appropriate Site Selection; Landscape Shading; Light Shelves; Shading Devices; Natural Ventilation through Windows.

Direct-Gain Passive Solar Heating

Description: Installing south-facing glazing in an occupied space enables the collection of solar energy, which is partially stored in the walls, floors, and/or ceiling of the space, and later released.

Goals: With direct-gain passive solar heating, the savings achieved in heating energy is augmented by the aesthetic and productivity-enhancing benefits of daylighting, a valuable amenity for occupants. The functioning of the space should not be compromised by direct glare from glazed openings or by local overheating.

Best Applied: This strategy works well in cold, clear climates.

How to Do It: Glazing must face within 15 degrees of true (solar) south, and the affected areas must be compatible with daily temperature swings.

Examples: Some appropriate contexts for direct-gain heating include corridor spaces, eating spaces, meeting spaces that can be scheduled for use during times when the temperature is most comfortable, sleeping spaces, and recreational sunspaces. Working with the energy consultant, the designer can fine tune the amount and type of glazing with glare and temperature controls, materials in the affected space, auxiliary heating, and cooling to address local climatic changes.

Related Strategies: Atrium Spaces; Differentiated Façades; Extended Plan; Perimeter Circulation Space; Daylighting through Windows; Building-Appropriate Site Selection; Landscape Shading; Selective Glazing; Shading Devices; Window Geometry.

Comments: Because true north and magnetic north are different, the design team will need to account for magnetic decli-

Warren Gretz/PIX03348

An example of direct-gain passive solar used in a residential building.

nation. For optimum effect, floor and wall finish materials with high heat-storage capacity must be exposed to direct illumination by the low winter sun. Overall, this strategy is considered central to low-energy building design.

Atrium Spaces

Description: Atrium spaces are multi-floor open areas appropriate for circulation, lobbies, dining, or other shared space. Atriums are typically covered by a glazed roof or one that incorporates roof monitors.

Goal: Configure the atrium for minimum impact on the building's energy load.

Best Applied: Buildings with programmed spaces that can be well-served by one or more atrium spaces.

How to Do It: Avoid configurations that produce heat losses or gains with no compensatory benefits. The atrium should bring daylight to the interior of the building while providing a "chimney" for natural ventilation during mild weather. In some cases, atriums can collect useful solar heat in cold climates—serving as a kind of transition zone, with larger temperature swings than would otherwise be appropriate in the rest of the building. The atrium's configuration should be defined at the earliest possible stages of the design process, before an undesirable or arbitrary configuration is locked in.


Warren Gretz/PIX02194

An example of an atrium space.

Related Strategies: Building-Appropriate Site Selection; Extended Plan; Perimeter Circulation Space; Roof Monitors; Glazed Roofs; Fabric Roofs; Direct-Gain Passive Solar Heating; Selective Glazing; Shading Devices; Induced (Stack-Effect) Ventilation.

Comments: There is no hard and fast distinction between atriums and glazed roofs over large open spaces (such as gallerias).

Induced (Stack-Effect) Ventilation

Description: Heated air rises within a mid- or high-rise building to the top (often below a glazed roof in an atrium), where it exits through roof openings. This process induces ventilation of the adjoining spaces below.

Goals: This strategy removes heat and reduces mechanical cooling and fan energy use requirements.

Best Applied: Spaces that are not adversely affected by increased air motion are appropriate targets for natural whole-building ventilation, which effectively conditions the space during fair weather without using air conditioning.

How to Do It: Incorporate air inlets, generally in the form of operable windows, at the building perimeter. For best results, use open-office space planning and avoid partitions that inhibit air movement. Consider complementing natural ventilation with controllable passive ventilators located in the upper portions of the building. Carefully coordinate the implementation of this strategy with building HVAC system and controls.

Related Strategies: Atrium Spaces; Glazed Roofs; Roof Monitors; Natural Ventilation through Windows; Night-time Cooling Ventilation.

Comments: Natural ventilation works best in low-humidity climates. An atrium often serves as an ideal chimney to exhaust hot air.

Open Office Space at Perimeter

Description: Locating private offices at interior positions leaves the perimeter open to general office space.

Goal: Program open spaces at the perimeter to allow for more extensive use of daylighting deeper into interior sections.

Best Applied: Use this strategy in buildings with large areas of office space.

How to Do It: Private, interior-located offices need compensating amenities. At minimum, install glazing that lets onto the open office space or overlooks an atrium space. This strategy is especially appropriate for buildings with limited façade glazing, such as earth-protected buildings.

Related Strategies: Atrium Spaces; Earth-Protected Space; Perimeter Circulation Space; Daylighting through Windows; Light Shelves; Selective Glazing; Shading Devices; Window Geometry; Natural Ventilation through Windows.

Comments: This is an effective strategy that requires a strong commitment by the agency or organization to keep perimeter spaces open and not reserve them for high-ranking executives. (This is perhaps not as significant an issue in Federal buildings as compared to the private sector.)

Landscape Shading

Description: The use of existing or planned trees and major landscaping elements to provide beneficial shading.

Goal: Locate trees and major landscape elements to provide useful shading and reduce cooling loads.

Best Applied: Landscape shading works best when shading west and south façades.

How to Do It: Study planting plans of existing site landscaping to determine whether existing trees can be retained and incorporated into the planning process. Perform shading analyses of plants in both immature and mature forms to estimate energy savings during plants' anticipated life span. Whenever possible, avoid or remove plantings that would compromise useful solar gain.

Warren Gretz/PIX03779

Landscaping and trees help minimize heat gain to the building and surrounding concrete.

Related Strategies: Atrium Spaces; Daylighting through Windows; all forms of Passive Solar Heating; Building-Appropriate Site Selection; Selective Glazing; Shading Devices; Natural Ventilation through Windows.

Comments: Trees and landscaping can reduce peak cooling loads through shading and can cool the ventilation air entering a building. Even during the winter, most deciduous trees and plants cast substantial shade on solar collectors (e.g., south-facing windows).

Earth-Protected Space

Description: Bermed, or partially buried, construction can moderate building temperature, save energy, and preserve open space and views above the building.

Goals: To minimize heating and cooling energy use by protecting more of the building from fluctuating outdoor air temperatures.

Best Applied: Sites with a large natural slope in cold climates are ideal candidates for incorporating earth-protected spaces.

How to Do It: Berm against walls or earth-cover roofs (in severely hot or cold climates) or combine high horizontal windows with light shelves located above earth-sheltered walls. In some cases, using "invisible" earth-protected buildings can help counter community resistance to bulky new construction.

Related Strategies: Open Office Space at Perimeter; Roof Monitors; Building-Appropriate Site Selection; Landscape Shading; Insulation.

Comments: Similar low-energy performance can also be achieved by using additional insulation.

Solar Water Heating

Description: Solar water heating uses flat-plate solar collectors to preheat domestic hot water.

Goal: To be considered effective, this strategy should yield a significant portion (50% or more) of the domestic hot water needed for day-to-day operations.

Best Applied: Look to building types where hot water use is high year-round, such as hospitals and laboratories. Best performance will be achieved in hot climates with high solar radiation levels.

How to Do It: Design an array of flat-plate solar collectors that include an absorber plate (usually metal), which heats when exposed to solar radiation. Most common among these are indirect systems that circulate a freeze-protected fluid through a closed loop and then transfer heat to potable water through a heat exchanger. Typically roof-mounted, solar collectors should face south and tilt at an angle above horizontal, approximately equal to the latitude of the project location. This configuration will provide optimum year-round performance. Provide a pipe chase to a mechanical room. The room needs to be large enough for storage tanks.

Related Strategies: Roof Monitors; Non-Absorbing Roofing.

Comments: Collectors should be mounted in a location that is unshaded by surrounding buildings or trees during the hours of 8 a.m. to 4 p.m. (at minimum) throughout the year. As is the case with many of the strategies described herein, an effective conservation program will help to minimize hot water demand and, in turn, reduce material and systemic requirements.

Building-Integrated Photovoltaic Systems

Description: Photovoltaic (PV) arrays are now available that take the place of ordinary building elements (such as shingles and other roofing components), converting sunlight into electrical energy without moving parts, noise, or harmful emissions.

Goal: Reduce the first cost of the PV array by using it in place of high-cost building elements and take into account the energy cost reductions over time.

Best Applied: Consider deployment in sunny climates with high electrical utility charges.

Pamm McFadden/PIX02909

An example of an earth-sheltered building in Tempe, Arizona.

How to Do It: Commercially available systems include thick, crystal, circular cells assembled in panels and thin-film products deposited on glass or metal substrates. At today's prices, BIPV often provides a good payback if it replaces high-cost glazing, such as fritted glass (the arrays can even resemble fritted glass). To be cost effective, BIPV must intercept nearly a full day's sun, so it is often most effective as a replacement for roof or atrium glazing. BIPV also works well as spandrels that are fully exposed to the sun.

Related Strategies: Atrium Spaces; Differentiated Façades; Glazed Roofs; Roof Monitors; Building-Appropriate Site Selection; Shading Devices.

Comments: One of the benefits of gridtied BIPV systems is that power production is typically greatest (on bright, sunny days) at or near the time of the building's peak electrical and cooling loads.

Schematic Design (or Preliminary Design) Phase

During the previous phase of the time line, Project Planning, basic decisions were made regarding site placement, plan organization, and building massing. Those determinations will now influence the basic low-energy design strategies (e.g., daylighting) that will be evaluated in detail during this phase, especially those relating to the building enclosure (or envelope).


Andrew Gordon Photography and Fox & Fowle Architects/PIX09052

An example of Building-Integrated PV is 4 Times Square in New York City.

Traditional building design has assigned a protective role to the walls, roofs, and floors of buildings—protection against cold, sun, rain, and unwanted intrusion. In low-energy building design, the protective role still exists, but the building envelope is also thought of as a membrane that manages or "mediates" interactions between the interior spaces and the outside environment. During schematic design, the Envelope-Related Strategies discussed below will be evaluated and integrated into the overall building design.

Action Items

- As the preliminary layout is refined, ensure that access to daylight continues to be optimized. Consider perimeter access to light and views, roof monitors, skylights and clerestory windows, and light shelves.
- Develop material specifications and a building envelope configuration that maximizes energy performance. Consider window shape and placement, shading devices, differentiated façades, reflective roofing, fabric roofs, induced ventilation, nighttime cooling ventilation, and selective glazing.
- Continue energy analyses, including multiple runs of similar products (e.g., various glazings and insulation levels) to determine best project-specific options. In addition to first cost, consider durability and long-term energy performance.

Strategies to Consider During this Phase

Selective Glazing for Walls

Description: Glass products are now available with a wide range of performance attributes that allow designers to carefully select the amount of solar gain, visible light, and heat that they allow to pass through. Solar heat is measured by the properties of shading coefficient (SC) and solar heat gain factor (SHGF). An SC of 1.0 applies to clear 1/8-inch-thick glass with other glasses that admit a lesser amount of solar heat having a lower SC (e.g., 0.50 for a tinted glass that admits 50% as much solar heat as 1/8-inch clear glass). The term SHGF, which is now widely used by the glazing (fenestration) industry because it takes into account a range of angles of solar incidence, is considered to be equal to a value of 0.86 times the SC. The degree of daylight, or visible light transmission, is expressed by the term "Tvis," and the amount of heat loss is measured by the U-factor, which, expressed numerically, is the inverse of the total resistance of the glazing assembly.

Single-glazing is about R-1 or 1/1 for a U-factor of about 1.0. Double-glazing is about R-2 for a U-factor of about 0.50. Commercially available low-e glass typically ranges in U-factor from about 0.35 down to 0.10, depending on the type and number of coatings and the fills (e.g., argon) used in the spaces between glazing layers.

Goal: Specify glazings with the best combination of performance characteristics for the specific application at hand.

Best Applied: The choice of glazing(s) is an essential consideration for all building types.

How to Do It: Begin by incorporating glass performance characteristics (e.g., U-factor, shading coefficient) as required by the applicable codes or standards. Then, use computer analysis to investigate alternate glazings and narrow the field to those most beneficial to admitting daylight and saving energy, while still remaining within the project budget. Glazing technology has now advanced to the point that alternative glazings with very different performance characteristics can physically look very much alike. This increases the potential to use different glass types on different façades, although such an approach may be considered a maintenance headache. The best glazing selections are not merely those with the highest numerical performance levels in a given area. For example, daylighting a space with a large expanse of glass, using glazing with the highest daylight transmission may result in excessive glare. Fritted glass should be considered when glare reduction through other means is difficult to achieve.

Related Strategies: Atrium Spaces; Glazed Roofs; Roof Monitors; Scattered Skylights; Daylighting through Windows; Direct-Gain Passive Solar Heating; Landscape Shading; Light Shelves; Shading Devices; Window Geometry.

Comments: Of the various building envelope components, glazing almost always has the most significant effect on heating, cooling, and lighting energy use. In the last 20 years, glazing technology has progressed more dramatically than perhaps any other building product or system. By using high R-factor glazing (indicating substantial resistance to heat inflow), it is often possible to eliminate perimeter baseboard heaters.

Shading Devices

Description: Fixed or movable (manual or motorized) devices located inside or outside the glazing are used to control direct or indirect solar gain.

Goal: Shading should be used to provide cost-effective, aesthetically acceptable, functionally effective solar control.

Best Applied: This strategy works well on south façades where overhangs provide effective shading for work space and can also serve as light shelves. Shading west façades is critical to reduce peak cooling loads.

How to Do It: A wide range of shading devices are available, including overhangs (on south façades), fins (on east and west façades), interior blinds and shades, louvers, and special glazing (such as fritted glass). Reflective shading devices can further control solar heat gain and glare.

Related Strategies: Atrium Spaces; BIPV; Differentiated Façades; Open Office Space at Perimeter; Perimeter Circulation Space; Glazed Roofs; Roof Monitors; Scattered Skylights; Daylighting through Windows; Direct-Gain Passive Solar Heating; Light Shelves; Selective Glazing; Window Geometry.

Comments: Devices without moving parts are generally preferable. Movable devices on the exterior are typically difficult to maintain in corrosive environments or in climates with freezing temperatures. Other building elements, such as overhanging roofs, can also serve as shading devices.

Daylighting through Windows

Description: Using daylighting through building windows can displace artificial lighting, reduce energy costs, and is associated with improved occupant health, comfort, and productivity.

Goal: Reduce lighting and cooling energy more than the increase in heating energy occasioned by reduced lighting loads. (In summer, cooling energy demand is less because the heat from artificial lighting sources is reduced. In winter, the heat that is not being produced by artificial lighting may need to be compensated for by the building's heating system).

Best Applied: Daylighting through windows is best accomplished on façades that have a generally clear view of the sky, particularly the sky at angles of 30 degrees or more above the horizon.

How to Do It: Place much of the façade glazing high on the wall, so that daylight penetration is deeper. Consider the enhanced use of daylighting by installing light shelves on south façades. Recognize the interdependencies in glazing, light fixtures and controls, and HVAC systems. Whenever possible, electrical lighting should be considered a supplement to natural light. When the sun goes down on buildings with long hours of operation, however, efficient electrical lighting design takes on added importance.

Related Strategies: Differentiated Façades; Extended Plan; Open Office Space at Perimeter; Perimeter Circulation Space; Direct-Gain Passive Solar Heating; Building-Appropriate Site Selection; Landscape Shading; Light Shelves; Selective Glazing; Shading Devices; Window Geometry.

Comments: Daylighting is a central component of the vast majority of low-energy

Warren Gretz/PIX00217

Shade from trees is a simple but effective strategy to reduce costly cooling requirements.

buildings and, as such, merits significant time and attention.

Extended Daylighting through Windows—Light Shelves

Description: A horizontal device or "shelf" that bounces direct sunlight off the ceiling and deeper into the interior spaces. Light shelves are also used to provide shading and suppress glare. Light shelves are located above vision glazing (up to and slightly above eye level), but below high glazing above. They may be positioned inside or outside (where they also provide shading), or both (this is typical).

Goal: Save lighting energy, reduce glare, and provide useful shading.

Best Applied: In clear climates, light shelves are appropriate for integration on façades facing within about 30 degrees of true (solar) south.

How to Do It: Integrate the light shelves with façade design, office layout, lighting design, lighting controls, glazing, and shading devices. They tend to work best with moderately high ceilings (about 10 feet, minimum) and open planning.

Related Strategies: Differentiated Façades; Open Office Space at Perimeter; Daylighting through Windows; Selective Glazing; Window Geometry.

Comments: Transom windows can be used to allow light from the shelves to enter interior office spaces located far from exterior walls. Maintenance may be an issue, and pigeons present a concern in some areas.

Natural Ventilation through Windows

Description: User-controlled operation of windows provides outdoor air for ventilation and cooling, and should improve indoor air quality.

Goal: A balanced approach involves taking advantage of users' desire for environmental control without interfering with efficient HVAC operation.

Best Applied: Particularly appropriate in building types and locations where security concerns and exterior noise or air quality is not an issue. Users must be tolerant of increased horizontal air motion.

How to Do It: Locate windows that will serve as air inlets to face prevailing winds. During the cooling season, this strategy can be enhanced by landscaping features and projecting building features (such as fins). This strategy tends to work best in residential-type occupancies, where the user already has control over HVAC.

Related Strategies: Atrium Spaces; Differentiated Façade; Perimeter Circulation Space; Window Daylighting; Landscape Shading; Window Geometry; Economizer Cycle Ventilation; Induced Ventilation; Nighttime Cooling Ventilation.

Comments: A well-considered control strategy (either mechanical or social) is required to prevent air conditioning from operating in a space with open windows. If such a control strategy cannot be devised or is not effective or realistic because of the building occupants, operable windows can increase building energy use.

Window Geometry

Description: Windows should be shaped and located in a manner that minimizes glare and unwanted solar gain and maximizes useful daylight and desirable solar heating.

Goal: The design team should apply functional criteria to the size, proportion, and location of windows. It is important to avoid incorporating more window area than is beneficial to the building occupants or that is needed to enhance low-energy performance.

Best Applied: Shape, size, and location of windows are important considerations in all projects.

How to Do It: Make window decisions based on occupant activities and low-energy performance rather than simply for aesthetic purposes. Having said this, reduce glass area whenever possible. To minimize glare and enhance daylighting benefits, substitute horizontal strips of high windows for "punched" windows, and scattered small windows in lieu of a few large ones.

Related Strategies: Atrium Spaces; Differentiated Façades; Extended Plan; Perimeter Circulation Space; Light Shelves; Selective Glazing; Shading Devices; Natural Ventilation through Windows.

Comments: The best way to evaluate the lighting effects of window geometry and configuration is through computer analysis, using programs such as RADIANCE.

Scott Bly/PIX07626

Daylighting retrofits for U.S. Army warehouse in Hawaii.

Differentiated Façades

Description: In this strategy, the designer creates variations in the façade design in response to changes in orientation, the use of space behind the façade, and the low-energy design strategies being employed.

Goal: Strive for seamless integration of energy-related design strategies with the overall aesthetic and functional design components of the project.

Best Applied: If each façade is to be optimized, this strategy will work on almost all projects.

How to Do It: Select a design consultant who can work with the concept that the appearance of a building's various façades will likely differ in response to variations in their environmental loads. To that end, pursue a building style that is compatible with functionally varied façade elements.

Related Strategies: Atrium Spaces; BIPV; Perimeter Circulation Space; Daylighting through Windows; all forms of Passive Solar Heating; Complementary Building Uses; Landscape Shading; Light Shelves; Selective Glazing; Shading Devices; Window Shape; Natural Ventilation through Windows.


Warren Gretz/PIX02191

This building uses a light shelf on the south side for daylighting. It also has small square windows on the east and west to minimize glare.

Comments: Considered as one of the most basic and effective low-energy building strategies, using different façades is really an approach to design and style that is driven by function. Different façades do not necessarily have to be radically unique; rather, they may simply be variations on a theme. For the sake of uniformity, designers sometimes put overhangs on all façades, even though they may only provide significant energy benefits on the south side. Such an approach can greatly compromise the basic cost-effectiveness of the strategy and should generally be avoided.


Warren Gretz/PIX00132

This building has differentiated façades—broad overhangs for shading on the south side and no overhangs on the north side.

Insulation

Description: A well-insulated building envelope reduces energy use, controls moisture, enhances comfort, and protects the energy-saving potential of passive solar design.

Goal: Identify the optimum amount of building insulation to use in the walls, roof, and floor construction.

Best Applied: Residential building types in cold climates benefit most from large amounts of insulation.

How to Do It: Begin by incorporating insulation levels required by code or standard, then use computer analysis to investigate optimum insulation amounts. For buildings with mass walls, use computer analysis to determine the

HOW TO USE THE TIME LINE:

This time line is to be used by Federal project managers to remind them when they should be thinking about low-energy, sustainable design during the various phases of planning, design, construction, and turnover of a building. Without explicit actions throughout the process, the resulting buildings will often not meet the owner's requirements and expectations. Because each agency has its own terms for these phases, the time line uses the traditional American Institute of Architects (AIA) terminology and notes the stages at which Federal agencies often demand milestone submissions (15%, 35%, 50%–60%, and 95%). During each of these stages, there are very different opportunities to ensure, or to lose, low-energy sustainable design. This guidebook is focused primarily on low-energy issues and recognizes that low-energy does not equal sustainability. Comprehensive sustainability includes many other issues such as water use, indoor environmental quality (IEQ), and green materials.

It is assumed that whatever agency you are in already has specific directives for facility managers that provide guidance for procuring low-energy, sustainable buildings and facilities. These directives might range from general guiding principles to more specific energy and water use targets, foot-candle levels, requirements for using renewable energy sources, and even materials criteria for each building type. It is conceivable that there might be some existing policies that are contrary to your newly emerging low-energy, sustainable goals, and these should be recognized and eliminated if at all possible.

You will need a unique perspective, one that relies on a whole-building approach to the problem. The time line suggests potential steps that will help you realize your goal of a low-energy (and a sustainable) facility. The time line will show you some new steps you will incorporate into your thinking, planning, and budgeting steps that are not needed in the traditional design process. For example, you will see the requirement for an energy champion and several stages where you have to conduct some evaluations to really understand the consequences of some very complex tradeoffs. You must be clear about the costs to have "extra" people (like the energy champion) on the job or additional costs to perform the necessary evaluations and include them in your budgets from Day One.

There will be some new roles and responsibilities if you expect to deliver a low-energy, sustainable building: you will need to state your expectations clearly and give your team the resources and the authority they need to accomplish the goals on time and within budget.

Refer to the section called "How to Apply," which follows the time line. This section provides the details about which low-energy strategies should be considered during each phase. Each one notes Description, Goal, Best Applied, How to Do It, Related Strategies, and Comments for that strategy.

FEASIBILITY PHASE

Action Items:

- Conduct all required feasibility analyses;
- Review all existing directives and policies to be sure what your agency currently requires;
- Select an ‘energy champion and give them the necessary authority;
- Establish explicit energy use targets that surpass 10 CFR 435;
- Identify your agency's goals for the other sustainable issues such as site planning, materials use, water use, and IEQ.

See page 12 for details on Action Items and the strategies to consider during this phase.

BUDGETING PHASE

Action Items:

- Program any special requirements into your budget submission;
- Submit a budget that allows for an energy champion, the necessary meetings to accommodate a team process, the extra studies, analyses and verifications that will be needed, and slightly higher design fees (2%–4%);
- Include the requirement for an energy expert in your RFP/A&E solicitation;
- Conduct a design charrette BEFORE concept development;
- Identify the certification and testing measures you will require.

See page 13 for details on these Action Items and the strategies to consider during this phase.

PROJECT PRE-PLANNING

Action Items:

- Establish low-energy as a core project goal;
- Establish energy use targets;
- In selecting consultants, consider their level of experience;
- Classify the energy-related requirements of the users;
- Identify the climate and utility costs at the project site;
- Identify the characteristic space and building uses that apply to the project.

See pages 13 for details on Action Items and the strategies to consider during this Phase.

PROJECT PLANNING PHASE

Action Items:

- Establish interdisciplinary design team;
- Develop a preliminary layout;
- Develop landscape plans;
- Develop a basic layout;
- Investigate renewable power sources;
- Conduct preliminary energy analysis.

See page 14 for details on Action Items and the strategies to consider during this phase.

MILESTONE (15% DESIGN)

SCHEMATIC DESIGN PHASE
(OR PRELIMINARY DESIGN)

Action Items:

- Ensure optimization of daylighting;
- Develop material specs and envelope configuration that maximizes performance;
- Continue energy analyses; determine best project-specific options.

See page 18 for details on Action Items and which strategies to consider during this phase.

MILESTONE (35% DESIGN)

DESIGN DEVELOPMENT I

Action Items:

- Continue energy analysis; ensure that performance objectives are maintained.

See page 25 for details on these Action Items and the strategies to consider during this phase.

MILESTONE (50%–60%)

VALUE ENGINEERING PHASE

Action Items:

- Ensure that VE is based on life-cycle considerations;
- Incorporate energy analysis directly into VE;
- Ensure that energy targets are maintained.

See page 28 for details on these Action Items and the strategies to consider during this phase.

DESIGN DEVELOPMENT II

Action Items:

- Ensure that construction details and specifications are consistent;
- Ensure that mechanical equipment meets design targets;
- Lighting system;
- Conduct a final design review.

See page 28 for details on Action Items and the strategies to consider at this phase.

MILESTONE (95%)

CONSTRUCTION DOCUMENTS

Action Items:

- Ensure that construction details and specifications are consistent;
- Ensure that mechanical equipment meets design targets;
- Conduct a final design review.

See page 28 for details on Action Items and the strategies to consider at this phase.

MILESTONE (100%)

BID SOLICITATION/CONTRACT AWARD

CONSTRUCTION PHASE (CM)

Action Items:

- Ensure energy features are constructed/installed as designed.

See page 28 for details on Action Items and the strategies to consider at this phase.

TURN OVER TO OCCUPANTS

OPERATIONS & MAINTENANCE
WARRANTY PERIOD

Action Items:

- Monitor energy performance;
- Implement a full commissioning protocol.

See page 28 for details on Action Items and the strategies to consider at this phase.

relative advantages of placing the insulation on the inside or on the outside of the mass. Detail assemblies containing insulation to avoid thermal bridges, where conductive elements (e.g., metal studs) penetrate the insulation and short-circuit the system by conducting heat. In non-residential construction, there are many cases, particularly in hot climates, where using more insulation to enclose a sealed building will cause it to behave like a Thermos bottle—trapping heat and using even more energy.

Related Strategies: High-Efficiency HVAC.

Comments: The law of diminishing returns applies to additional levels of insulation, whereby the first increment of insulation reduces heat loss dramatically, and each additional increment provides less and less of an improvement. The quality of insulation—and how well it is installed—is very important, especially when it comes to batt insulation in walls.

Air Leakage Control

Description: Air retarder systems are used to reduce air leakage into or out of a building.

Goal: To deploy a system that reduces energy use and serves to protect the building's envelope, structure, and finishes.

Best Applied: Air leakage control is considered to be standard low-energy procedure in cold climates.

How to Do It: Install air-impermeable components that are sealed at the joints and penetrations to create a continuous, airtight membrane around the building. Note, however, that air retarders placed on the winter/cold side of the insulation must be vapor-permeable to avoid trapping moisture within the walls.

U.S. Department of Energy/Craig Miller/PIX02214

Insulation.

Related Strategies: Insulation, High-Efficiency HVAC.

Comments: Designers of many non-residential building types attempt to reduce air infiltration by maintaining the indoor space at a higher pressure than the outside ambient air. When an air retarder is installed, pressurization becomes easier to achieve, while at the same time, the need for pressurization becomes less critical. In masonry construction, bituminous membranes are sprayed or trowel-applied to serve as air retarders, with bitumen-based sheets typically used in curtain-wall construction. Evaluate the benefits of an air retarder not only for improved energy use, but also for reduced wall maintenance and repair costs. Also evaluate the air leakage characteristics of manufactured components such as windows, doors, and curtain walls.

Roof Monitors

Description: Roof monitors are windows installed at roof level, typically vertical or steeply sloped.

Goal: To admit useful natural light and often desirable solar heat gain during the heating season.

Best Applied: This approach works well on many building types, particularly low buildings with one or two stories.

How to Do It: South-facing roof monitors should use vertical glass and be shaded by overhangs to provide daylight and useful solar heating (for many building types in many locations). By contrast, north-facing roof monitors need not be concerned with glare or the unwanted entry of direct solar rays. North-facing glazing can be inclined (tilted) somewhat to access the overhead sky better, which provides a much greater level of diffuse daylight than does the sky near the horizon. As a general rule of thumb, avoid east- and west-facing roof monitors. Also avoid horizontal glazing, which typically overheats the building, thereby dramatically increasing cooling loads. Minimize the amount of glass required to achieve desired illumination levels, and avoid narrow slots with glazing on opposite sides.

Related Strategies: Direct-Gain Passive Solar Heating; Selective Shading; Shading Devices; Window Geometry; Induced Ventilation; Lighting and Lighting Controls.

Comments: Design guidelines are available for various geometries of roof monitors and other toplighting strategies. To fine tune monitor locations, provide quality lighting environments, and quantify resulting energy benefits, computer analysis is advised.

Scattered Skylights

Description: Small, individual spot-located skylights.

Goal: To obtain useful daylighting.

Best Applied: Appropriate for use in one-story buildings, such as warehouses, and especially useful in buildings where sun control is of secondary importance.

How to Do It: Generally achieved with prefabricated elements that have flat or domed glazing, spot-located skylights should be used with care, except in cases where potential glare and direct sun penetration is of little concern within the building. Use sparingly—large numbers of separate skylights are expensive in comparison to glazed roofs.

Related Strategies: Extended Plan; Selective Glazing.

Comments: Even when mounted above prefabricated or site-built wells, it is very difficult to entirely eliminate sun penetration when solar altitude angles are at their highest (around the summer solstice, June 21). Guidelines for spacing scattered skylights are available, and computer analysis to fine-tune sizing and spacing and quantify energy benefits is advised. Potential roof leaks are often a concern and should be addressed by proper detailing. Despite these drawbacks, scattered, spot-located skylights are widely applicable to warehouses, low-rise residential, and many other smaller buildings.

Glazed Roofs

Description: Glazed roofs are large-area skylights typically found over atrium spaces.

Goal: To provide daylighting in a manner that may increase the architectural impact of the space while providing a more direct connection between building occupants and the outside world.

Best Applied: Glazed roofs work well above circulation areas and other high-occupancy spaces.

How to Do It: Consider installing a clear-span glazed roof between buildings or building sections to create a covered "street." Solar heat gain can be controlled through use of fritted glass or louvers.

Related Strategies: Atrium Spaces; Extended Plan; Selective Glazing; Shading Devices; Induced Ventilation.

Comments: Excessive cooling loads frequently accompany this design approach. When used over high spaces (such as atriums), incorporate induced ventilation strategies whenever possible. As a secondary option, mechanical cooling should be provided through a displacement ventilation approach, where only the air in the occupied zone of the space near the floor is conditioned.

Non-Absorbing Roofing

Description: Roofs covered by light-colored or reflective membranes are a viable passive solar strategy, as they tend to absorb less heat.

Goal: To reduce cooling loads.

Best Applied: This is a common approach for use on low buildings in hot climates.

How to Do It: Use roofing systems with light-colored or reflective top layers.

Related Strategies: Extended Plan.

Comments: Reflected light may complement other efforts aimed at daylighting "wedding cake"-type building forms. Early in the process, the designer needs to know the color of any roofing systems that will be visible to building occupants.

Fabric Roofs

Description: These are tension roofs constructed of stretched, light-transmitting fabric—an increasingly popular architectural element.

Goals: Provides a buffer from direct exposure to solar heat gains occasioned by daylighting of space.

Warren Gretz/PIX07340

Denver International Airport in Denver, Colorado, is an example of a fabric-covered roof.

Best Applied: Deploy fabric roofs over large, clear-span spaces.

How to Do It: The overall approach must be decided early in the design process. Before committing to the design, carefully evaluate the balance between lighting, cooling, and heating loads for the specific building use and climate.

Related Strategies: Extended Plan; Atrium.

Comments: Fabric roofs are useful as temporary or permanent coverings over outdoor spaces (i.e., tents). They have been effectively used at the Denver International Airport and the San Diego Convention Center.

Design Development I Phase

During the earlier phases of the project, basic decisions are made that affect building massing and determine which low-energy design strategies will be implemented. During those phases, the overall thrust is to reduce the heating and cooling loads as much as possible. During design development, the design team's attention should shift to identifying efficient lighting and HVAC systems.

Action Item

- Continue energy analysis and the "trade-off" process.

Lawrence Berkeley Lab/PIX01053

A skylighted entryway that also demonstrates the integration of photovoltaics at the Thoreau Center for Sustainability at Presidio National Park, California.

Strategies to Consider During this Phase

Energy-Efficient Lamps and Ballasts

Description: Identifying and using application-specific, high-efficiency lamps and ballasts.

Goal: Minimize the amount of electrical power required by lighting systems, while still meeting the task-specific needs of building occupants.

Best Applied: The savings will be greatest in buildings with long hours of occupancy or in areas with high electrical utility rates.

How to Do It: Use T-8 (tubular, 8/8th of one inch in diameter) lamps and compatible electronic ballasts for general ambient lighting. Compact fluorescent lamps should replace incandescent or halogen lamps in downlights, as they only use about one-third the electrical power. Determine what lamp/ballast combinations work best with other strategies (i.e., daylighting, shading, lighting controls). Use light-emitting diode (LED) exit lights with an estimated life of 30 years or more to enhance building safety and all but eliminate required maintenance.

Related Strategies: All daylight-related strategies.

Comments: The color rendition of all fluorescent lamps has improved dramatically in recent years, to the point where they are now deemed acceptable for most applications. Compact fluorescent lamps also provide maintenance savings, as the lamps last 10 to 20 times longer than the incandescents they replace.

Lighting Controls

Description: Lighting controls automatically adjust lighting levels in response to daylight availability. Other controls automatically turn lights off in response to unoccupied space.

Goal: This strategy significantly reduces lighting-based electricity demand.

Best Applied: Dimming controls are used in conjunction with building designs that encourage entry of natural daylight. Occupancy sensors are best used in spaces that have intermittent occupancy, such as conference rooms and storage areas.

How to Do It: Automatic daylight dimming controls either provide light levels in discrete steps or through continuous dimming, based on light levels sensed.

Dimming systems can also be used to dim newly installed lamps when their light output is greater than it will be once they "burn in" and achieve their rated output.

Occupancy sensors are used to turn off lights and sometimes HVAC in unoccupied areas. They are made with multiple activation technologies, including those that sense body heat (infrared) as well as those that detect motion (ultrasound). Some sensors employ more than one technology as a means of eliminating false signals. Manual switching and timeclocks can also be used to control certain daylit spaces.

Related Strategies: HVAC Controls

Comments: Automatic lighting control functions are often included in a computerized energy management system that also controls the HVAC, fire safety, and security systems.

High-Efficiency Heating, Ventilation, and Cooling Equipment

Description: This category of equipment offers operating efficiencies far greater than those afforded by systems designed to simply meet applicable codes or standards.

Goal: Integrate more efficient equipment whenever it can be shown to be cost effective.

Best Applied: These systems are appropriate for use with large loads, long operating hours, and high energy prices (particularly for electricity).

How to Do It: There are various types of efficient heating and cooling equipment that can readily address the specific needs and operating patterns of a given building. Many agencies require that alternate systems be subjected to a life-cycle cost analysis. If such an exercise is conducted, it should involve detailed computer analysis (such as DOE 2.2) rather than a process that simply confirms the selection of a preferred system. Ask the design team to prepare a list of performance criteria for equipment required by applicable codes and standards to be used as a basis for comparing more efficient equipment options. In some cases, the cost premium for more efficient equipment is small and can be justified by hand calculations. More often, DOE 2.2 computer analyses are required along with some form of rigorous life-cycle cost analysis. Consider using modular equipment (e.g., three small boilers instead of one


D&R Int., LTD/PIX07737

Some examples of energy-efficient lamps.

large one or a dual compressor chiller) and variable-speed equipment (modulating burner or variable-speed chiller) for greater flexibility in achieving targeted reductions in energy use.

Related Strategies: All design decisions that affect heating and cooling loads.

Comments: Specifying systems that are larger than necessary can be costly. The energy consultant should be careful throughout the design process to size the systems, components, and equipment appropriately. HVAC systems should also be designed to ensure healthful indoor air quality in a manner appropriate to individual spaces and the overall building type.

Exhaust Air Heat Recovery

Description: This process involves the recovery of useful heat from the air being dispelled from a building.

Goal: Transfer 50% to 70% of the heat that would otherwise be lost to the incoming air stream.

Best Applied: Apply this strategy in buildings with large populations or significant ventilation requirements, particularly those located in cold climates.

How to Do It: Various types of heat exchangers are in use today, including heat wheels, plate and fin air-to-air heat exchangers, and heat pipes. Heat pipes are very simple devices that consist of a highly conductive tube filled with refrigerant which, when vaporized, transfers heat from the outgoing to the incoming air stream. Because heat exchangers obstruct the air passage of both intake and exhaust ducts, bypass dampers should be installed to facilitate operation during mild or warm weather.

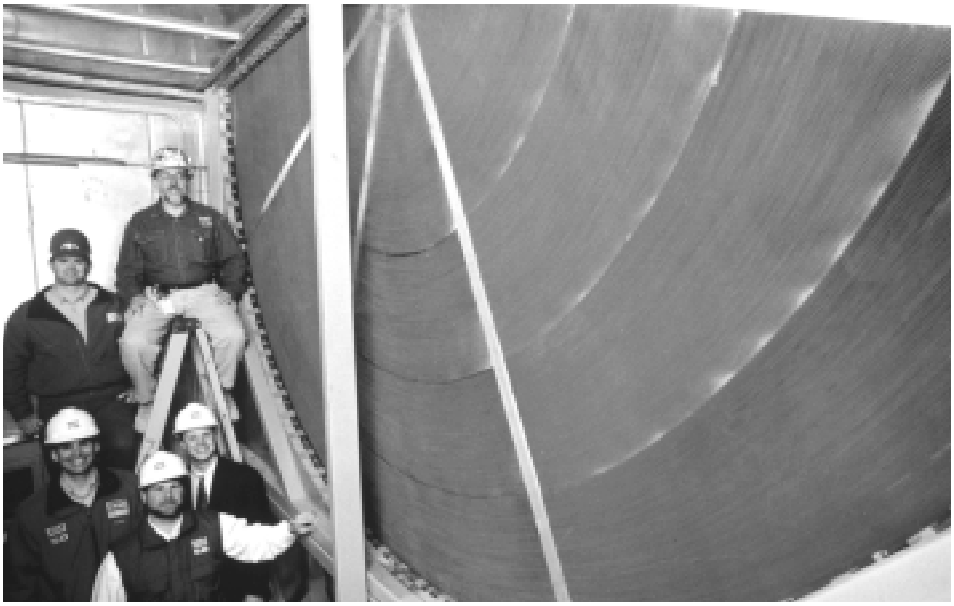
Related Strategies: HVAC controls

Comments: Depending on the application, potential contamination of the incoming air stream may need to be monitored. For instance, recovery of heat from a combustion process is usually accompanied by a carbon monoxide sensor located in the intake.

Economizer Cycle Ventilation

Description: Contributing to both energy reduction and good indoor air quality, this strategy introduces a varying amount of ventilation air to cool the building in combination with normal air conditioning (AC).

Goal: Avoid using the AC compressors or other mechanical cooling method when ambient air can provide some or all of the needed cooling.



Frank Kutlak/PIX03683

The Louis Stokes Laboratory at the National Institute of Health in Bethesda, Maryland, is using desiccant heat wheels for exhaust air heat recovery.

Best Applied: Look to buildings in cool climates where there is low relative humidity.

How to Do It: Provide appropriate controls, along with 100% outside-air capability. Consider including enthalpy (total heat, sensible plus latent) controls to maximize benefits.

Related Strategies: Induced Ventilation; Natural Ventilation through Windows; Nighttime Cooling Ventilation.

Comments: This should be considered a standard low-energy HVAC procedure in all but the most humid climates.

Nighttime Cooling Ventilation

Description: High-volume, fan-powered ventilation of large areas during cool, dry nights.

Goal: Cool the building (particularly exposed massive structural elements) with outside air as a means of saving more AC power than the sum of the power drawn by the ventilating fan, plus what is needed to overcome any excessive humidity the following day.

Best Applied: This strategy is appropriate for hot, dry climates where the diurnal temperature difference (between day and night) often exceeds 30°F to 35°F.

How to Do It: This strategy relies on moving large quantities of air in an economical manner and requires a secure source of intake ventilation that can be directed into spaces to be cooled.

Related Strategies: Natural Ventilation through Windows; Economizer Cycle Ventilation

Comments: Large amounts of interior mass enhance the cooling effect in dry climates that consistently experience significant temperature swings. In variable climates, lower mass is desirable. Relying on open windows for ventilation (in lieu of forced-air fan operation) may compromise security or lead to wind or water damage.

HVAC Controls

Description: Specify controls that maintain intended design conditions, including temperature, humidity, and airflow rate in terms of cubic feet per minute (cfm) throughout the building.

Goal: The proper use of controls and building automation reduces energy consumption and electrical peak demand.

Best Applied: In all circumstances, strive for a level of functional complexity that is compatible with the skills and capabilities of the building's operating personnel.

How to Do It: Keep control systems as simple as possible. Avoid controls that offer little in the way of improved operations or energy savings, especially if they complicate the system and add features that require frequent maintenance or are subject to malfunction. Evaluate the use of variable-speed drives (VSD) on all large pumps and fans serving loads that only occasionally function at peak capacity. In large spaces with varying occupancies (auditoriums, large meeting rooms, cafeterias), investigate control strategies (e.g., the use of carbon dioxide monitors) that regulate the amount of outside air in accordance with actual occupancy. Consider using setback thermostats in all building types. However, avoid setting temperatures back in spaces where a large amount of exposed thermal mass will make it difficult to reestablish comfortable temperatures.

Oberlin College/PIX09677

This building incorporates many features that lessen its impact on the environment.

Related Strategies: Lighting Controls

Comments: HVAC control systems can often be integrated into computerized systems that also control lighting, fire safety, and security.

Value Engineering (VE) Phase

Action Items

- Ensure that VE analysis is based on life-cycle considerations rather than solely on cutting initial construction costs.
- Incorporate energy analysis directly into the VE process.
- Be certain that energy targets for the facility are maintained during VE.
- Meet the needs of the building occupants and the intended use through design that is consistent with agency or organizational values and mission.

Design Development II Phase

Action Items

- Continue energy analysis as design is finalized to ensure that desired energy performance objectives are maintained.
- Review final working drawings, specs, and cost estimates.

Construction Documents Phase

Action Items

- Ensure that construction details and specifications are consistent with energy use targets and strategies.
- Be sure that mechanical system details and equipment sizing meet design targets.
- Reaffirm that lighting system details and equipment specifications are consistent with energy design intent.
- Before documents are sent out for bid, conduct a final energy design review.

Bid Solicitation/Contract Award Phase

Action Items

- If cutting costs is required due to high bids, advocate preserving vital energy-saving features in lieu of more easily replaceable or aesthetic components.
- Conduct additional energy analyses as necessary to ensure that intended energy performance targets are still intact.

Construction Phase

Action Item

- Ensure that energy features are constructed or installed as designed.

Turn Over to Occupants Phase

Action Item

- Verify that occupants understand the building systems and the proper use of low-energy equipment and features of the building.

Warranty Period/Commissioning Phase

Action Items

- Verify occupant comfort and understanding of building operation using a Post Occupancy Evaluation (POE).
- Monitor the energy performance of the facility once per quarter during the warranty period and fine-tune the system as needed.
- If feasible, develop and implement a full commissioning protocol.

What to Avoid

Some low-energy buildings fail to meet the expected energy savings because the energy-efficient technologies incorporated into the design are not correctly integrated into the building. This may be due to a lack of understanding on the part of some team members as to the relationships between the specific energy technologies needed to reduce a given building's energy use and the effective integration of these technologies into the design. Changing just one of the recommended building components changes the total environment and, thus, the effectiveness of the remaining technologies. To avoid this, it is crucial that all team members understand how each of the technologies interacts with all other building components in a given environment.

When choosing energy-saving technologies, team members should be skeptical of claims for unrealistically high levels of performance and should avoid dependence on proprietary devices. It is not advisable to have a design that relies on a particular technology for which only one product is available. In those few cases where the use of such proprietary products can be defended in the context of competitive bidding requirements, a contingency design strategy should be in place. Claims of high-level performance should be supported by objective tests and case study results.

Design Considerations and Computer Modeling

The Base Case

A base-case design—a code-compliant building design without low-energy design features—is needed for comparison purposes in analyzing the cost and effectiveness of the low-energy design strategies identified for consideration. Considerations other than low-energy design often dictate the basic design of a building. In these instances, the base-case building is automatically created through the normal design process. To be effective, some low-energy building design technologies need to be applied during the early stages of the project, such as authorization, site selection, budgeting, and programming. In these instances, the base-case building may already include some low-energy design features.

For example, an atrium is a desirable amenity that, if incorporated early in the project, should influence decisions about site selection, building orientation on the site, and the number of buildings required to satisfy the space needs of the facility. But if the atrium is introduced after the overall building configuration is set, the parallel use of the atrium as a low-energy design component will be compromised, and it may end up being an energy liability. Similarly, in climates where a campus plan yields energy benefits, these benefits can be included among the criteria used to define the basic site plan—especially if introduced in the early project stages.

Anticipating low-energy design strategies early in the project can also influence the choice of a base case. One attraction of many low-energy building design strategies is that the occupants gain a closer connection with the outdoors environment. If this attraction is part of the design program, low-energy building design strategies may become more economical relative to the base-case design. For example, if the maximum allowable distance between any office worker and a source of natural light is lowered from the 60 feet typically accepted in a standard office buildings to 30 feet, a linear atrium between two 60-foot-wide building segments may result in a more attractive, compact, and, therefore, potentially more economical, design when compared to a 60-foot-wide base-case building.

Strategy Interactions

An important low-energy design approach involves rank-ordering a list of candidate technologies. At each step in a series of computer-driven energy simulations, candidate strategies are ranked in order of cost effectiveness relative to the base-case design. The top-ranked strategy would be the one that yields the largest energy savings for the smallest investment—the one with the shortest simple payback. [Note: according to the U.S. Department of Energy's (DOE's) *A Guide to Making Energy-Smart Purchases*, the simple payback period is the amount of time required for the investment to pay for itself in energy savings. You can obtain an estimate of the simple payback period by dividing the total cost of the product by the yearly energy savings. For example, an energy-efficient dryer that costs $500 and saves $100 per year in energy costs has a simple payback period of 5 years.]

As each strategy is applied, the payback for all subsequent candidates may change. Because there is less energy to be saved, the savings potential is often reduced. If all the strategies were independent, the remaining ones would retain their order in the ranking as each is applied in succession. In practice, however, low-energy building design strategies do interact and change their relative order in the ranking as they are applied. Presuming that the initial ranking will remain constant can lead to misjudgments about which strategies to pursue. After applying each strategy in a simulation, re-rank the remaining candidate strategies. Designing Low-Energy Buildings with ENERGY-10 can perform this task automatically (see Design Tools).

Another example of the interaction among building elements is in an office building where natural lighting displaces electrical energy by reducing the use of auxiliary lighting. In this case, the need for auxiliary heating increases in cold weather in response to the reduced heat contribution previously supplied by electrical lighting that is now dimmed or turned off. If this effect is not taken into account in the simulation, exaggerated estimates of energy savings will occur. Finally, it is important to remember that using one technology may preclude using certain others. For example, in buildings where heating or cooling loads have been significantly reduced, the benefits of using high-efficiency equipment to meet those loads may also be reduced and the resulting simple paybacks lengthened.

The Benefits of Multiple Use

As previously noted, BIPV—integrating PV into the building envelope—can replace conventional building envelope materials and their associated costs. PV is a solid-state, semiconductor-based technology that converts light energy directly into electricity. For example, spandrel glass, skylights, or roofing materials might be replaced with architecturally equivalent PV modules that serve the dual function of building skin and power generator. By avoiding the cost of conventional materials, the incremental cost of PV is reduced and its life-cycle cost is improved. BIPV systems can either be tied to the available utility grid or they may be designed as stand-alone, off-grid systems. One of the benefits of grid-tied BIPV systems is that on-site production of power is typically greatest at or near the time of a building's peak loads. This provides energy cost savings through peak load shaving and demand-side management capabilities.

Maintenance

A well-designed, low-energy building requires less maintenance than one that relies on large mechanical systems. Unlike other technologies, well-integrated low-energy building design is much less dependent on hardware and equipment, so there is little to go wrong. The traditional building trades that use available construction materials are able to make repairs as needed. The reliability and performance record of other technologies (such as movable shading devices) should be investigated, and when deployed, moving parts should be regularly maintained. Cleaning and protecting the surface of shading devices and glazing is important and should be incorporated as part of ongoing, scheduled maintenance.

When properly implemented, low-energy building design can reduce heating and cooling loads to allow for equipment downsizes and reductions in maintenance costs. Ideally, it also yields a building that can continue to function on a basic level and remain habitable even when systems experience unexpected downtime.

Costs

Cost effectiveness is typically the primary criterion for evaluating low-energy building technologies. 10 CFR 435 and Executive Order 13123 require that energy-related design decisions be evaluated on a life-cycle basis, rather than simply on a first-cost basis (e.g., construction costs) alone. It should be noted that the higher first costs of low-energy design can often be avoided or greatly minimized by anticipating and incorporating these strategies at the outset of the planning process. Exceptions might include:

- Demonstration projects with supplemental funds specifically earmarked for technology promotion.
- High-profile projects where publicity value adds to the payback.
- Cases where it is impractical to establish cost effectiveness. For example, relatively small investments that cannot justify a detailed simulation and seem practical based on prior experience.
- The amenity value of the technology outweighs its energy performance. Care must be taken to ensure that the amenity does not increase energy demand.

Typically, a building's cost effectiveness should be measured using appropriate design and analysis tools, such as those described below. As previously noted, different forms of energy have different costs, with electricity costs approximately three times that of natural gas. Because the costs of various energy sources vary greatly by region, specific input is required in each case.

Except for residences, utility cost data is not simply a matter of cents per kilowatt-hour of electricity, or dollars per therm of gas. Especially in larger buildings, the various fixed costs, variable costs, step rates, and demand charges must be accurately calculated. It is sometimes appropriate to run separate simulations, with and without demand rates, to see the extent to which the savings offered by a low-energy feature is dependent on demand rates. Small-scale co-generation may also be evaluated along with other energy sources appropriate for larger projects. To accurately model these costs, the more sophisticated design tools (such as DOE 2.2) accept all the details of utility rate structure, whereas simpler tools rely on a simplification of the rates. It is important to realize, however, that simplified rates may mask a large demand component and can be very misleading. It is also worth noting that when necessary energy-efficient technologies are well balanced and function in a complementary manner, they will significantly reduce energy consumption during peak load periods.

This guidebook does not discuss utility rates, assuming that one of the final calculations made in evaluating a given technology involves using actual, project-specific utility rates to determine the anticipated savings. Team members with experience in using a given technology in a particular locality can often predict probable outcomes based on their knowledge of the interaction between the climate and utility costs. For example, measures affecting electrical consumption (such as fan energy or reduced lighting demand) will have a better payback in New England, where electricity costs are high, than in the Northwest, where lower-cost hydropower is available.

Financing Options

Energy savings performance contracting (ESPC) arrangements are a relatively new method of helping Federal agencies invest in energy-efficient building measures. ESPC is a contracting agreement that enables agencies to implement energy-saving projects without making costly up-front investments. The contractor or other partner, such as a utility, owns the energy system and incurs all costs—design, installation, testing, operations, and maintenance—in exchange for a share of any energy cost savings realized.

FEMP provides ESPC and utility financing workshops, model solicitations, and a how-to manual. For more information, call FEMP at 703-243-8343. You may also wish to contact the Energy Efficiency and Renewable Energy Clearinghouse at 800-363-3732, or check their Web site at *www.eren.doe.gov/femp*.

Design and Analysis Tools

Typically, a building's cost-effectiveness needs to be measured using an appropriate design and analysis tool, such as those described below.

ADELINE (includes SUPERLITE and RADIANCE): A software tool for daylighting design that links daylighting and thermal performance. Available from Lawrence Berkeley National Laboratory, 510-486-4000.

BLAST: A detailed, annual energy performance software tool capable of modeling the interactive effects of low-energy building design strategies such as daylighting, passive solar heating, and thermal mass. Available from the BLAST Support Office, 217-333-3977.

BLCC: A software tool to calculate life cycle cost according to federal criteria. See *http://www. eren.doe.gov/buildings/tools_directory/software/blcc.htm*

CFD: An abbreviation for "computerized fluid dynamics," this highly sophisticated type of program can track the flow of air within a space or building component and determine the temperature distribution within that space during system operation. It requires considerable experience to operate, but is invaluable for assessing the effectiveness of air diffusers. Available from several vendors under several names. See *http://www. eren.doe.gov/buildings/tools_directory*

DOE 2/DOE 2.2: 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 HVAC systems. Available from Lawrence Berkeley National Laboratory, 510-486-4000.

Designing Low-Energy Buildings With *ENERGY-10*: An hour-by-hour, annual simulation program designed to analyze residential and commercial buildings of less than approximately 10,000 square feet (one or two zones). Specifically conceived for use during the earliest phases of design when low-energy building strategies can be incorporated at the lowest possible cost. Available from the Sustainable Buildings Industry Council (SBIC), 202-628-7400, ext. 209.

FRAME: A powerful thermal analysis program that accurately tracks the flow of heat through assemblies. A basic tool for analyzing thermal bridging through façade elements, such as window frames. Requires some experience for optimum use. See *http://www.eren. doe. gov/buildings/tools_directory/software/framepls.htm*

POWERDOE: Windows-based version of DOE 2 with user-friendly interface. Available from Fred Winkleman, 510-486-4925.

SERI-RES: (also SUNREL, which is an upgraded version of SERI-RES that features enhanced algorithms): Analyzes passive solar design and thermal performance in residential and small commercial buildings. Available from Ron Judkoff, National Renewable Energy Laboratory (NREL), 303-275-3000.

TRNSYS: Modular FORTRAN-based transient simulation code that allows simulation of any thermal energy system, particularly solar thermal, building, and HVAC systems. Available from the Solar Energy Laboratory, University of Wisconsin, TRNSYS Coordinator, 608-263-1589

Energy Savings

Energy savings will vary, depending on climate, building type, and strategies selected. In new office buildings, it is economically realistic to reduce energy costs by 30% or more below national averages if an optimum mix of low-energy design strategies is applied. According to the Building Owners and Managers Association (BOMA), the average energy cost (taking into account indicative samples of both public and private buildings) is $1.85 per rentable square foot. As previously noted, the Federal government maintains approximately 2.9 billion square feet of rentable space. Thus, a 30% reduction in energy use would yield annual taxpayer savings of 55.5¢ per square foot, or a $1.6 billion reduction in the nation's annual energy bill. This figure does not take into account the additional savings realized through pollution prevention, resource conservation, and related cost-reduction measures. Although a 30% reduction may seem ambitious, buildings monitored by NREL's Low-Energy Building Program show energy consumption reductions as high as 75% in residential buildings and 70% in some non-residential buildings.

Other Impacts

Better design techniques and superior technologies have largely eliminated any negative impacts associated with low-energy building design, such as overheating due to uncontrolled solar gain. The environmental benefits of low-energy building design can be significant, depending on how many energy-efficient or sustainable products are used. For example, a building that incorporates green materials (such as paints with low or no volatile organic compounds [VOCs] and recycled building materials) has less of an impact on natural resources than does a conventional building. HVAC systems that use non-chlorofluorocarbon (CFC) refrigerants are less harmful to the earth's ozone layer, and passive solar buildings that use significantly less energy from fossil fuels contribute less to the greenhouse gas effect than conventional buildings. Taken together, these low-energy, sustainable buildings not only reduce the burden on American taxpayers, but also contribute to the health, well-being, and productivity of their occupants.

Case Studies

The United States Courthouse Expansion, Denver, Colorado

The United States Courthouse expansion in Denver, Colorado, consists of 17 new courtrooms and associated support spaces, totaling 383,000 square feet. The General Services Administration (GSA) designed this project to serve as a showcase for sustainable design and devoted considerable attention to the building's energy and environmental design features. Sustainable design strategies integrated into the building include:

- High-performance glazing system

- Daylighting complemented by energy-efficient electric lighting
- Energy-efficient HVAC systems and controls (e.g., displacement ventilation and evaporative cooling)
- Building-integrated photovoltaic system
- Recycled and low-VOC materials used throughout
- Integrated building automation system
- Low-impact landscaping
- Water-saving faucets and toilets.

Based on computer analysis using DOE 2.2, the building is expected to consume approximately 50% less energy than a minimally compliant building designed in conformance with the Federal Energy Standard 10 CFR 435. As such, its annual energy costs will be reduced from just under $300,000 per year to just over $150,000. Much of the energy savings achieved in the Denver Courthouse expansion will be the result of reduced energy demand associated with lighting, heating, and cooling.

Beyond its energy- and resource-efficient design features, the building will also provide an improved indoor environment that is expected to increase workplace performance while improving staff health, safety, and satisfaction.

In keeping with its sustainable design approach, the Denver Courthouse expansion will also reduce operations and maintenance costs and will rely, in part, on non-polluting renewable energy sources. Descriptions of the facility's specific low-energy, high-performance features follow.

High-Performance Glazing

Taking full advantage of Denver's sunny, dry climate, a high-performance, triple-glazed curtain wall system is used on the court tower to minimize HVAC heating and cooling loads, while affording dramatic views and a source of natural light for adjacent courtroom and conference spaces. A series of PV cells are integrated into the curtain wall system, providing a clean, renewable source of power, as well as a visible representation of the government's commitment to climate-responsive, sustainable architecture.

Daylighting

The daylighting design for the Denver Courthouse expansion is based on a conscious separation of view glass from daylighting-specific glass. The system provides for maximum daylight harvesting and usage to reduce electric lighting loads during the day, as well as occupant satisfaction based on a strong sense of connection with the outdoors.

The U.S. Courthouse Expansion in Denver, Colorado, will be a showcase for sustainable building design.

Perimeter light shelves are incorporated throughout the high-rise section of the building and are positioned at the junction between the view and the daylight glazing. The shelves diffuse daylight onto the ceiling plane and adjacent surfaces, thus minimizing contrast ratios between interior surfaces and elements viewed through the glazing. This, in turn, serves to increase visual comfort and improves the quality of the view to the outside.

Energy-Efficient Electric Lighting

The facility's artificial lighting system is designed to supplement daylight and will use a combination of direct and indirect luminaries with T-5 fluorescent lamps and dimmable electronic ballasts, together with compact fluorescent and metal halide downlights and wall washers. Illumination levels are designed to work in tandem with daylighting and high-performance glazing systems to provide a balanced luminous environment with low energy consumption. Photocell controls will be used in conjunction with electronic fluorescent dimming ballasts to save energy in areas receiving daylight, while low-level ambient lighting enhanced by occupant-controlled task lighting will illuminate areas not served by daylighting. Occupancy sensors will control lighting in private offices.

Displacement Ventilation

The ventilation systems that serve the courtrooms, various offices, and public corridor spaces incorporate displacement ventilation air distribution. This system features low-velocity air introduced at floor level to efficiently condition the space and remove indoor air pollutants.

Evaporative Cooling System

Much of the building's cooling and humidification loads are met using an indirect and direct evaporative cooling system, which provides a cooling effect through water evaporation. This process greatly reduces the need to run an electric-powered chiller. Denver's dry climate makes this system ideal for much of the cooling season; indeed, computer simulations show less than 100 full load hours of chiller operation per year. The system is also used to add humidity to the building during the winter to improve occupant comfort.

Variable Air Volume Systems (VAV) Using Variable-Speed Drives (VSD)

The heating and cooling needs are further addressed by a VAV air-handling system, which adjusts supply air volumes in response to the heating and cooling needs of the various zones. VSDs are installed on all fans and pumps to reduce the energy consumption of these devices during part-load operation. The main air handler incorporates four separate supply fans that can be individually staged, allowing for efficient operation of the system down to 5% of design air flow. The use of VSDs is especially important in courthouse facilities, due to their variable occupancy characteristics and occasional nighttime use.

Building Automation System

A full direct-digital-control system is used to control the HVAC and lighting systems. The system is designed to shut down the HVAC and lighting systems in unoccupied spaces and, in tandem with the VAV air handling and pumping systems, provides efficient operation under partial occupancy.

Building-Integrated Photovoltaics

PV is integrated into the southeast curtain-wall system adjacent to the public corridor areas of the tower, and a skylight is located over the security drum element in the Special Proceedings pavilion. Translucent, thin-film cells are applied to the skylight and selected panels in the curtain wall system, and additional polycrystalline PV panels are used as spandrel panels in the curtain wall system. The PV panels provide electricity during sunlight hours, reducing peak electric demand. Battery storage is not necessary, because system output is greater than building demand.

Landscaping

A variety of measures can be implemented to optimize the landscape surrounding a building. Among these, preservation of existing landscape features should be the designer's first course of action. Mature trees and vegetation are valuable resources that take many years to replace. Preserving them not only allows for their use in natural shading (and in some climates, as a wind break or shelter belt), it also maintains existing wildlife habitats, existing drainage patterns, and soil conditions. Tree preservation reduces the need for excavation, transportation, and relocation of soil. In addition, it reduces the need for supply and transportation of fill and landscape materials. When adding new vegetation to a site, use regionally consistent landscaping strategies, composed of locally grown, native plants.

Water Efficiency

One of the most overlooked areas in developing a whole-building design strategy is the efficient use of water resources. To process and use water, the Federal government expends 59.2 billion Btu of energy on an annual basis; more than 98% of this energy is used to heat water. Thus, significant energy and dollar savings can be realized by implementing water-efficient measures. Water efficiency is the planned management of water to prevent waste, overuse, and exploitation of the resource. Effective water-efficiency planning seeks to "do more with less," without sacrificing comfort or performance. Water-efficiency planning is a relatively new management practice that involves analyzing cost and water usage, specifying water-saving solutions, installing water-saving measures, and verifying the savings to quantify results.

A variety of water conservation technologies and techniques can be used to save water and associated energy costs, including:

- Water-efficient plumbing fixtures (e.g., ultra-low-flow toilets and urinals, waterless urinals, low-flow and sensored sinks, low-flow showerheads, and water-efficient dishwashers and washing machines)
- Reducing water use associated with irrigation and landscaping (water-efficient irrigation systems, irrigation-control systems, low-flow sprinkler heads, water-efficient scheduling practices, and xeriscaping)
- Graywater and process recycling systems that recycle or reuse water
- Reducing water use in HVAC systems.

Demand-side management methods reduce the amount of water consumed on-site at a facility and include system optimization, water conservation measures, and water reuse and recycling systems. Other efficiency options include leak detection and repair, industrial process improvements, and changing the way fixtures and equipment are operated and maintained.

National Renewable Energy Laboratory's Thermal Testing Facility, Golden, Colorado

NREL's Thermal Testing Facility (TTF) is an open-space laboratory building comprised of high-bay laboratory areas, offices, and conference rooms. Design of the 10,000-square-foot building began early in 1994, and construction was completed in the summer of 1996. Performance monitoring has been underway since occupancy. Although the TTF was designed to serve as a laboratory, the technologies discussed in this case study are appropriate to a wide range of commercial buildings, offices, warehouses, and institutional facilities. Sustainable design strategies integrated into the building include:

- Passive solar features
- Efficient electric lighting
- Daylighting features
- Occupancy sensors
- Efficient HVAC design
- Energy management system with direct digital control (DDC).

The TTF's design team included an architect, mechanical engineer, electrical engineer, structural engineer, building-owner facilities staff, and an energy consultant. From the outset, the team focused on optimizing the interactions among the building's various systems, taking into account the influence of building occupants, their daily activities, and climatic conditions in the surrounding area. Energy-related design decisions were based in part on the results of computer simulations using DOE 2 (1994). The building's owner (U.S. DOE) and eventual occupants (NREL staff) determined necessary building criteria at the outset of the design phase. The type of spaces required included flexible generic laboratory space, assorted open-area support offices, a conference room, washrooms, and a kitchenette area.

Once the building's use was established, the design team and NREL research engineers set a building energy cost reduction goal of 70%, and a strategic design and construction plan was developed to serve as a "road map" to guide the process. The plan included integrating passive solar features, low building load coefficient, efficient electric lighting, daylighting features, occupancy sensors, efficient HVAC design, and an energy management system with DDC.

With a Congressional budget of $1.5 million to cover all design, construction, and commissioning costs, a code-compliant base case was created for the TTF's design, using 10 CFR 435 (1995) as the reference. (The base-case design is a useful benchmark for gauging the relative cost effectiveness of both individual and collective performance improvements.) The base case was simulated using SERI-RES to study the thermal aspects of the building, and DOE 2.2 for HVAC and lighting studies.

Initial base-case results showed that electrical lighting loads accounted for a large portion of the energy use—roughly 73%, not including plug loads. Cooling loads were next, at 15% of the building's total energy consumption. Based on this information, the NREL research staff believed that internal heat gains could be minimized by reducing the electric lighting load and by minimizing unwanted solar gains. This was accomplished by integrating daylighting and efficient artificial lighting strategies, specifying high-performance windows, and by engineering the dimensions of overhangs. By minimizing the cooling load, the design team was also able to downsize the HVAC system in comparison to what would have been required in the base-case scenario.


Warren Gretz/PIX04117

The National Renewable Energy Laboratory's Thermal Testing Facility shows how sustainable design strategies can be integrated into a variety of commercial buildings, offices, warehouses, and institutional facilities.

Computer modeling indicated that the largest energy savings could be achieved by reducing the electric lighting load. Reducing plug loads had a similar effect, but plug loads are not related to the building envelope design. Reducing infiltration, controlling ventilation and unwanted solar gains, and improving the building's opaque envelope all produced similar energy-saving results. In addition, the facility's interior was arranged to free up additional floor area. By moving the mechanical room from the exterior east wall to a location above the central core (where the restrooms, storage, and kitchen areas are located), an additional 800 square feet of laboratory floor space was created without a concomitant increase in energy use. The TTF's final low-energy design achieved its energy reduction goal by applied energy-efficient design strategies as described below.

Passive Solar Design

To take advantage of Colorado's sunny climate, the TTF integrates many passive solar features, including appropriate siting and building orientation. The design also incorporates a small amount of thermal mass in the slab floor and north wall of the building, and the north wall also acts as a retaining wall for a mesa, providing the thermal benefits of earth berming. Among the facility's most important features, however, are the proper selection, orientation, and placement of windows and clerestories.

The building was carefully engineered to provide passive solar gain in the winter months, while minimizing this gain during the summer. The final design incorporates 88% of its total fenestration as a single row of view glass and two rows of clerestories along the southern façade. An additional 8% of view glass is divided equally between the east and west façades, while the remaining 4% is positioned on the north wall. South-facing clerestory windows were designed with a high SC of 0.76 (SHGC of 0.68), while all others have a lower SC of 0.51 (SHGC of 0.45). The higher SCs allow more solar gain to enter the building. In addition, all windows have a low-e coating, which prevents the transmission of most non-visible spectrum light and unwanted solar gain. The careful design and placement of overhangs rounds out the picture by blocking direct solar radiation during the summer when sun angles are high, while allowing direct solar radiation in winter, when sun angles are much lower.

Overall, the TTF's envelope and its passive solar features were designed to heat the building during the day and into the evening hours, such that the only heat load on the building will take place during the morning hours. Bear in mind that the glazing configurations and other passive solar strategies described above are very much site- and application-specific and will not necessarily apply to different building types in other locales.

Thermal Envelope

The TTF's floor is constructed of a 6-inch concrete slab with 4-foot perimeter insulation. The north wall is constructed of an 8-inch concrete slab with 2 inches of rigid polystyrene, while the east, west, and south walls use 6-inch steel studs with batt insulation positioned between the studs. Expanded polystyrene is placed over the entire exterior surface, which is finished with Exterior Insulation and Finish System (EIFS) stucco. The roof is constructed using metal decking atop steel supports with a 3-inch polyisocianurate covering. The thermal insulation positioned on the wall exterior creates an energy sink within the building, which dampens the building's natural temperature swings. For example, during cold winter nights, when outdoor temperatures drop well below freezing, the TTF's indoor temperature drops by only 10ºF.

Lighting

The TTF is illuminated by a dynamic combination of electric lighting and daylighting, depending on real-time occupancy status and daylight luminance values. A stair-stepped design is integral to the daylighting plan; daylight enters the building through a row of view glass and two additional rows of clerestories lining the south façades of the open office areas, mid-bays, and high-bays, respectively. Additional windows exist along the east, west, and north walls to balance incoming daylight. Again, all windows are engineered to take full advantage of daylighting opportunities.

A sensor that measures illumination levels controls the building's supplemental electric lighting system, and the building's energy management system (EMS) uses this information to control electric lighting status, depending on the amount of natural light available in each lighting zone. In terms of lighting systems, the facility uses T-8 and compact fluorescent lighting, 72% of which provides supplemental lighting to daylit zones, while the remaining 28% provides primary lighting to the building's central core. The EMS-integrated occupancy control protocol uses passive infrared and ultrasonic occupancy sensors to disengage lighting when not required. Together, these features have significantly reduced the building's (lighting-based) electrical use as well as its cooling load, while heating loads increased only slightly during the winter months.

Heating, Ventilation, and Air Conditioning

Because the TTF minimizes HVAC requirements, a smaller, more efficient, and less expensive HVAC system was installed. Actually, the TTF uses two separate HVAC systems: a VAV air handling unit (AHU) to serve the main building, and a packaged single-zone AHU to serve the conference room. The VAV unit relies on direct and indirect evaporative cooling as its primary cooling source, supplemented by ceiling fans, which help reduce the temperature stratification that is common in spaces with large ceiling heights.

The TTF's efficient HVAC design limited the total amount of ductwork throughout the building, which, in turn, reduces material costs during construction, as well as maintenance thereafter. All ductwork is insulated and located indoors to reduce losses to the outside environment and bordering zones.

Energy Management System

The TTF uses a digital building control system for most mechanical building operations. This EMS allows for easy monitoring, tuning, and diagnosis, helping to keep the building operating as designed. The EMS operates each of the HVAC units and the electrical lighting system and also collects diagnostic and performance data. Two tankless heat-on-demand water heaters provide the facility with domestic hot water (DHW): one serving the kitchen and the other dedicated to the washrooms. Both units are natural gas-fired and provide 80% thermal efficiency.

The Technology in Perspective

Technology Development

Since ancient times, people have designed buildings for the local climate, taking advantage of natural daylight and prevailing winds. Today, these same principles apply to low-energy building design but are combined with what we have learned about energy conservation; advanced materials, products, and mechanical systems; renewable energy; and energy performance design tools. When designed in tandem, technology clusters, such as energy-efficient lighting, occupancy sensors, and daylighting strategies, can reduce a building's energy load and improve occupant comfort.

Federal energy managers can be assured that sound, climate-responsive design will yield long-term energy savings regardless of fluctuations in energy prices and will serve as the basis for durable, comfortable, environmentally sound buildings. Advances in other key technologies will further transform the building industry. New design and analysis tools have greatly improved the designer's ability to predict building energy performance, while giving energy managers better control over operations and maintenance costs. As these tools continue to be refined and their use becomes more commonplace, low-energy building design will emerge as the only logical approach to new construction and renovation.

Technology Outlook

The technologies, systems, and design strategies discussed in this guidebook are helping to ensure a bright future for low-energy buildings. As consumers continue to demand more sustainable development and wise environmental stewardship from their elected leaders, the Federal government is uniquely positioned to take the lead in making its own buildings as energy efficient as possible, and at the same time making them more comfortable and attractive than their conventional counterparts. It is likely, however, that institutional barriers (e.g., restrictive codes, procedures, budget processes) will have to be revised or removed before the Federal sector can fully meet this challenge.

This guidebook is a tangible step toward achieving more widespread use of whole-building energy design and analysis because it makes the process more comprehensible for all project team members. There is also an important role for those who develop new Federal guidelines and requirements that encourage the use of low energy and renewable energy strategies. Though often unsung, these individuals are laying the cornerstone for meaningful, enduring change.

When starting your next project, remember that an accurate assessment of low-energy design features and technologies comes from a clear understanding—not just of how the many components of a building work—but of how they work together. This often begins with an awareness that the current, highly fragmented building process is not producing the best results, and that a new view of the building as a system of interdependent components is required.

Product Resources

A vast array of products for low-energy buildings are available from suppliers of traditional building materials as well as from manufacturers of specialized technologies, such as PV systems. Because passive solar buildings are design intensive, it also is useful to know how to locate design professionals with special expertise in low-energy building design. For information on products and professional services, please refer to the following resources, as well as building product suppliers.

Air-Conditioning and Refrigeration Institute
Arlington, Virginia
Phone: 703-524-8800, 800-AT-ARIES
Web site: *http://www.ari.com*

American Institute of Architects
Committee on the Environment
Washington, D.C.
Phone: 202-626-7515
Web site: *http://www.e-architect.com*

Architects' First Source for Products
Web site: *http://www.afsonl.com*

APA—The Engineered Wood Association
Tacoma, Washington
Phone: 206-565-6600
Web site: *http://www.apawood.org*

Association of Home Appliance Manufacturers
Chicago, Illinois
Phone: 312-984-5800

Building Design Assistance Center
Florida Solar Energy Center
E-mail: bdac@fsec.ucf.edu
Web site: *http://www.fsec.ucf.edu/~bdac/*
Manufactures and supplies controls (i.e., dimming systems, motion/occupancy sensors, power reducers, switching systems), energy management systems, glazing (e.g., glass, windows, window films, skylights), insulation systems and radiant barriers, lighting (e.g., energy efficient ballasts, lamps, luminaries, exit lighting, specular reflectors), and roofing (e.g., energy-efficient reflective coatings, paints, tiles, shingles).

Center for Renewable Energy and Sustainable Technology (CREST)
Web site: *http://www.crest.org*

Gas Appliance Manufacturers Association
Arlington, Virginia
Phone: 703-525-9565

Greening Federal Facilities: An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers (1997). U.S. DOE/FEMP
Phone: 800-DOE-EREC
Web site: *http://www.eren.doe.gov/ femp/techassist/greening.html*

Primary Glass Manufacturers Council
Topeka, Kansas
Phone: 785-271-0208

Structural Insulated Panel Association
Phone: 253-858-SIPA (7472)
Web site: *http://www.sips.org*

Sustainable Buildings Industry Council (formerly Passive Solar Industries Council)
Washington, D.C.
Phone: 202-628-7400
E-mail: SBIC@SBICouncil.org
Web site: *http://www.sbicouncil.org*

Sustainable Building Sourcebook
Green Building Program
Austin, Texas
Web site: *http://www.greenbuilder. com/sourcebook*

Sustainable Building Technical Manual: Green Building Design, Construction and Operations (1996).
Public Technology, Inc.
U.S. Green Building Council
U.S. DOE/U.S. EPA.
U.S. Green Building Council
San Francisco, California
Phone: 415-543-3001
E-mail: info@usgbc.org
Web site: *http://www.usgbc.org*

Who is Using the Technology

Thousands of low-energy buildings and homes have been constructed throughout the United States, many by the Federal government. The GSA has used low-energy approaches for some of its buildings. Several Federal facilities that feature low-energy design strategies are in the design phase, under construction, or recently completed, including an environmental learning center on the National Mall in Washington, D.C., and a 570,000-square-foot Federal courthouse in Phoenix, Arizona. The National Park Service (NPS) has integrated passive solar strategies into new employee housing units. NPS houses in Grand Canyon and Yosemite National Parks are included in the DOE Exemplary Buildings program. Projects have been completed or are in progress at Grand Teton National Park, Hovenweep National Monument, and Capitol Reef National Park. The Department of Defense is also using these low-energy strategies.

Federal Sites

Excellence in Facility Management, Five Federal Case Studies (1998).
National Institute of Building Sciences
Phone: 202-289-7800
E-mail: nibs@nibs.org
Web site: *http://www.nibs.org/fmochome.htm*

The case studies included in this document are: (1) U.S. Department of Agriculture Headquarters, (2) Carbondale Federal Building, (3) Merritt Island Launch Annex, (4) Naval Station Everett, and (5) Defense Logistics Agency.

National Park Service Employee Housing at Capitol Reef National Park

National Renewable Energy Laboratory
High-Performance Buildings Program
Golden, Colorado
Phone: 303-275-3000
Web site: *http://www.nrel.gov/buildings/highperformance*
Detailed case studies of state-of-the-art, low-energy buildings; pictures are available for download.

The Naval Facilities Engineering Command has completed several projects that demonstrate low-energy design principles. A physical fitness center at Camp Pendleton, California; a $7.8 million project in Sugar Grove, West Virginia; and a restoration project at the Washington Navy Yard.

Brown, Linda R. "SERF: A Landmark in Energy Efficiency." (May/June 1994). *Solar Today*, American Solar Energy Society.

U.S. Fish and Wildlife Service National Education and Training Center, Shepherdstown, West Virginia. A FEMP case study will soon be available. Among a host of energy-efficient features, the center incorporates passive solar design strategies. In winter, large southern windows capture solar gain, and brick floors behind windows store heat. Windows are made of high-performance glass. In summer, extended rooflines (overhangs) and landscaping provide optimum shading. Some windows are fitted with sunscreens, which also help reduce summer cooling loads.

Non-Federal Sites

Besser Company manufacturing facility, Alpena, Michigan. By Innovative Design. Energy conservation, daylighting.

Blue Cross/Blue Shield building in New Haven, Connecticut. The 21,000-square-foot building has deep overhangs on the south façade to protect it from direct solar radiation in summer and to reduce cooling loads. An atrium divides the building into two sectors. Light shelves on façades and in the atrium project natural light deep into the space. The project was completed in 1990; Ellenzweig Associates, Inc., were the architects.

Brown Summit Youth Dormitory cabins, North Carolina. By Cooper-Lecky CUH2A, LLP. Natural ventilation.

Buildings for a Sustainable America Case Studies, American Solar Energy Society, 303-443-3130, ases@ases.org, *http://www.ases.org/solar* and Sustainable Buildings Industry Council (formerly Passive Solar Industries Council), 202-628-7400, SBIC@SBICouncil.org, *http://www.sbicouncil.org*, with funding from U.S. Department of Energy. A collection of 18 case studies, with easy-to-read summaries, thorough project details, and photographs.

The Florida Solar Energy Center (FSEC) is building a state-of-the-art complex (office building, visitor's center, and laboratories) for its new facility in Cocoa, Florida. The objective is to design and construct the most energy-efficient facility possible within the limits of Florida's hot and humid climate. For a detailed analysis of the low-energy design strategies used, check the FSEC Web site: *http://www.fsec.ucf.edu/About/TOUR/Tourhome.htm*

Illinois Department of Energy and Natural Resources
Contact: R. Forrest Lupo
Phone: 217-785-3484

Massachusetts State Transportation Building, Boston, Massachusetts
A solar water-heating system installed in 1982 cost $250,000 but saves $26,280 per year in avoided electricity costs. At this rate, the system will pay for itself in 9.5 years. Four thousand square feet of closed-loop propylene glycol solar collectors enable the solar water heaters to operate year-round, even though the outside temperature is below freezing for extended periods of time. The collectors supply 83% of the building's annual domestic hot water needs, offsetting roughly 5,800 gallons of oil annually.

Contact: Martha Goldsmith, Director, Office of Leasing
Commonwealth of Massachusetts
Phone: 617-727-8000

Sacramento Department of Transportation Building
Uses nighttime flushing and passive solar cooling with atrium.
Contact: Craig Hoellwarth
Phone: 916-683-8378

Union of Concerned Scientists building
Cambridge, Massachusetts
Phone: 617-547-5552
E-mail: energy@ucsusa.org
Web site: *http://www.ucsusa.org*

Utah Department of Natural Resources (profiled in *Solar Today*, American Solar Energy Society, July/August 1997)

For Further Information

Trade/Professional Organizations

American Council for an Energy Efficiency Economy (ACEEE)

Alliance to Save Energy

American Institute of Architects
Committee on the Environment
Washington, D.C.
Phone: 202-626-7515
Web site: *http://www.e-architect.com*

American Portland Cement Alliance
Washington, D.C.
Phone: 202-408-9494
Web site: *http://www.portcement.org*

American Solar Energy Society
Phone: 303-443-3130
E-mail: ases@ases.org
Web site: *http://www.ases.org*

American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)
Atlanta, Georgia
Phone: 404-636-4800
Web site: *http://www.ashrae.org*

American Society for Testing and Materials
West Conshocken, Pennsylvania
Phone: 610-832-9500
Web site: *http://www.astm.org*

Association of Energy Engineers
Atlanta, Georgia
Phone: 770-447-5083
Web site: *http://www.aeecenter.org*

Building Owners and Managers Association International
Washington, D.C.
Web site: *http://www.boma.org*

Brick Institute of America, Mid East Region
North Canton, Ohio
Phone: 330-499-3001

Brick Industry Association
Reston, Virginia
Phone: 703-620-0010
Web site: *http://www.bia.org*

Ceilings and Interior Systems Construction Association
St. Charles, Illinois
Phone: 630-584-1919

Electricity Consumers Resource Council
Washington, D.C.
Phone: 202-682-1390

Energy Efficient Building Association (EEBA)
Minneapolis, Minnesota
Phone: 612-851-9940
E-mail: EEBANews@aol.com

Illuminating Engineering Society of North America
New York, New York
Phone: 212-248-5000

International Masonry Institute
Ann Arbor, Michigan
Phone: 313-769-1654

National Association of Energy Service Companies
Washington, D.C.
Phone: 202-822-0952

National Association of Home Builders
Washington, D.C.
Phone: 202-822-0200 (bookstore: extension 463)
Web site: *http://www.nahb.com*

National Concrete Masonry Association
Herndon, Virginia
Phone: 703-713-1900
Web site: *http://www.ncma.org*

National Electrical Manufacturers Association
Rosslyn, Virginia
Phone: 703-841-3200

National Fenestration Rating Council
Silver Spring, Maryland
Phone: (301) 588-0854
Web site: *http://www.nfrc.org*

National Institute of Building Sciences
Phone: 202-289-7800
E-mail: nibs@nibs.org
Web site: *http://www.nibs.org/fmochome.htm*

National Society of Professional Engineers
Alexandria, Virginia
Phone: 703-684-2800
Web site: *http://www.nspe.org*

National Wood Window and Door Association
Des Plaines, Illinois
Phone: 847-299-5200
Web site: *http://www.nwwda.org*

North American Insulation Manufacturers Association
Alexandria, Virginia
Phone: 703-684-0084
Web site: *http://www.naima.org*

North Carolina Solar Center
Phone: (919) 515-3480

Northeast Sustainable Energy Association
Phone: 413-774-6051
E-mail: buildings@nesea.org
Web site: *http://www.nesea.org*

Solar Energy Industries Association
Washington, D.C.
Web site: *http://www.seia.org*

Southface Energy Institute
Atlanta, Georgia
Phone: 404-872-3549
E-mail: info@southface.org
Web site: *http://www.southface.org*

Sustainable Buildings Industry Council (SBIC) (formerly Passive Solar Industries Council)
Washington, D.C.
Phone: 202-628-7400
E-mail: SBIC@SBICouncil.org
Web site: *http://www.sbicouncil.org*

U.S. Green Building Council (USGBC)
San Francisco, California
Phone: 415-543-3001
E-mail: info@usgbc.org
Web site: *http://www.usgbc.org*

Design Guides

Designing Low-Energy Buildings: Passive Solar Strategies and ENERGY-10 Software; Passive Solar Design Strategies: Guidelines for Home Building; Low-Energy, Sustainable Building Design for Federal Managers (Sustainable Buildings Industry Council [formerly Passive Solar Industries Council])
Phone: 202-628-7400
E-mail: SBIC@SBICouncil.org
Web site: *http://www.sbicouncil.org*

General Services Administration / Public Buildings Service—Proposed *Comprehensive Building Commissioning*

LEED™ (Leadership in Energy and Environmental Design) Rating System, Version 2.0, available at *http://www.usgbc.org*

Sustainable Building Technical Manual: Green Building Design, Construction and Operations, Public Technology, Inc.
U.S. Green Building Council
U.S. DOE, U.S. EPA, 1996.

Whole Buildings Design Guide, a federally sponsored, vertical portal to a wide range of building specific criteria, technology, and product information.
Web site: *http://www.wbdg.org*

Utility, Information Service, or Government Agency Tech-Transfer Literature

Utility Sources

American Gas Association
Arlington, Virginia
Web site:*http://www.aga.com*

Edison Electric Institute
Washington, D.C.
Phone: 202-508-5557
Web site: *http://www.eei.org*

The Electricity Consumers Resource Council
Washington, D.C.
Phone: 202-682-1390
E-mail: elcon@elcon.org
Web site: *http://www.elcon.org*

Electric Power Research Institute
Palo Alto, California
Phone: 650-855-2000
Web site: *http://www.epri.com*

National Association of Regulatory Utility Commissioners
Washington, D.C.
Phone: 202-898-2200
Web site: *http://www.naruc.org*

National Association of State Utility Consumer Advocates
Washington, D.C.
Phone: 202-727-3908
Web site: *http://www.nasuca.org*

Public Utilities Reports
Vienna, Virginia
Phone: 703-847-7720, 800-368-5001
E-mail: info@pur.com
Web site: *http://www.pur.com/*

General Information Sources

Energy Design Update
Cutter Information Corp.
37 Broadway, Suite 1
Arlington, Massachusetts 02174-5552
Phone: 800-964-5118
Web site: *http://www.cutter.com/energy/*

Environmental Building News
RR 1, Box 161
Brattleboro, Vermont 05301
Phone: 802-257-7300;
Web site: *http://www.ebuild.com*

E Source, Inc.
Boulder, Colorado,
Phone: 303-440-8500
Web site: *http://www.esource.com*

Florida Solar Energy Center
Phone: 407-638-1015
Web site: *http://www.fsec.ucf.edu*

International Energy Agency
Web site: *http://www.iea.org*

Iris Catalog: Publications, Videos and Software for Green Construction
Iris Communications, Inc.
P.O. Box 5920
Eugene, Oregon 97405-9011
Phone: 800-346-0104
Web site: *http://www.oikos.com*

ReInState, a guide to state-by-state renewable energy and sustainable development resources, including case studies, products and services, utility information, programs and policies, and energy usage and design data for each state.
Web site: *http://www.crest.org/gem.html*

American National Standards Institute

Government Sources

Energy Efficiency and Renewable Energy Clearinghouse
Merrifield, Virginia,
Phone: 800-363-3732
E-mail: erec@nciinc.com
Web site: *http://www.eren.doe.gov*

Energy Science and Technology Software Center
Web site: *http://www.osti.gov/estc*

Federal Laboratory Consortium
1850 M Street, NW, Suite 800
Washington, D.C. 20036
FLC Locator: 609-667-7727
Web site: *http://www.Federallabs.org/*

Guiding Principles of Sustainable Design
U.S. Department of the Interior
National Park Service
Denver, Colorado: GPO, 1993.

Lawrence Berkeley National Laboratory
Berkeley, California
Phone: 415-486-5771
Web site: *http://www.lbl.gov/*

National Energy Information Center
Washington, D.C.
Phone: 202-586-1181
E-mail: infoctr @eia.doe.gov

National Institute of Standards and Technology
Washington, D.C.
Web site: *http://www.nist.gov*

National Oceanic and Atmospheric Administration (NOAA)
Phone: 704-271-4800
E-mail: orders@ncdc.noaa.gov
Web site: *http://www.ncdc.noaa.gov*

National Renewable Energy Laboratory
Web site: *http://www.nrel.gov/buildings/highperformance*

National Technical Information Service
Washington, D.C.
Phone: 800-553-6847
Web site: *http://www.fedworld.gov*

Oak Ridge National Laboratory
Building Technology Center
Web site: *http://www.ornl.gov/ornl/btc*

Office of Scientific and Technical Information
Oak Ridge, Tennessee
Phone: 423-576-1188. Technical reports: 423-576-8401

Partnership for Advancing Technology in Housing (PATH)
U.S. Department of Housing and Urban Development
Phone: 202-708-1600
Web site: *http://www.pathnet.org*

Procuring Low-Energy Design and Consulting Services: A Guide for Federal Building Managers, Architects, and Engineers, 1997
Phone: 800-DOE-FEMP
Web site: *http://www.eren.doe.gov/femp/*

Sacramento Municipal Utility District
Phone: 916-732-6679

Sandia National Laboratories
Phone: 505-844-3077
Web site: *http://www.sandia.gov/EE.htm*

U.S. Department of Energy
Building Technology
State and Community Programs
Phone: 202-586-2998

U.S. Environmental Protection Agency
Energy Star Program
Web site: *http://www.epa.gov*

Codes and Standards

Executive Order 13123 mandates improvements in energy efficiency and water conservation in Federal buildings nationwide, including cost-effective investments (payback of less than 10 years) in low-energy building design and active solar technologies.

10 CFR 435 establishes performance standards to be used in designing new Federal commercial and multifamily high-rise buildings. Some of the guidelines are relevant to retrofits.

10 CFR 436 establishes procedures for determining the life-cycle cost effectiveness of energy conservation measures and for prioritizing energy conservation measures in retrofits of existing Federal buildings.

In general, building codes and standards address specific technologies and minimum requirements for building energy efficiency. They do not address whole building performance. A well-designed, low-energy building can exceed existing Federal codes, as well as commercial code (ASHRAE 90.1—Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings), by as much as 50%.

Documents and Other References

American Institute of Architects, Committee on the Environment, *Energy, Environment and Architecture*, Washington, D.C., 1991.

Ander, Gregg, *Daylighting Performance and Design*, New York, New York, Van Nostrand Reinhold, 1998.

Balcomb, J. Douglas, editor. *Passive Solar Buildings*. Cambridge, Massachusetts, MIT Press, 1992.

Bobenhausen, William, *Simplified Design of HVAC Systems*. New York, John Wiley and Sons, Inc., 1994.

Idea exchange among facility managers Web site: *www.fmdata.com*

Interstate Renewable Energy Council
15 Haydn Street
Roslindale P.O.
Boston, Massachusetts 01131-4013
Phone: 617-323-7377

International Energy Agency Solar Heating and Cooling Programme. *Passive Solar Commercial and Institutional Buildings: A Sourcebook of Examples and Design Insights*. West Sussex, United Kingdom, John Wiley and Sons, Ltd., 1994.

National Institute of Building Sciences
www.nibs.org

Productivity Studies

- *www.workplaceforum.com*
- Miller, Burke, *Buildings for a Sustainable America Case Studies*; *Daylighting and Productivity at Lockheed*, Boulder, Colorado, American Solar Energy Society.
- Joseph Romm and William Browning, *Greening the Building and the Bottom Line: Increasing Productivity through Energy-Efficient Design*, Snowmass, Colorado, Rocky Mountain Institute, 1994.

Steven Winter Associates, Inc., *The Passive Solar Design and Construction Handbook*, New York, John Wiley and Sons, Inc., 1998.

Tuluca, Adrian; Steven Winter Associates, Inc., *Energy-Efficient Design and Construction for Commercial Buildings*. New York, McGraw-Hill, 1997.

Appendixes

Appendix A: Climate and Utility Data Sources

Appendix B: Federal Life-Cycle Costing Procedures and the Building Life Cycle Cost (BLCC) Software

Appendix A: Climate and Utility Data Sources

Energy User News includes a ranking of electricity and gas utility prices by state in each of its monthly issues. Available at *http://www.energyusernews.com*.

NOAA provides detailed available climate data and summaries for sites in or near a locality. Call 704-271-4800, e-mail requests to orders@ncdc.noaa.gov, or available on the World Wide Web at *http://www.ncdc.noaa.gov*.

Opportunities for Renewable Energy Supply in New Buildings (Solar Potential Maps). A Buildings for a Sustainable America Education Campaign Resource from the Sustainable Buildings Industry Council, Washington, D.C. Funded by the U.S. DOE, researched and produced by Mark Kelley and Henry Amistadi of Building Science Engineering in Harvard, Massachusetts. For more information, call 202-628-7400, send e-mail to SBICouncil@aol.com, or access the SBIC Web site at *http://www.sbicouncil.org*.

Putting Energy into Profits. U.S. Environmental Protection Agency, #430-B-97-040, December 1997. Five U.S. climate zones are mapped, showing average annual energy use and average annual energy costs for specific building types. Available from Government Printing Office, Superintendent of Documents, Washington, DC 20402, or call 202-512-1800.

Appendix B: Federal Life-Cycle Costing Procedures and the Building Life Cycle Cost (BLCC) Software

Federal agencies are required to evaluate energy-related investments on the basis of life-cycle costs (10 CFR 436). Life-cycle cost analysis (or life-cycle costing [LCC]) is a means of predicting the overall cost of building ownership, including initial costs, operating costs for energy, water and other utilities; personnel costs; and maintenance, repair, and replacement costs. LCC analyzes changes to the building, including all significant costs over the predicted life of the building. It can be used to refine the design to ensure the facility will provide the lowest overall cost of ownership consistent with its desired quality and function.

Analysis tools such as the National Institute of Standards and Technology's (NIST) BLCC computer program performs calculations to predict life-cycle costs, providing an economic analysis of proposed capital investments that are expected to reduce long-term operating costs of buildings. BLCC is designed to comply with 10 CFR 436. ERATES (electricity rates) is another computer program from NIST that calculates monthly and annual electricity costs for a facility under a variety of electric rate schedules. ERATES block-rate and demand-rate schedules can be imported by BLCC. BLCC is available from the FEMP Help Desk at 800-566-2877.

About FEMP's New Technology Demonstration Program

The Energy Policy Act of 1992, and subsequent Executive Orders, mandate that energy consumption in Federal buildings be reduced by 35% from 1985 levels by the year 2010. To achieve this goal, the U.S. Department of Energy's Federal Energy Management Program (FEMP) is sponsoring a series of programs to reduce energy consumption at Federal installations nationwide. One of these programs, the New Technology Demonstration Program (NTDP), is tasked to accelerate the introduction of energy-efficient and renewable technologies into the Federal sector and to improve the rate of technology transfer.

As part of this effort, FEMP is sponsoring a series of publications that are designed to disseminate information on new and emerging technologies. New Technology Demonstration Program publications comprise three separate series:

Federal Technology Alerts—longer summary reports that provide details on energy-efficient, water-conserving, and renewable-energy technologies that have been selected for further study for possible implementation in the Federal sector.

Technology Installation Reviews—concise reports describing a new technology and providing case study results, typically from another demonstration program or pilot project.

Technology Focuses—brief information on new, energy-efficient, environmentally friendly technologies of potential interest to the Federal sector.

Federal Energy Management Program

The Federal Government is the largest energy consumer in the nation. Annually, in its 500,000 buildings and 8,000 locations worldwide, it uses nearly two quadrillion Btu (quads) of energy, costing over $8 billion. This represents 2.5% of all primary energy consumption in the United States. The Federal Energy Management Program was established in 1974 to provide direction, guidance, and assistance to Federal agencies in planning and implementing energy management programs that will improve the energy efficiency and fuel flexibility of the Federal infrastructure.

Over the years, several Federal laws and Executive Orders have shaped FEMP's mission. These include the Energy Policy and Conservation Act of 1975; the National Energy Conservation and Policy Act of 1978; the Federal Energy Management Improvement Act of 1988; and, most recently, Executive Order 12759 in 1991, the National Energy Policy Act of 1992 (EPACT), Executive Order 12902 in 1994, and Executive Order 13123 in 1999.

FEMP is currently involved in a wide range of energy-assessment activities, including conducting New Technology Demonstrations, to hasten the penetration of energy-efficient technologies into the Federal marketplace.

Log on to FEMP's New Technology Demonstration Program Web site

http://www.eren.doe.gov/femp/prodtech/newtechdemo.html

You will find links to:

- An overview of the New Technology Demonstration Program
- Information on the program's technology demonstrations
- Downloadable versions of program publications in Adobe Portable Document Format (PDF)
- A list of new technology projects underway
- Electronic access to the program's regular mailing list for new products when they become available
- How Federal agencies may submit requests for the program to assess new and emerging technologies.

For More Information

FEMP Help Desk
(800) 363-3732
International callers please use
(703) 287-8391
Web site: www.eren.doe.gov/femp

General Contacts

Ted Collins
New Technology Demonstration Program Manager
Federal Energy Management Program
U.S. Department of Energy
1000 Independence Ave., SW, EE-92
Washington, D.C. 20585
Phone: (202) 586-8017
Fax: (202) 586-3000
theodore.collins@ee.doe.gov

Steven A. Parker
Pacific Northwest National Laboratory
P.O. Box 999, MSIN: K5-08
Richland, WA 99352
Phone: (509) 375-6366
Fax: (509) 375-3614
steven.parker@pnl.gov

Technical Contact

Nancy Carlisle
National Renewable Energy Laboratory
1617 Cole Boulevard, M.S. 2723
Golden, CO 80401
Phone: (303) 384-7509
Fax: (303) 384-7411
Nancy_Carlisle@nrel.gov

Prepared for the U.S. Department of Energy by the National Renewable Energy Laboratory, a DOE national laboratory

DOE/EE-0249

July 2001

Printed with a renewable-source ink on paper containing at least 50% wastepaper, including 20% post consumer waste