Passive Solar Design:

The Foundation for Low-Energy Federal Buildings

Our nation's buildings have a proven influence on how we feel, learn, and work. Some studies indicate that indoor lighting, temperatures, and air quality even affect how much we earn.

Our buildings also consume 37% of the energy and 67% of the electricity we use in the United States each year. This electricity is produced mainly by burning fossil fuels that emit gases, such as nitrogen oxide, that can contribute to the nation's air-quality problems. Therefore, the Federal government, which now owns or occupies more than 500,000 facilities, is taking a look at passive solar and low-energy building designs for both new construction and renovations.

Passive solar design strategies involve more than just using large, south-facing windows to capture some of the sun's warmth. They also include the use of natural light (daylighting), appropriate insulation, high-performance window glazings, and optimum building layouts and orientations with respect to the path of the sun in the sky. Sometimes they involve the use of thermal mass, such as tiled floors and Trombe walls. These strategies take advantage of local climate conditions as well as the seasonal path of the sun in a given region. They help to bring outdoor light into interior spaces and they make use of as much natural warmth and ventilation as possible. In warm climates, passive solar design can reduce cooling loads. Measures such as overhangs can control solar heat gain and prevent overheating.

Passive solar strategies are the foundation of low-energy building designs. To build on this foundation, designers look at how all the building's components can be engineered to work together as a whole. Rather than viewing a building as a collection of independent parts, many of today's architects, builders, and policy makers are adopting a more sustainable, "whole-building" approach to design and construction.

In this approach, designers usually start with appropriate siting. Then they add an energy-efficient envelope and layout. They also specify energy-efficient mechanical equipment, to help promote a comfortable indoor environment. Often, this equipment can be powered by renewable energy, such as a solar electric or wind energy system, as well as by conventional electricity or natural gas.

Whole-building design strategies make the most of the complex ways that a building's occupants, components, and materials connect and interact. A successful whole-building design, then, is a solution that is greater than the sum of its parts. In addition, high-performance, low-energy buildings help to meet at least five key national objectives:

- They provide affordable housing, including residences for government employees.
- They increase the health, comfort, and productivity of their occupants (see box on p. 2).

Robb Williamson/PIX09256

An attractive new Visitor Center in Zion National Park, Utah, features clerestory windows, a Trombe wall, daylighting, and a solar electric system. The Center is a joint project of the National Park Service, the DOE Office of Building Technology, State and Community Programs, the Federal Energy Management Program, and the National Renewable Energy Laboratory.

- They help reduce pollution and atmospheric greenhouse gases.
- They alleviate the strain on our nation's gas and electric utilities.
- They help us conserve conventional fossil fuels like oil and natural gas.

Renewable Energy Technologies for Federal Facilities

U.S. Department of Energy

Office of Energy Efficiency and Renewable Energy

A proven, "passive" way to increase productivity

Recent studies performed in our country by the Heshong Mahone Group on behalf of the Pacific Gas and Electric Company (PG&E) have begun quantifying the benefits of using more natural lighting — daylighting — in buildings, with some surprising results. Retail stores that incorporate daylighting strategies have increased their sales volume an average of 40%. Students in daylit classrooms have improved 10% to 20% on test scores, and they progress 20% and 26% faster than others on math and reading tests, respectively. Commercial and institutional facilities that use daylighting are reducing their annual energy consumption by 30% to 60%, and workplace performance in these facilities is on the rise.

Low-energy building design teams also evaluate candidate designs on the basis of ease of maintenance, opportunities to use automated controls, and safety and security issues, as well as energy efficiency. They also consider cost-effectiveness. An integrated, whole-building design approach can actually help reduce both construction costs and long-term operating costs (see p. 3).

What are the opportunities for passive solar design in the Federal government?

Because they involve such integral elements of a building as walls, floors, and windows, passive solar and low-energy designs are probably most suitable for new Federal construction and major renovations. However, depending on the conditions at a specific site, numerous passive and low-energy strategies can be retrofit into existing buildings. For example, installing double-pane windows, skylights, or new heating, ventilating, and air-conditioning (HVAC) equipment in an older facility often makes it much more energy efficient. All types of Federal buildings are potential candidates:

- Schools and training facilities
- Visitor centers
- Libraries
- Small office buildings
- Health care facilities
- Post offices
- Airport and airfield hangars and terminals
- Warehouses
- Employee residences (including single-family and multifamily housing, dorms, and barracks).

In fact, facility managers can choose almost any building to be a candidate for lower conventional energy costs through passive solar design. In addition, some utilities provide financial incentives to customers that use these designs. For specific information, government planners and designers can contact the utility that serves their proposed new facility or planned renovation.

What is required?

A whole-building, systematic approach begins in the predesign phase and continues throughout

Dave Parsons, NREL/PIX04219

The District Attorney Building in Jefferson County, Colorado, is a high-quality, 52,000-square-foot structure housing more than 130 judicial employees; this energy-efficient, two-story building was built with recycled materials.

Try a design charrette to share ideas, give feedback

Designing and building a high-performance, low-energy building usually requires a collaborative, interactive approach. To successfully integrate the many energy-efficient components of such a building, those who specify and configure these components — architects, designers, consultants, engineers, and contractors — must work together closely throughout the design process. Often, they decide to participate in a peer review or design charrette early in the process.

A design charrette is a focused, collaborative brainstorming session, usually held in the predesign or design development phase of a project. The charrette allows participants to exchange ideas and information, so that integrated solutions take shape along with the design. Because participants are encouraged to offer ideas and solutions beyond the scope of their expertise, charrettes are particularly helpful in complex situations. Design charrettes allow participants to consider many different solutions, address organizational differences, reduce adversity, verify decisions, and expedite the design process.

design development and building construction. These are some key activities in the process:

- Establish low-energy, whole-building design as a goal from the outset (perhaps with assistance from an energy consultant).
- Site and orient the building to maximize southern exposures and minimize western exposures (i.e., to have a long east-west axis) and to respond to local climate conditions, natural landscape features, and nearby services such as transportation and utilities.
- Conduct energy performance and lighting analyses, using tools that account for the interactions between lighting, envelope, and mechanical systems, such as *DOE 2.2*, *Designing Low-Energy Buildings with ENERGY-10*, and *Radiance*. These enable mechanical, electrical, lighting, and other systems to be sized and configured to reduce energy demand.
- Specify energy-reduction targets and "green" building material requirements in all contracts.
- Select contractors for their demonstrated expertise in low-energy design and construction, and their experience in monitoring a building's energy performance.
- Consider the building's location, envelope, intended use, hours of operation, occupancy levels, and equipment loads in determining HVAC requirements.
- Ensure that the building envelope has adequate insulation and that windows are sized and located appropriately, according to site-specific heating, cooling, and ventilation needs, and make sure the envelope incorporates high-performance glazing and other energy-efficient materials.

Scott Bly, US Army/PIX07625

Daylighting retrofits at Wheeler Army Airfield in Hawaii included new skylights for the airplane hangars; skylights like these reduce an agency's electricity bills.

Warren Gretz, NREL/PIX04116

Daylighting is just one of the passive solar strategies featured in the Thermal Test Facility and other lab buildings at the National Renewable Energy Laboratory in Golden, Colorado.

- Include natural ventilation systems, radiative or ground-coupled cooling, geothermal heat pumps, or peak-load shifting through the use of thermal mass, as appropriate.

What does it cost?

In evaluating potential design strategies, it is important to think in terms of life-cycle costs rather than first costs. Life-cycle cost analysis takes into account factors such as durability; energy cost savings over a component's or building's anticipated life; and the component's impacts on maintenance, replacement, and disposal costs, among other considerations. The U.S. Department of Energy's Federal Energy Management Program (DOE FEMP) has developed a number of tools that can help designers determine life-cycle costs; see FEMP's Web site at http://www.eren.doe.gov/femp/ or the contacts on p. 4 for more information.

An increase in the design cost of 2% to 4% over that of conventional buildings is considered acceptable for most sustainable, low-energy building designs. Buildings with unusually high heating or cooling demands may require slightly higher expenditures. However, these increases, and those associated with materials and system enhancements, are often recouped in the first few years of operation through energy savings alone. This simple payback period can be calculated using the energy analysis programs developed by DOE.

Some energy-efficient features actually reduce the first cost of certain building components. For

What are the important terms?

Daylighting — involves using natural, outdoor light to illuminate the interior spaces of a building evenly by means of proper window placements and orientations, skylights, clerestories, and other methods.

Direct gain — occurs when sunlight directly entering a building through a window is absorbed, converted to heat, and stored in floors or walls, as opposed to Trombe walls and sunspaces.

Glazing — transparent or translucent window glass having three main performance characteristics that affect energy use: U-value, which determines conductive heat losses and gains; visible light transmission, which determines the relative amount of light that will enter a space; and solar heat gain coefficient, which determines the relative amount of solar gain.

Overhang — a projection over a south-facing window that shades it from the summer sun.

Sunspace — an unconditioned room with south-facing windows that collects and absorbs heat for itself and adjacent areas.

Sustainable design strategies — use the standard elements of a building — walls, windows, and floors — to collect, store, and release the sun's energy for heating, lighting, and cooling. Building materials, equipment, and systems should all contribute to indoor air quality, durability, ease of maintenance, cost-effectiveness, and environmental soundness through the full cycle of production, operation, and recycling or disposal. Sustainability involves the wise use of resources today to ensure their availability for generations to come.

Thermal mass — walls and floors that absorb heat during the day and release it at night, in winter (or cool down at night, in summer) as outside temperatures rise or drop.

Trombe wall — a glazed concrete or masonry wall with a black surface that absorbs and stores solar heat.

example, using more energy efficient windows and awnings usually allows designers to specify smaller, less expensive HVAC systems.

Passive solar designs and low-energy buildings can make Federal facilities more energy-efficient, more comfortable, safer to operate, easier to work in, less expensive to maintain, and more environmentally benign. In nearly every case, using this integrated, innovative approach to building design is well worth the investment in time and effort, because it pays off in the long run. Low-energy buildings help our government reduce its energy use, save money, and preserve the environment — valuable benefits both now and in the future.

For More Information

The Sustainable Buildings Industry Council (SBIC) and the U.S. Department of Energy's Federal Energy Management Program (FEMP) provide workshops and Web-based instructional materials on sustainable building design and construction strategies. For details about SBIC, please contact:

Helen English, Executive Director
Sustainable Buildings Industry Council
1331 H Street, N.W., Suite 1000
Washington, DC 20005-4707
202-628-6100, ext. 205
On the Internet:
http://www.sbicouncil.org

For more information about building design assistance available through FEMP, please contact:

Andy Walker
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3393
303-384-7531
On the Internet:
http://www.nrel.gov/femp/

FEMP Help Desk:
800-DOE-EREC
(363-3732)
Internet:
http://www.eren.doe.gov/femp

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