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SUSTAINABLE BUILDING TECHNICAL MANUAL

Green Building Design, Construction, and Operations

PUBLIC TECHNOLOGY, INC.

Produced by Public Technology Inc. ■ US Green Building Council

Sponsored by U.S. Department of Energy ■ U.S. Environmental Protection Agency

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Public Technology, Inc. developed this manual to address the growing demand for information on the design and construction of green buildings. The manual was jointly sponsored by PTI's Urban Consortium Environmental and Energy Task Forces. The U.S. Green Building Council (USGBC) worked with PTI to develop the manual. David Gottfried of Gottfried Technology Inc., served as managing editor. An Advisory Committee of local-government and private-sector representatives assisted in developing the manual. The manual underwent a consensus review process by members of the USGBC and was peer reviewed by U.S. DOE and U.S. EPA officials.

Public Technology, Inc.

Public Technology, Inc., is the non-profit technology research and development organization of the National League of Cities, the National Association of Counties, and the International City/County Management Association. PTI's mission is to bring technology to local and state governments. Through the collective R&D work of its membership, PTI spreads the use of technology to effectively serve communities. PTI uses strong, dynamic public-private partnerships to offer to local and state government cost-saving technology services and products.

PTI is committed to a sustainable environment. Its Urban Consortium (UC) Environmental and Energy Task Forces unite cities and counties behind that goal to explore, test, and promote technologies that maintain the critical balance between healthy development and a healthy environment. Many of its members' innovative programs are highlighted in the annual PTI *SOLUTIONS* publication series.

The UC Environmental Task Force is chaired by Randy Johnson, Commissioner, Hennepin County, Minnesota. The UC Energy Task Force is chaired by Michael Lindberg, Commissioner of Public Utilities, City of Portland, Oregon.

U.S. Green Building Council

The U.S. Green Building Council (USGBC) is a balanced, nonprofit coalition of the building industry promoting the understanding, development, and accelerated implementation of green building policies, programs, technologies, standards, and design practices on a national basis. Since its formation in 1993, the council has attracted more than 100 leading national organizations to its ranks, including product manufacturers, environmental groups, building owners, utilities, state and local governments, research institutions, professional societies, and colleges and universities. USGBC has also established effective and ongoing liaisons with the White House, federal agencies, standards organizations, and organizations representing state and local governments. Issues being addressed by the council include economic analysis, full-cost accounting, green building rating systems, product certification, life-cycle analysis, environmental policies, standards development, and education of the building industry.

U.S. Department of Energy

The mission of the U.S. Department of Energy (U.S. DOE) is to assure that the nation has adequate and stable supplies of energy. The department is also committed to helping the nation discover and adopt cleaner and more sustainable energy resources and technologies—in other words, technologies that improve energy efficiency, prevent pollution, and make use of renewable resources to diversify the nation's energy mix. U.S. DOE's Office of Energy Efficiency and Renewable Energy (OEERE) operates a number of technical and financial assistance programs to improve the resource efficiency of America's buildings. Among them are Building America, which brings the diverse elements of the building industry together to practice a systems approach to building design and construction, improving cost, durability, indoor air quality, and energy efficiency. In addition, the Office encourages green building practices through its Center of Excellence for Sustainable Development, which helps communities create and implement sustainable development programs. The center will help communities adopt a comprehensive approach to planning—an approach that recognizes the links between energy, environment, economy, and community livability. Information and a "tool kit" on sustainable development is available on the Center's Internet home page, <http://www.crest.org/doe/sustainable>, or by calling (800) 357-7732.

U.S. Environmental Protection Agency

The Safety, Health and Environmental Management Division (SHEMD) of U.S. EPA is responsible for developing and implementing the agency's internal policies, programs, and infrastructure for environmental management and public and occupational safety and health. SHEMD works closely with all U.S. EPA operating units to provide management support and technical assistance. Through collaborative relationships with other federal, state, and local government agencies and organizations, business and industry, educational and research institutions, and other entities, SHEMD jointly develops products and services that have widespread public- and private-sector application. A particular emphasis is placed upon learning, information, and performance-support systems, especially those employing new technologies, to help advance the nation's objectives for a sustainable future.

Producing a manual that covers all disciplines involved in the design, construction, and operation of a building is an enormous challenge. Early in the process it was decided that this book, like a building project, would best be designed and constructed via a collaborative, integrated effort of practitioners in the field. Many individuals across the building professions provided a great deal of assistance and deserve thanks for making the manual a success.

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Foreword

Author
David A. Gottfried

Since the Industrial Revolution, the world has witnessed incalculable technological achievements, population growth, and corresponding increases in resource use. As we enter a new century, we are recognizing the "side effects" of our activities: pollution, landfills at capacity, toxic waste, global warming, resource and ozone depletion, and deforestation. These efforts are straining the limits of the Earth's "carrying capacity"—its ability to provide the resources required to sustain life while retaining the capacity to regenerate and remain viable.

As the world's population continues to expand, implementation of resource-efficient measures in all areas of human activity is imperative. The built environment is one clear example of the impact of human activity on resources. Buildings have a significant impact on the environment, accounting for one-sixth of the world's freshwater withdrawals, one-quarter of its wood harvest, and two-fifths of its material and energy flows. Structures also impact areas beyond their immediate location, affecting the watersheds, air quality, and transportation patterns of communities.[1]

Within the United States, buildings represent more than 50 percent of the nation's wealth. In 1993, new construction and renovation activity amounted to approximately $800 billion, representing 13 percent of the Gross Domestic Product (GDP), and employed ten million people.[2] The resources required to create, operate, and replenish this level of infrastructure and income are enormous, and are diminishing. To remain competitive and continue to expand and produce profits in the future, the building industry knows it must address the environmental and economic consequences of its actions.

That recognition is leading to changes in the way the building industry and building owners approach the design, construction, and operation of structures. With the leadership of diverse groups in the public and private sectors, the building industry is moving toward a new value in its work: that of environmental performance.

The industry's growing sustainability ethic is based on the principles of resource efficiency, health, and productivity. Realization of these principles involves an integrated, multidisciplinary approach—one in which a building project and its components are viewed on a full life-cycle basis. This "cradle-to-cradle" approach, known as "green" or "sustainable" building, considers a building's total economic and environmental impact and performance, from material extraction and product manufacture to product transportation building design and construction, operations and maintenance, and building reuse or disposal. Ultimately, adoption of sustainable building practices will lead to a shift in the building industry, with sustainability thoroughly embedded in its practice, products, standards, codes, and regulations.

Understanding the specifics of sustainable building and determining effective sustainable practices can be confusing. Local governments and private industry often do not have the resources to perform the necessary research to assemble information on sustainable practices, assuming such information is readily available.

The S*ustainable Building Technical Manual* was written to fill that void. In its pages, noted private practitioners and local government experts extract, consolidate, and prioritize—from their own experience and expertise—the scattered and growing volume of information pertaining to sustainable buildings. The manual's primary intent is to provide public and private building industry professionals with suggested practices across the full cycle of a building project, from site planning to building design, construction, and operations.

We hope that you will find this technical manual a useful and vital resource in advancing your organization's adoption and daily practice of sustainable building principles—a necessary and important step toward recognizing the Earth's finite carrying capacity and addressing the depletion of its natural resources.

NOTES

1 David Rodman and Nicolas Lenssen, "A Building Revolution: How Ecology and Health Concerns Are Transforming Construction," *Worldwatch Paper 124* (Washington, D.C., March 1996).

2 National Science and Technology Council, Subcommittee on Construction and Buildings, *Preliminary Report* (Washington, D.C., 1993).

The Role of Local Governments

Local governments own and maintain a wide range of buildings and facilities, including administrative and office buildings, park facilities, health clinics and hospitals, fire and police stations, convention centers, wastewater treatment plants, and airports.

At their disposal are a variety of administrative, regulatory, and financing tools that can help local governments develop and operate these building resources in a sustainable manner. Local governments can create policies for municipal procurement, contract specifications, building performance, and building codes regulating community standards; enact resolutions, training and education programs, and ordinances that focus attention on sustainable development; create community boards and commissions to study local sustainable issues; and provide economic incentives for sustainable development.

Finally, many local governments have the experience and capability to create model programs and buildings, which set examples for resource-efficient guidelines and support green building programs elsewhere in their communities. Green building programs can be a first step to helping local stakeholders—policymakers, businesses, citizens, financiers, homeowners, and building owners—understand the economic and environ-

mental wisdom of adopting sustainable principles for their communities.
Many successful green building initiatives are being developed and implemented at the local level across the United States.

The city of Austin, Texas, has consistently demonstrated leadership and vision in this area. Over the last decade, the city of Austin developed its Green Builder Program to support green practices in the residential sector. More recently, it passed a resolution encouraging environmentally sound development within the residential, municipal, and commercial building sectors. Austin's ultimate goal is to be a model sustainable city.

The city of Portland, Oregon, passed an ordinance requiring the recycling of construction waste, along with a set of city-wide principles that promote a sustainable future. Metro-Dade County, Florida, is working with Habitat for Humanity and other partners to plan and develop an energy-efficient and environmentally sound low-cost housing development. Some communities, such as San Francisco, California; Seattle, Washington; San Diego, California; Hennepin County, Minnesota; and New York, New York, are developing their own green building guidelines for municipal and private buildings, or launching demonstration projects that incorporate green building principles.

Communities may also address sustainability from an overall quality-of-life perspective, as Jacksonville, Florida, did. Jacksonville, which has tracked quality indicators since 1985, involves citizens in setting targets and reports annually on progress in education, economy, public safety, health, natural environment, social environment, government, recreation, and mobility. Other communities, such as Chattanooga, Tennessee, have sought to address environmental damage in the process of redesigning their communities. In Chattanooga, more than 2,600 citizens participated in the ReVision 2000 planning process to identify specific environmental improvement goals and recommendations for future city development. Some of the cities efforts to become a model sustainable city include developing a network of greenways and eco-industrial parks, renovating and constructing new public facilities to be model green buildings, and proposing an expansion of the city's trade center to include a variety of green technologies.

Green building initiatives, as well as sustainable development activities, offer many opportunities to local governments and communities. The key to success for local governments is to take the first step toward sustainability, working initially within areas that are most likely to succeed, such as a green building project. A few possible starting points include the following:

- Examine local government policies and procurement procedures for inclusion of green building measures.
- Develop a demonstration green building project or local sustainable building design competition.
- Require that government building projects incorporate renewable energy and energy efficient systems, indoor-air-quality guidelines, and waste and water-efficiency measures.
- Survey and review other cities with green building projects, programs, and standards.
- Assemble a multidisciplinary team within the community to discuss the possibility of developing a green building program.
- Develop a green building awards program; co-sponsor the program with the local utility and local chapters of design, engineering, and property-management societies.
- Survey and publish the community's green building resources.
- Initiate a conference or series of lectures on green building issues.
- Assemble a green building resource library within an existing library or municipal office.
- Initiate a green building computer-based bulletin board or Internet site.
- Publish case studies of local green building projects or develop a green building

Overview

Sustainable Building Technical Manual: Green Building Practices for Design, Construction, and Operations is intended to meet the building industry's need for a comprehensive manual of sustainable building practices. Its goal is to provide clear, easily applied guidelines and useful practices that can be readily introduced into new construction, renovation, and building operations. The manual is designed to synthesize the large volume of available information on green buildings and direct the reader to more detailed resources for further review and reference.

The manual focuses on commercial-size building projects in both the public and private sectors. Building professionals who will find this manual a useful resource include landscape architects, planners, architects, interior designers, engineers, contractors, property managers, building owners and developers, product manufacturers, utility companies, building tenants, maintenance staff, and code officials.

Organization of the Manual

The manual is organized in seven parts, along with an Introduction and Appendix. Part I discusses the economic and environmental significance of sustainable buildings. Parts II through VI describe the sequential design, construction, and operational process for a building project, and Part VII reviews sustainable building financing issues and opportunities for local governments, as well as future green building issues and trends.

Introduction

This section contains a foreword by managing editor David Gottfried, a discussion of the role of local governments in promoting green building practices, and the manual overview.

Part I: Economics and Environment

Part I outlines the financial benefits and environmental ramifications of green building practices. It focuses on energy and water efficiency, waste reduction, construction costs, building maintenance and management savings, insurance and liability, employee health and productivity, and building value. It also reviews the local economic development potential of green building initiatives and presents a methodology for environmental life-cycle assessment and its application to green buildings.

Part II: Pre-Design Issues

This section reviews pre-design environmental issues such as design team selection, environmental guidelines, and "whole-building" design integration—the first and essential steps in creating and implementing a successful green building project.

Part III: Site Issues

Site issues chapters provide detailed information on sustainable site design, water use, and site materials. Discussed are design issues such as assessment and selection of building sites, development of landscaping that preserves natural vegetation and maintains watershed integrity, and consideration of green site materials.

Part IV: Building Design

Building design is divided into three subsections that provide information on passive solar design strategies; building systems, indoor environmental quality, and building commissioning; and building materials and specifications.

Part V: The Construction Process

Environmentally sound construction methods are outlined and the section discusses site management issues, indoor air quality, and resource efficiency as they relate to construction processes.

Part VI: Operations and Maintenance

This section reviews environmental operations and maintenance issues including indoor environmental quality, energy efficiency, resource efficiency, and renovation. Housekeeping and custodial practices that help maintain high environmental standards are also discussed.

Part VII: Issues and Trends

The first chapter in this section discusses financing options and cost issues for local governments seeking to implement green building practices. The last chapter presents green building issues such as building standards, rating systems and product certification, and green business trends such as performance contracting and product "environmental" leasing.

Appendices

The Appendices contain a comprehensive listing of information resources for local government; a glossary of terms, acronyms, and abbreviations used in this manual; and biographies of the manual's contributing writers. They also contain the PTI Advisory Committee of public and private experts, and other manual reviewers, including members of the U.S. Green Building Council and American Institute of Architects, and representatives from the U.S. Department of Energy and the U.S. Environmental Protection Agency.

Format of the Manual Chapters

Sections of this manual that discuss green building practices—Parts II through VI—are organized according to the traditional project phases of building design, construction, and operations. The chapters in each section focus on sustainable issues and green practices relevant to the specific processes that occur in each of these phases. Parts II through VI also include chapters on local government information, which provide the local government perspective on implementation issues, give examples of action taken by jurisdictions, and include lists of local options. Readers may choose to add other relevant information and resources about local green building experts, products, or regulations to these local government chapters.

Most of these chapters are organized in the following standard format:

★ SIGNIFICANCE

This section summarizes the sustainability issues relevant to the chapter's topic. It also provides background information on the subject.

☞ SUGGESTED PRACTICES AND CHECKLIST

This section suggests action-oriented, environmentally based practices that design and construction professionals may apply directly to their projects. Brief discussions accompany the practices which are presented in a checklist format.

➜ RESOURCES

Resource lists accompanying chapters direct the reader to publications with additional information on the subject. These lists are not exhaustive, and are intended generally as starting points.

NOTES

The numbered citations at the end of each chapter are endnotes related to information cited in the text.

Chapter Presentation and Approach

Successful sustainable design requires an integrated approach; green building systems and operational practices are dependent on siting, solar access and light penetration, architectural design, and product specification. Green buildings must take all of these factors into consideration on a "whole-building," integrated basis. This approach is not linear; rather it is circular and multi-dimensional.

Given this level of complexity and the interrelationships between different parts of the design process, chapters cross-reference pertinent information in other chapters. Each chapter, however, can stand on its own. As a result, some of the material in a given chapter may echo information provided elsewhere. For example, topics covered in the chapter on the design of heating, ventilating and air-conditioning (HVAC) systems may be repeated, to some extent, in the chapter on operations and maintenance. The goal of this approach is to allow professionals from different fields—design, engineering, products, and operations—to use the relevant parts of this manual independently. To further this goal, we have published the manual in a notebook format, allowing easier concurrent use by several practitioners as well as additions and updates to the information contained therein.

PART I

Economics and Environment

Introduction

Sustainable development is the challenge of meeting growing human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future life and development. This concept recognizes that meeting long-term human needs will be impossible unless we also conserve the earth's natural physical, chemical, and biological systems.[1]

Sustainable development concepts, applied to the design, construction, and operation of buildings, can enhance both the economic well-being and environmental health of communities in the United States and around the world. The Union Internationale des Architects/American Institute of Architects (UIA/AIA) World Congress of Architects recognized that in its 1993 Declaration of Interdependence, which acknowledges that buildings and the built environment play a major role in the human impact on the natural environment and on the quality of life. If sustainable design principles are incorporated into building projects, benefits can include resource and energy efficiency, healthy buildings and materials, ecologically and socially sensitive land use, transportation efficiency, and strengthened local economies and communities.

In the United States, federal agencies and the building industry, under the leadership of the National Science and Technology Council, have undertaken the development of goals for improved construction practices. These National Construction Goals promise enormous benefits for the nation, in terms of both economic prosperity and general well-being. Embracing sustainability concepts, the goals aim to reduce energy, operation, and maintenance costs; reduce building-related illnesses; increase the productivity and comfort of building occupants; reduce waste and pollution; and increase building and component durability and flexibility.[2]

Locally, public and private leaders have realized the economic and environmental benefits of green building practices and are instituting policies, developing building guidelines, and manufacturing products and systems that will achieve sustainable development goals.

This section of the manual examines the economic benefits and environmental ramifications of green buildings, and outlines a life-cycle assessment process that building professionals can use to understand the environmental and economic impact of up-front building design decisions over the full life of a property.

NOTES

1 Sustainable development definition from the Civil Engineering Research Foundation, Washington, D.C.

2 National Science and Technology Council, Committee on Civilian Industrial Technology, Subcommittee on Construction and Building, *Construction and Building: Federal Research and Development in Support of the U.S. Construction Industry* (Washington, D.C.: National Science and Technology Council, 1995).

CHAPTER 1

The Economics of Green Buildings

Author
David A. Gottfried

Few realize that construction, including new construction and building renovation, constitutes the nation's largest manufacturing activity.[1] Over 70 percent of this effort is focused on residential, commercial, industrial, and institutional buildings; the remaining 30 percent on public works. Construction contributes $800 billion to the economy, or 13 percent of the Gross Domestic Product (GDP), and provides nearly 10 million professional and trade jobs. More than 50 percent of the nation's reproducible wealth is invested in constructed facilities.[2] Because of the building industry's significant impact on the national economy, even modest changes that promote resource efficiency in building construction and operations can make major contributions to economic prosperity and environmental improvement.

Several parties—including owners, tenants, and the general public—bear the cost of building construction. The main direct cost expenditures fall within the categories of building construction, renovation, operation, and building-related infrastructure. Indirect cost expenditures stem from building-related occupant health and productivity problems as well as external costs such as air and water pollution, waste generation, and habitat destruction.

A building's "life" spans its planning; its design, construction and operation; and its ultimate reuse or demolition. Often, the entity responsible for design, construction, and initial financing of a building is different from those operating the building, meeting its operational expenses, and paying employees' salaries and benefits. However, the decisions made at the first phase of building design and construction can significantly affect the costs and efficiencies of later phases.

Viewed over a 30-year period, initial building costs account for approximately just two percent of the total, while operations and maintenance costs equal six percent, and personnel costs equal 92 percent.[3] Recent studies have shown that green building measures taken during construction or renovation can result in significant building operational savings, as well as increases in employee productivity. Therefore, building-related costs are best revealed and understood when they are analyzed over the life span of a building.

Life-cycle cost analysis—an increasingly accepted analytical method that calculates costs over the "useful" or anticipated life of an asset—reveals that low up-front expenditures, though easier to finance at building inception, can result in much higher costs over the life of a building or system. Choosing space-conditioning systems with the lowest first cost, for example, may prove to be a poor life-cycle decision, when energy operations costs over the useful years of the systems are factored into the analysis.

Because local governments often own and operate their buildings, they are in a good position to maximize environmental and economic efficiencies across all building-related cost areas through integration of green building measures. To date, however, green building measures have not been widely adopted, with the exception of energy efficient systems. Some energy-saving measures have become almost commonplace, because their economics are relatively easy to calculate, and because the utility industry has provided financial incentives and rebates that encourage their implementation.

Obstacles to adoption of other green measures include general confusion as to what the measures entail, how to select high-environmental-performance products, and what overall economic and associated benefits can result. A perception that green building measures cost more persists despite cost-effective examples. Even simple design changes that use daylighting and natural heating and cooling potential, and can be incorporated with minimal increased up-front costs, are often misunderstood and underutilized. Too few green building demonstration projects today provide the industry with needed "how-to" information that reduces the perceived risk of "pioneering." Moreover, building owners and tenants are often aware of the connection between building-related environmental improvements and increased building economics and value, as well as increased occupant productivity.

This chapter reviews the economic opportunity and reduced liability for building projects that incorporate green building measures. The areas covered include energy efficiency, water efficiency, waste reduction, construction, building operations and maintenance, insurance and liability, occupant health and productivity, building value, and local economic development opportunities.

Energy Efficiency

Approximately 50 percent of the energy use in buildings is devoted to producing an artificial indoor climate through heating, cooling, ventilation, and lighting.[4] A typical building's energy bill constitutes approximately 25 percent of the building's total operating costs. Estimates indicate that climate-sensitive design using available technologies could cut heating and cooling energy consumption by 60 percent and lighting energy requirements by at least 50 percent in U.S. buildings.[5]

ENERGY RETROFIT

San Diego, California

In a 1995 building renovation project for the city of San Diego's Environmental Services Department, an extensive energy-efficiency retrofit package was projected to yield a four-year payback on investment. The local utility, San Diego Gas & Electric, offered incentives that covered most of the up-front cost of the energy-related improvements, thereby yielding an even earlier payback.

Thanks to efficient mechanical systems, lighting, appliances, and computer-control measures, the building is projected to achieve energy savings of approximately 60 percent over those required under California's Title 24 Energy Code. The annual energy savings are estimated at $66,000 for the 73,000-square-foot building—a savings of $0.90 per square foot, compared to typical energy costs in a similar building. DOE-2 energy-modeling software projected the building's total electricity consumption at approximately 8.4 kilowatt-hours per square foot, placing the project in the lowest five percent of all energy consumers among buildings in the city.

Returns on investment for energy-efficiency measures can be higher than rates of return on conventional and even high-yielding investments. Participants in the Green Lights program of the U.S. Environmental Protection Agency (EPA) have enjoyed annual rates of return of over 30 percent for lighting retrofits. When participants complete all program-related improvements, Green Lights could save over 65 million kilowatts of electricity, reducing the nation's electric bill by $16 billion annually.[6]

If the United States continues to retrofit its existing building stock into energy-efficient structures and upgrade building codes to require high energy efficiency in new buildings, it will be able to greatly reduce the demand for energy resources. This reduction, in turn, will lessen air pollution, contributions to global warming, and dependency on fossil fuels.

Water Efficiency

Water conservation and efficiency programs have begun to lead to substantial decreases in the use of water within buildings. Water-efficient appliances and fixtures, behavioral changes, and changes in irrigation methods can reduce consumption by up to 30 percent or more.[7] Investment in such measures can yield payback in one to three years. Some water utilities offer fixture rebates and other incentives, as well as complimentary water surveys, which can lead to even higher returns.

WATER EFFICIENCY
in a Typical 100,000 sq. ft. Office Building

Water Usage	
Number of Building Occupants	650
Water Use per Occupant per Day	20
Total Annual Building Water Use (gallons)	3,250,000
Total Annual Building Water Use (HCF*)	4,345
Water Cost	
Water Cost per HCF	$1.44
Sewer Cost per HCF	$1.93
Total (water + sewer) Cost per HCF	$3.37
Total (water + sewer) Annual Cost	$14,643
Savings	
Initial Cost of Water Measures**	$10,983
Annual Water Conservation, at 30% Reduction (HCF)	1,304
Annual Water + Sewer Savings (1,304 HCF at $3.37)	$4,394
Payback Period	2.5 years

*One hundred cubic feet (HCF) = 748 gallons
** Measures include efficient, low-flow appliances and fixtures as well as control sensors.
Source: Figures based on communications with Water Department specialists in San Diego, Phoenix, and Sacramento.

Figure 1

As *Figure 1* reveals, for a typical 100,000-square-foot office building, a 30 percent reduction in water usage through the installation of efficiency measures can result in annual savings of $4,393. The payback period is 2.5 years on the installed conservation and efficiency measures. In addition to providing a 40 percent return on investment, the measures result in annual conservation of 975,000 gallons of water.

As demand on water increases with urban growth, the economic impact of water conservation and efficiency will increase proportionately. Water efficiency not only can lead to substantial water savings, as shown in the above example, it also can reduce the requirement for expansion of water treatment facilities. Non-residential water customers account for a small percentage of the total number of water customers, but use approximately 35 percent or more of the total water.[8] More information on water conservation programs and incentives can be obtained from your local water utility, or by calling WaterWiser, a national water-efficiency clearinghouse of the American Water Works Association and the U.S. Environmental Protection Agency, at 800/559-9855.

Waste Reduction

Of the 20,000 landfills located within the United States, more than 15,000 have reached capacity and closed.[9] Many more are following this pattern each year. Construction-related waste constitutes more than 25 percent of landfill content and equals total municipal garbage waste generated in the United States.[10] As a result of this volume of waste, an increasing number of landfills will not permit, or are charging extra for, the dumping of construction-related waste. In response, recycling of such debris is increasing at the job site. Materials such as gypsum, glass, carpet, aluminum, steel, brick, and disassembled building components can be reused, or, if that is not feasible, recycled.

In addition to construction-waste recycling, the building industry is beginning to achieve significant waste reductions through more building reuse and adaptation, as opposed to demolition. In past decades, the trend has been to raze a building at the end of its first life (assumed to be the "useful" life) and replace it with a new building. With ingenuity, older structures can be successfully renovated into cost-effective and efficient "new" structures. Adaptive reuse of older structures can result in financial savings to both sellers and purchasers. One example is the National Audubon Society headquarters building in New York, the product of a 1993 project that recycled a 100-year-old eight-

PORTLAND TRAILBLAZERS ROSE GARDEN ARENA[11]

Portland, Oregon

One of the best examples of the savings potential for recycling of construction-related demolition debris is the Portland Trailblazers Rose Garden Arena, a new 750,000-square-foot stadium built in Portland, Oregon, in 1995. In demolishing the old stadium and an adjacent facility, the project contractor, Turner Construction Company, was able to divert successfully from the landfill the majority of the construction and demolition debris—including 1,300 tons of wood, 1,000 tons of metal, and 29 tons of cardboard—through reuse and recycling. In addition, the contractor diverted large quantities of gypsum wallboard, site-clearing debris, concrete, and asphalt. For a recycling cost of only $19,000, the contractor avoided an estimated $166,000 in landfill costs. Rebates totaling $39,000 were received from third party vendors for the metal and cardboard. The resulting net savings from the project for the full recycling effort was approximately $186,000.

story building. Conservation of the building's shell and floors saved approximately 300 tons of steel, 9,000 tons of masonry, and 560 tons of concrete. Audubon estimates a savings of approximately $8 million associated with restoration instead of demolition and new construction.[12]

Construction

Application of green building concepts can yield for savings during the construction process. Measures that are relatively easy to implement can result in savings to the contractor in the following areas:

- Lower energy costs, by monitoring usage, installing energy-efficient lamps and fixtures, and using occupancy sensors to control lighting fixtures;
- Lower water costs, by monitoring consumption and reusing stormwater and/or construction wastewater where possible;
- Lower site-clearing costs, by minimizing site disruption and movement of earth and installation of artificial systems;
- Lower landfill dumping fees and associated hauling charges, through reuse and recycling of construction and demolition debris;
- Lower materials costs, with more careful purchase and reuse of resources and materials;
- Possible earnings from sales of reusable items removed during building demolition; and
- Fewer employee health problems resulting from poor indoor air quality.

This listing suggests some possible areas for cost savings; the project team can identify other possibilities through a cooperative and integrated team approach. The contractor can also improve relations with the community and building owner by viewing them as part of the team effort to implement environmentally sound construction measures. See Part V of this manual for more detailed information and discussion of environmental construction guidelines.

Building Operations and Maintenance

The green building measures discussed in this manual can lead not only to lower building operating expenses through reduced utility and waste disposal costs, but also to lower on-going building maintenance costs, ranging from salaries to supplies. For example, in many buildings, maintenance staff collect recycled materials on each floor—or even at every employee's desk—and carry the materials down to the basement for hand sorting. Recycling chutes, a viable green alternative, allow direct discarding of materials from any floor in the building to the basement. The chute system, which ideally is installed during initial construction or renovation, can sort materials automatically, saving labor costs by eliminating the need to collect, transport, and sort recyclables. Other savings come in the form of lower waste hauling fees; reduced workers' compensation insurance premiums due to lower claims for accidents from sharp glass and cans; reduced elevator maintenance; less frequent cleaning of spills on carpets and floors; and less need for pest control.

OPERATIONS AND MAINTENANCE SAVINGS

One private waste handling company has estimated that a typical 20-floor building can realize estimated annual labor savings of $27,209 for handling recyclables with a chute system, as opposed to floor-by-floor recycling. The potential annual savings from reduced hauling is $4,800. Together, the reductions add up to a total annual savings of $32,009. The savings are offset by the installation cost of the chute system, totaling $24,000, resulting in an initial increase in net cash flow for the building owner or manager of $8,000.[13]

Environmentally friendly housekeeping products can also have financial advantages. For example, cleaning products that are purchased as concentrates and use minimal packaging not only promote waste reduction, but also can reduce product usage by 30 to 60 percent with dispensers that more accurately measure and dilute the cleaning products for optimum effectiveness.[14]

Building owners need to view the building manager and staff as vital participants in environmentally sound and cost-effective operations. Building managers, charged with the efficient operation and maintenance of multi-million-dollar assets, have experience in all areas of operations and maintenance over the life of a building. Once a building is operational, training of management and maintenance staff—including education on effective green building measures such as building energy management systems, new cleaning products, and new building codes and standards—can help them to maintain the building in a resource-efficient and economically favorable manner.

Insurance and Liability

The past decades' conventional office design, construction, and operational practices have decreased the quality of the indoor office environment, resulting in new health concerns and associated economic costs and liability. The introduction of a multitude of new contaminant pollution sources into the workplace, combined with tighter building construction, has intensified air-quality problems. For example, poor indoor air quality can result from such factors as faulty air-conditioning systems, occupant-related pollutants, construction materials that emit high levels of volatile organic compounds, and poor maintenance practices. The U.S. EPA ranks indoor air pollution among the top five environmental risks to public health. Unhealthy indoor air is found in up to 30 percent of new and renovated buildings.[15]

Sick Building Syndrome (SBS) and Building Related Illness (BRI) have become more common in the workplace, increasing building owner and employer costs due to sickness, absenteeism, and increased liability claims. It has been estimated that SBS and BRI cost roughly $60 billion each year in medical expenses and lost worker productivity in the United States.[16]

Legal actions related to Sick Building Syndrome and other building-related problems have increased. These actions against building designers, owners, or employers may be initiated by occupants who have short- or long-term problems, ranging from headaches and burning eyes to more serious ailments. Initial economic impact may come in the forms of higher health insurance premiums, increased workers' compensation claims, and decreased productivity. Expensive remediation projects and environmental cleanups may follow, and building owners may try to recover losses from the original project contractors and architects through litigation.

CASE IN LIABILITY

One liability case, settled in 1995, involved a suit between Polk County, Florida, and the insurance company of the builders of the county's eight-year-old courthouse. The court awarded the county nearly $26 million to correct design and construction flaws that resulted in a high level of mold growth and caused occupant illnesses.

In DuPage County, Illinois, the court found the county responsible for health-related complaints at its new courthouse due to improper operations and maintenance procedures. At another courthouse complex, in Martin County, Florida, a $10 million renovation to mitigate the growth of health-threatening fungi responsible for previous building evacuations has been unsuccessful.[17]

By ensuring better indoor air quality, building owners, employers, and design professionals can lower their risk of future litigation by building occupants. Professional liability insurance companies have indicated a willingness to offer design professionals lower insurance premiums for higher operating-procedure standards that lead to improved indoor air quality.[18] Some national architectural firms are attempting to rate building products according to the levels of volatile organic compounds they emit after installation, and to educate building owners and managers about healthier product choices.

Occupant Health and Productivity

The purpose of a building is not only to provide shelter for its occupants, but also to provide an environment conducive to high performance of all intended occupant activities. Recent studies have shown that buildings with good overall environmental quality, including effective ventilation, natural or proper levels of lighting, indoor air quality, and good acoustics, can increase worker productivity by six to 16 percent.[19]

An organization's most significant financial commitment is usually to its employees. Many employers spend at least as much on salary-related expenditures as they do on constructing an entire company building. In many organizations, salaries and associated benefits consume the majority of the annual operating budget.[20] For example, based on the sample calculations in *Figure 2,* a typical employer could spend $233 per square foot annually for an employee. Building construction costs generally fall below this level, often by 50 percent. In addition, annual employee salary-related expenditures, using the numbers in *Figure 2,* are approximately 130 times greater than energy costs. A productivity increase of six percent equates to savings to the employer of $14 per square foot—eight times the cost of the building's annual energy bill.

Given this information, an employer can decide to maximize the performance and efficiency of personnel resources through assessment of, and improvement to, the indoor environmental quality of its building. The following account of a recent renovation project illustrates this approach.

RENO POST OFFICE

Reno, Nevada

In the renovation of a U.S. Post Office in Reno, Nevada, the structure, a modern warehouse with high ceilings, was redesigned with a new ceiling sloped to enhance indirect lighting and improve acoustics. The original, harsh direct downlighting was replaced with softer, more efficient, and longer-lasting lamps. The total renovation cost was $300,000. The associated annual energy savings totaled $22,400, and the projected maintenance savings, $30,000, for a combined savings of $52,400, which equated to a six-year payback. What the Post Office also discovered was that the renovation measures, which resulted in better lighting and acoustics, led to a productivity increase of more than six percent. Productivity savings alone were worth $400,000 annually, returning the entire renovation cost within the first year.[21]

Both building owners and building tenant/employers can benefit in other ways by improving indoor environmental quality. For owners, these improvements can result in higher property values (see "Building Value" section below), longer tenant occupancy and lease renewals, reduced insurance and operating costs, reduced liability risks, extended equipment life, and good publicity. For tenants, benefits include reduced absenteeism and better employee morale, reduced insurance and operating costs, reduced liability risks, and community recognition.[22]

If the building owner is also the employer, an organization can offset initial construction design and systems costs with the reduction of long-term organizational and operational expenses over the building's life cycle.

PRODUCTIVITY SAVINGS

for a Typical 100,000 sq. ft. Office Building

Utility Costs	
Annual Utility Cost per Square Foot	$1.80
Total Annual Utility Cost	$180,000
Personnel Costs	
Average Employee Salary + Benefits	$35,000
Average Employee Space per Square Foot	150
Estimated Number of Building Occupants	667
Annual Average Personnel Cost per Square Foot	$233
Total Annual Building Personnel Cost	$23,345,000
Savings	
Value of 6% Productivity Increase per Square Foot	$14
Ratio of Productivity Increase to Energy Cost	8 times

Source: Example from David Gottfried, "Economics of Green Buildings," Presentation to OG&E Electric Services, October 1995.

Figure 2

Building Value

Green buildings' high efficiency and performance can result in higher property values and potentially lower lenders' credit risk. Lower operating costs associated with more efficient systems can lead to higher building net income.

In *Figure 3* the value of a 100,000-square-foot office building increases by over $1 million through implementation of green building measures. These measures, associated with energy, water, waste, and labor, result in annual operating savings of $101,400. The increased building value is calculated by using a fairly conservative building market capitalization rate—a formula used by building appraisers, brokers, and lenders to calculate a building's value—of 10 percent on the savings. As illustrated in *Figure 3,* a building's value is derived by dividing its net operating income, or savings, by the market capitalization rate.

In addition to increasing a building's net operating income or value, green building measures may allow building owners to charge higher rents or achieve higher rates of building occupancy, if tenants view green properties as more desirable. Currently, voluntary building rating programs are under development for commercial buildings in the United States (see Chapter 25, "The Future of Green Building"). As these programs are introduced into the marketplace and gain the acceptance of building owners and tenants, they could impact the value of properties. Prospective tenants will be able to rate buildings based on such measurable features as natural daylight, better indoor air quality, and lower energy, water, and waste costs. If enough buildings are rated for environmental performance, those that perform better will start to realize market advantages.

Figure 3

INCREASED VALUATION

of a Typical 100,000 sq. ft. Office Building

1. Energy Retrofit Savings (50%)	$90,000
2. Water Savings (30%)	$4,400
3. Waste + Labor Savings (e.g., chute system)	$7,000
4. Total Annual Operating Savings	$101,400
5. Market Capitalization Rate	10%
6. Increase in Building Value (divide 4 by 5)	$1,014,000

Source: Information based on discussion with CB Commercial, a commercial real estate brokerage firm.

MT. AIRY PUBLIC LIBRARY

Mt. Airy, North Carolina

Mt. Airy, North Carolina, has incorporated extensive daylighting into the passive solar design of its 13,000-square-foot public library, built in 1982. This design strategy helps to meet the town commissioners' goal of a 70 percent reduction in annual electricity consumption. The daylighting strategy admits glare-free, diffuse light to all corners of the library without damaging the books with direct illumination. It is combined with efficient lighting systems, where needed, and other features that conserve energy used for heating and cooling. Lighting energy use, usually a large portion of a library's total energy consumption, is now only one-eighth of the entire building's total energy usage. Not surprisingly, utility bills have been very low. The building's attractive design has drawn positive reactions from employees and visitors, and made the facility a town centerpiece. Visitation rates at the library are more than twice what was originally anticipated, and operating hours have been extended to accommodate users of this multipurpose cultural center.[23]

Local Economic Development Opportunities

Promotion and implementation of green building practices within a community can generate new economic development opportunities. These opportunities can take a variety of forms, including new business development to meet the demand for green products and services; resource-efficiency improvement programs that enable existing businesses to lower operating costs; development of environmentally oriented business districts; and job training related to new green businesses and products.

In Austin, Texas, the long-term existence of the city's Green Builder Program has contributed to the growth of green building trades, including, for example, companies to meet the demand for rainwater-harvesting systems and services. The city has also begun working with a non-profit organization to offer at-risk youths an opportunity to learn job skills while they build affordable green homes. On a national level, the EPA cites the potential creation of over 200,000 jobs through aggressive implementation of its Green Lights retrofit program.

In other communities, entrepreneurs have developed businesses to recycle usable building components. In Baltimore, Maryland, for example, one non-profit company redistributes over $1 million worth of building supplies a year. These materials, diverted from landfills and received as donations from construction-related businesses, are provided to non-profit organizations and low-income clients at about one-third of their retail price. A Berkeley, California, for-profit business has salvaged furniture, household goods, office equipment, and building materials for resale for over a decade. These materials are retrieved from the waste stream or donated by local residents, businesses, and construction sites. The company handles about 5,000 tons of material each year.

In Denver, Colorado, plans are underway to reuse Stapleton International Airport as a center for environmentally oriented businesses, as well as a site for training opportunities in environmental fields. San Jose, California, through its Green Industry Program, has created two Green Industry Districts, which will provide incentives such as loans and tax benefits to attract more recycled-product manufacturers and green industries. And in Portland, Oregon, the city's Businesses for an Environmentally Sustainable Tomorrow (BEST) program uses incentives and education to encourage businesses to realize the economic benefits of energy efficiency, water conservation, waste reduction or recycling, and efficient transportation practices.

Local governments facing rising building and operational costs may find that adoption of green building practices can slash public expenditures for energy, water, and waste processing. In Montgomery County, Maryland, for example, carefully crafted Energy Design Guidelines aim to reduce energy consumption in new government buildings by

40 to 50 percent, without increases in initial construction costs. These savings can help to balance budgets and offset budgetary cuts in critical areas such as education and public safety.

These examples are only a snapshot of the growing appeal of sustainable development. Local governments and businesses across the country are starting to find that green business practices, as well as the use of green building products, can result in short- and long-term economic and environmental advantages for their communities and the wider global marketplace.

NOTES

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CHAPTER 2

Selecting Environmentally and Economically Balanced Building Materials

Authors
Barbara C. Lippiatt and Gregory A. Norris

Introduction

Buildings significantly alter the environment. According to Worldwatch Institute[1], building construction consumes 40 percent of the raw stone, gravel, and sand used globally each year, and 25 percent of the virgin wood. Buildings also account for 40 percent of the energy and 16 percent of the water used annually worldwide. In the United States, about as much construction and demolition waste is produced as municipal garbage. Finally, unhealthy indoor air is found in 30 percent of new and renovated buildings worldwide.

Negative environmental impacts flow from these activities. For example, raw materials extraction can lead to resource depletion and biological diversity losses. Building materials manufacture and transport consumes energy, which generates emissions linked to global warming and acid rain. Landfill problems, such as leaching of heavy metals, may arise from waste generation. All these activities can lead to air and water pollution. Unhealthy indoor air may cause increased morbidity and mortality.

Selecting environmentally preferable building materials is one way to improve a building's environmental performance. To be practical, however, environmental performance must be balanced against economic performance. Even the most environmentally conscious building designer or building materials manufacturer will ultimately want to weigh environmental benefits against economic costs. They want to identify building materials that improve environmental performance with little or no increase in cost.

The National Institute of Standards and Technology (NIST) is teamed with the U.S. Environmental Protection Agency's (EPA) National Risk Management Research Laboratory, Air Pollution Prevention Control Division, to develop by 1997 a standardized methodology and publicly available database for balancing the environmental and economic performance of building materials. EPA is developing a database of environmental performance data, and with EPA support, NIST is developing the methodology and implementing it in decision-support software for building designers and materials manufacturers. NIST is adding economic performance data to the database. The decision-support software will access the database of environmental and economic performance data. The combined software and database product will be known as BEES (Building for Environmental and Economic Sustainability).

Measuring Environmental Performance

Environmental performance is measured using an evolving, multidisciplinary tool known as life-cycle assessment (LCA). LCA is a “cradle-to-grave” systems approach for understanding the environmental consequences of technology choices. The concept is based on the belief that all stages in the life of a material generate environmental impacts and must therefore be analyzed, including raw materials extraction and processing, intermediate materials manufacture, material manufacture, installation, operation and maintenance, and ultimately recycling and waste management. An analysis that excludes any of these stages is limited because it ignores the full range of upstream and downstream impacts of stage-specific processes.

The general LCA methodology is as follows. LCA begins with goal identification and scoping (defining boundaries). What is the purpose of the LCA? What decision is the LCA meant to support? Where are environmental impact boundaries to be drawn—secondary environmental impacts, tertiary impacts? Do we include all environmental impacts, or only a pre-defined subset of impacts?

After goal identification and scoping, the four-step LCA analytic procedure begins. The inventory analysis step identifies and quantifies the environmental inputs and outputs associated with a material over its entire life cycle. Environmental inputs include water, energy, land, and other resources; outputs include releases to air, land, and water. The impact assessment step characterizes these inputs and outputs in relation to a comprehensive set of environmental impacts. For example, the impact assessment step might relate carbon dioxide (CO_2) emissions to global warming.

The third step, impact valuation, synthesizes the environmental impacts by combining them with stakeholder values. For example, assume there are only two environmental impacts, stratospheric ozone depletion and global warming. The impact valuation step might combine quantitative measures of ozone depletion and global warming into a single measure of overall environmental impact by normalizing the quantitative measures and weighting each impact by its relative importance. (Note that while LCA practitioners generally agree on the nature of impact valuation, not all treat it as a separate LCA step. Some include it as part of impact assessment, while others include it as part of improvement assessment.)

The improvement assessment step identifies and evaluates opportunities for making changes in the product life cycle which improve its cradle-to-grave environmental performance. Depending on the goal of the LCA, the improvement step may be omitted. For example, if the goal of the LCA is to select the most environmentally preferable from among three building materials, the improvement step is unnecessary.

NIST is applying the LCA methodology to building materials. In so doing, NIST is adding explicit guidance to the LCA impact assessment and valuation steps. The guidance consists of the following three principles:

1) Avoid false precision.

There is some uncertainty associated with the data used at each LCA step, which influences the precision of the final results. It is important to document the precision with which conclusions can be drawn about the environmental performance of building materials. For example, if at the inventory analysis step, sulfur dioxide emissions are estimated within a range of plus or minus five percent, then an overall environmental impact score cannot be derived with 100 percent certainty. The NIST methodology avoids false precision by collecting uncertainty data at each LCA step and propagating (accounting for) uncertainty throughout the LCA. The final environmental impact score will thus be bounded by an uncertainty range.

2) Address scale of impact.

The LCA impact assessment step characterizes the inventory items in relation to environmental impacts. This step will also relate the flows (to or from the environment) occurring during the life cycle of a building material to the total flows occurring at scales such as the U.S. as a whole. For example, the NIST methodology will relate the chlorofluorocarbon (CFC) emissions associated with vinyl siding's life cycle to the total CFC emissions from the U.S., and will use this information in deriving the final environmental performance score for vinyl siding.

3) Minimize assumptions and uncertainty.

Each LCA step introduces additional assumptions and uncertainty. The NIST methodology minimizes these by checking data after each LCA step to see if one building material alternative shows dominance or near dominance. Dominance is shown when one alternative performs best on all criteria.

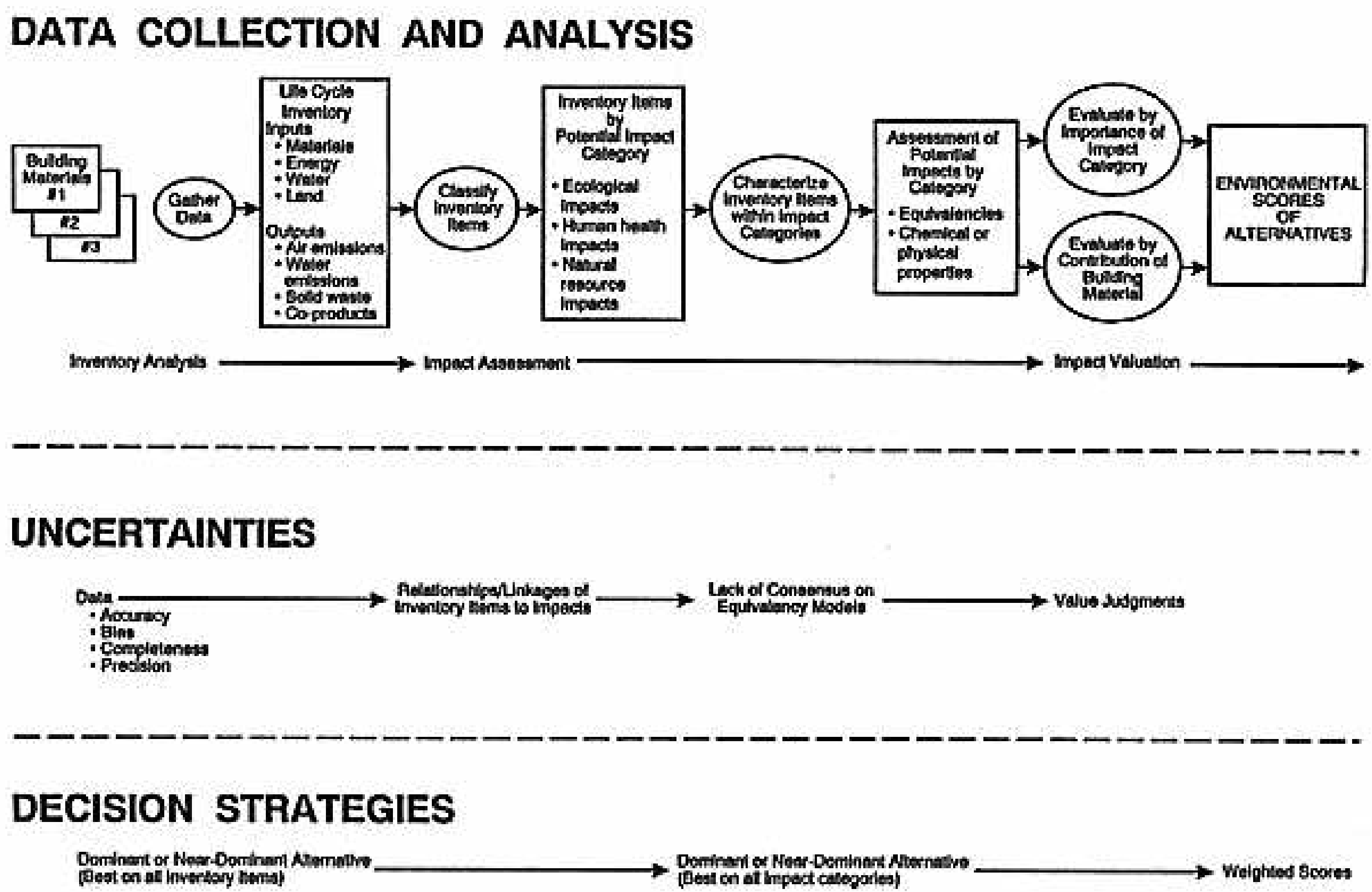
These three principles are implemented in the NIST LCA methodology for measuring the environmental performance of building materials, depicted in *Figure 1.* The goal is to assist material selection decisions by assigning relative environmental scores to a set of building material alternatives. To the extent possible, all environmental impacts will be included. The first step is inventory analysis. Environmental input and output data will be gathered for all building material alternatives on a per functional-unit basis, complete with uncertainty ranges. In the (unlikely) event that one alternative performs best or nearly best with respect to all inventory items, that alternative will be flagged as the dominant or nearly dominant alternative. Note that large uncertainty ranges do not preclude dominance as long as there is no overlap among alternatives.

The next step is impact assessment. First, inventory items are classified by impact category. Then inventory items are characterized within impact categories. For many of the impact categories, published "equivalency factors" are available to normalize the inventory items in terms of strength of contribution[2]. For example, equivalency factors have been developed for each of the major "greenhouse gases." These factors indicate the relative "global warming potential" of each greenhouse gas, taking into account the different strengths of radiative forcing as well as differences in atmospheric lifetimes[3]. The global warming potential equivalency factors will be used to convert all greenhouse gas inventory data (reported as tons of a given greenhouse gas emitted per functional unit of a particular building material—for example, tons emitted per square meter (square yard) of carpet) into "CO_2-equivalents" (reported as tons of CO_2 per functional unit). Following this conversion, all inventory data in the "global warming" impact category can be summed to arrive at a scalar total (tons of CO_2-equivalents) to allow direct numerical comparison among building materials.

Equivalency factors are subject to some uncertainty based on the strength of the underlying science. The NIST methodology will attempt to reflect the literature's assessment of this uncertainty by using intervals (ranges) rather than scalar numbers for the equivalency factors. Arithmetic operations on intervals are well-established[4] and will be used in the NIST methodology as a basic means for propagating uncertainty throughout the LCA.

For some impact categories and inventory items, equivalency factors have not been published, so there is no clear basis for normalizing and summing the inventory data within an impact category. In such instances the NIST methodology will allow the user to check for dominance or near dominance of one material alternative over the others. A flexible heuristic method will be available for assigning a summary score to the dominant and

MEASURING THE ENVIRONMENTAL PERFORMANCE OF BUILDING MATERIALS



Source: The Scientific Consulting Group, Inc.

Figure 1

non-dominant alternatives within all such impact categories, but the software will also flag these impact category results to indicate that the relative scores are not based on peer-reviewed, scientific methods for normalizing the inventory data in terms of strength of impact within the impact categories.

The third step in the LCA is impact valuation. At this step, impact assessment results will be normalized and synthesized into an overall environmental score for each material alternative. Multiattribute decision analysis (MADA) techniques are useful here[5]. MADA techniques apply to problems where the decision-maker is choosing or ranking a finite number of alternatives (building materials) which differ by two or more relevant attributes (environmental impacts). The attributes in a MADA problem will generally not all be measurable in the same units, and some may be either impractical, impossible, or too costly to measure at all (as is the case with some environmental impacts). Most MADA methods require the decision-maker to assign different levels of importance to the different attributes of the problem.

MADA techniques will be used to arrive at overall, relative environmental scores for building material alternatives. The NIST/EPA team plans to conduct workshops in 1996 to collect sets of MADA importance weights for environmental impacts from several stakeholder perspectives (e.g., policymaker, environmentalist, and building industry perspectives), with input from environmental scientists and others. The decision maker may then select that set of importance weights most appropriate for the decision at hand, and may also test the sensitivity of the environmental scores to the different stakeholder perspectives.

The LCA is complete after the impact valuation step. Impact valuation yields environmental scores, which are the goal of this LCA application, so the improvement assessment step is unnecessary.

Measuring Economic Performance

Measuring the economic performance of building materials is more straightforward than measuring environmental performance. Standardized methodologies and quantitative, published data are readily available.

The American Society for Testing and Materials (ASTM) Subcommittee E06.81 on Building Economics has published a compilation of standards for evaluating the economic performance of investments in buildings[6]. The single standard most appropriate for evaluating the economic performance of building materials for subsequent comparison with environmental performance is ASTM E 917-93, *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems*[7]. The life-cycle-cost (LCC) method sums over a given study period the costs of an investment. The sum is expressed in either present value or annual value terms. Alternative building materials for a given functional requirement, say flooring, can thus be compared on the basis of their LCCs to determine which is the least-cost means of providing flooring over that study period.

The LCC method includes the costs over a given study period of initial investment (less resale or salvage value), replacements, operations, maintenance and repair, and disposal. It is essential to use the same study period for each alternative whose LCCs are to be compared, even if they have different useful lives. The appropriate study period varies according to the stakeholder perspective. For example, a homeowner would select a study period based on the length of time he or she expects to live in the house, whereas a long-term owner/occupant of an office building might select a study period based on the life of the building.

It is important to distinguish between the life cycles underlying the LCA method (used to measure environmental performance), and the LCC method (used to measure economic performance). LCA uses an environmental life-cycle concept, whereas LCC uses a building life-cycle concept. These are different. The environmental life cycle of a building material begins with raw materials extraction and ends with recycling, reuse, or disposal of the material. The building life cycle of a building material begins with its installation in the building and lasts for the duration of the LCC study period, which is determined in part by the useful life of the material and in part by the time horizon of the investor. While there is overlap between these two life cycles once the material is installed in the building, it is important not to confuse the two. The reason why LCC uses a building life cycle rather than an environmental life cycle is because out-of-pocket costs to the investor are borne over this time frame. It is these costs to the investor upon which financial decisions are made.

The LCC for a building material is computed by discounting all costs occurring over the study period to the present and then summing. The discount rate converts future costs to their equivalent present values and accounts for the time value of money. Discount rate values to be used in federal projects are legislated by the Office of Management and Budget; these values apply to analyses of private-sector projects as well.

BALANCING ENVIRONMENTAL AND ECONOMIC PERFORMANCE

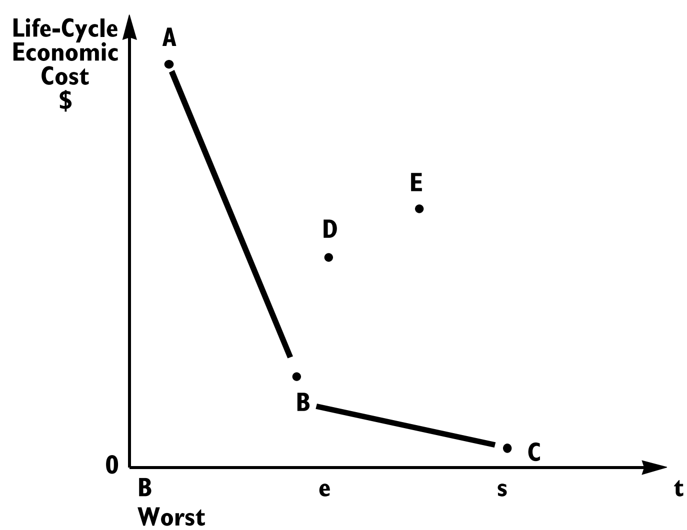


Figure 2

Balancing Environmental and Economic Performance

Figure 2 displays how environmental and economic performance are balanced. Suppose a building designer is choosing from among five alternative flooring materials and that each point in *Figure 2* represents one material's environmental/economic performance balance. The designer will first rule out Alternatives D and E because they are dominated by at least one other alternative; that is, they perform worse than another alternative (Alternative B) with respect to both the environment and economics. Of the remaining alternatives, Alternative A costs the most, but offers the best environmental performance. Alternative C offers the best economic performance and the worst environmental performance. Alternative B improves environmental performance (relative to C) at little increase in cost. The designer can now make an informed decision. He or she will select from among Alternatives A, B, and C that which best reflects the relative importance he or she gives to environmental versus economic performance.

Decision-Support Software Features

Decision-support software is being developed by NIST to implement the methodology described above for balancing the environmental and economic performance of building materials. The software will use as input the database of environmental and economic performance data. Together the software and database are known as BEES. BEES will be available over the Internet, which will offer instantaneous access to the tool as well as instant dissemination of data refinements. Data refinements are expected over time as the state of the art of environmental assessment advances, new building materials arrive on the scene, and the costs of building materials change.

BEES will accommodate different levels of user expertise. It will include built-in, "default" data so that users unfamiliar with LCA may readily make and defend building material selections. Note, however, that BEES will not include default values for the relative importance of environmental and economic performance. Rather, BEES will display, as in *Figure 2,* the environmental/economic tradeoffs offered by the decision alternatives. It will remain up to the user to select the alternative that best reflects his or her viewpoint.

The more experienced user will be able to customize the default data. For example, a materials manufacturer will be able to enter proprietary data on its products. Other data, such as relative importance weights for environmental impacts and the discount rate for LCC computation, will also be editable. These users will thus be able to do "what if" analyses to examine how changing the data affects the environmental/economic performance balance.

Finally, BEES will follow the data transparency principle of the LCA methodology by documenting data used and assumptions made at every LCA stage.

Summary

The building community is making decisions today that have environmental and economic consequences. Its decisions are plagued by incomplete and uncertain data as well as the lack of a standardized methodology for evaluating the data. The NIST/EPA team seeks to support these decisions by gathering environmental and economic performance data and by structuring and computerizing the decision-making process. The resulting BEES tool will be publicly available over the Internet.

NOTES

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7 American Society for Testing and Materials, *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems*, ASTM Designation E 917-93 (Philadelphia, March 1993).

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SELECTING ENVIRONMENTALLY AND ECONOMICALLY BALANCED BUILDING MATERIALS. Barbara C. Lippiatt, Economist. Gregory A. Norris, Environmental Engineer. Office of Applied Economics, Building and Fire Research Laboratory, National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899-0001

PART II

Pre-Design Issues

Introduction

The conventional process for a construction project involves the initial project conceptualization, followed by pre-design, design, bid, construction, and occupancy. An environmentally responsive design process adds the elements of integrated building design, design and construction team collaboration, and the development of environmental design guidelines. These new elements must be incorporated into the project from the very beginning and carried throughout the project phases to the final occupancy of the building.

Conventional buildings often fail to consider the interrelationship among building siting, design elements, energy and resource constraints, building systems, and building function. Green buildings, through an integrated design approach, take into consideration the effect these factors have on one another. Climate and building orientation, design factors such as daylighting opportunities, and building envelope and system choices, as well as economic guidelines and occupant activities, are all factors that need to be considered in an integrated approach.

A multidisciplinary design and construction team can develop a building's functional and operational design to meet environmental and financial goals. The multidisciplinary approach allows all team members—site planners, landscape architects, architects, engineers, contractors, interior designers, lighting designers, building owners, tenants, management companies, utilities, builders, and others—to share specialized expertise and coordinate their individual design efforts to achieve a well-functioning, integrated building.

Development of green building guidelines sets both general goals for the project and specific parameters for building design, products, systems, and siting. These guidelines help to shape the project as it moves through the project phases.

Chapters 3 and 4 provide information on the pre-design phase of the construction process—the critical stage that shapes the eventual design and development of a sustainable building.

CHAPTER 3

Pre-Design

Authors
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and William Reed

★ SIGNIFICANCE

An environmentally responsive design process, as outlined in *Figure 1,* follows the conventional process, with additional consideration given to sustainable design, materials, and systems. Activities which should occur in pre-design are discussed in this chapter; other parts of the manual discuss the activities that occur in the design, bid, construction, and occupancy phases of a building's development.

Because the pre-design stage is the first step in the building process, incorporating green building practices into the project at this juncture is critical. Decisions made during pre-design not only set the project direction, but also must prove cost-effective over the life of the project. Charting the course of the project at the very beginning by establishing green project goals, defining the process to achieve those goals, and developing a clear understanding of the expected results is vitally important. A clearly developed project framework guides the decision-making process throughout the project, incorporating issues related to site selection and design, the building design and its systems, the construction process, and building operations and maintenance.

Integrated building design is a cornerstone for developing sustainable buildings, which are efficiently combined systems of coordinated and environmentally sound products, systems, and design elements. Simply adding or overlaying systems will not result in optimal performance or cost savings. Rather, building designers can obtain the most effective results by designing various building systems and components as interdependent parts of the entire structure. This conceptual framework starts at the pre-design stage and is carried throughout design and construction to building completion and operation.

This integrated approach is well-illustrated in passive solar design strategies that combine siting, architectural, mechanical, and electrical features in a systemic manner that results in improved building function and increased occupant satisfaction. Incorporating increased daylighting into a building design, for example, will affect

ENVIRONMENTALLY RESPONSIVE DESIGN PROCESS

PRE-DESIGN
Develop Green Vision
Establish Project Goals and Green Design Criteria
Set Priorities
Develop Building Program
Establish Budget
Assemble Green Team
Develop Partnering Strategies
Develop Project Schedule
Review Laws and Standards
Conduct Research
Select Site

DESIGN
Schematic Design
Confirm Green Design Criteria
Develop Green Solutions
Test Green Solutions
Select Green Solutions
Check Cost

Design Development
Refine Green Solutions
Develop, Test, Select Green Systems
Check Cost

Construction Documents
Document Green Materials and Systems
Check Cost

BID
Clarify Green Solutions
Establish Cost
Sign Contract

CONSTRUCTION
Review Substitutions and Submittals for Green Products
Review Materials Test Data
Build Project
Commission the Systems
- Testing
- Operations and Maintenance Manuals
- Training

OCCUPANCY
Re-Commission the Systems
Perform Maintenance
Conduct Post-Occupancy Evaluation

Figure 1

PROJECT TEAM

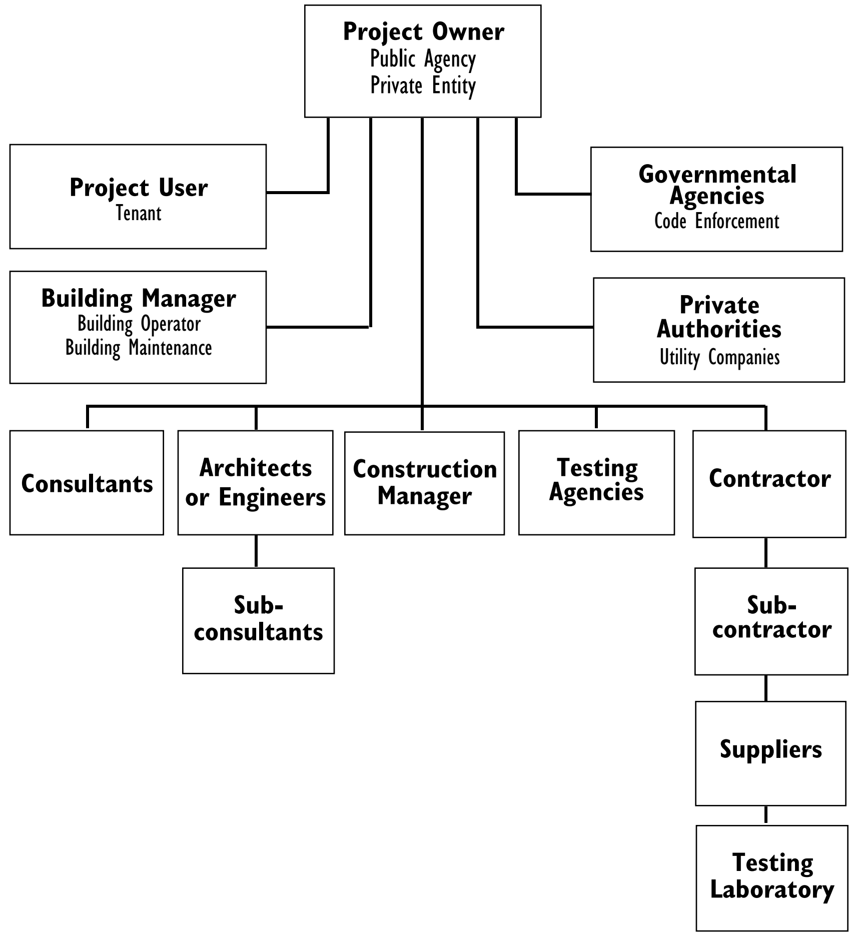


Figure 2

many other factors in the building. This strategy, which takes into account the building's orientation, as well as glazing choices and location, will permit reduction of artificial lighting. The resulting reductions in electricity use and internal heat loads will allow the downsizing of air-conditioning systems. As a result, overall energy usage and energy costs in the building are reduced, and the improved air quality and lighting conditions can result in increased productivity and health of occupants.

A team approach to design and construction is another important aspect of sustainable building that is established during the pre-design phase. This approach assures the development and implementation of an integrated building design. As illustrated in *Figure 2,* the team can comprise a wide variety of members—including the building owner, tenants, site planners, architects, engineers, contractors, local government agencies, management staff, and utility company representatives. For this approach to be successful, all parties on the design team must commit themselves to the sustainable goals of the project. Rather than working in isolation in their own areas of expertise, team members use a multidisciplinary approach in which the interrelated impacts of design, systems, and materials are recognized. Part of this process may involve education of team members to recognize the benefits of environmentally sound design or materials and to look beyond their own disciplines to conceptualize the integrated systems.

Environmental design guidelines, also an important component of green building development, direct the activities of the design team from the pre-design stage through all subsequent stages of the project. These guidelines may already exist as part of a building owner's operating policies, or may be developed for a particular construction project. If developed for a specific project, they can articulate principles that clarify the goals of the design team and rally support for the sustainable building concept from key parties such as the building owner, public officials, financiers, and the general community. The guidelines may initially state an overriding philosophy or vision, develop more defined goals in each area, and then relate specific objectives and priorities to a specific project. *Figure 3* outlines some of the green building issues—including those related to energy efficiency and renewable energy, direct and indirect environmental impact, indoor environmental quality, resource conservation and recycling, and community issues—to be considered when developing project guidelines.

These aspects of sustainable design, along with other activities that occur in the pre-design phase, including programming, budget analysis, and site selection, set the stage for successful construction of a green building.

☞ SUGGESTED PRACTICES AND CHECKLIST

Environmental Design Guidelines

❑ **Establish a vision statement that embraces sustainable principles and an integrated design approach.**
The project team, along with the client, should clearly define and articulate a vision statement that will support and enforce sustainable goals throughout the project.

❑ **Establish the project's green building goals, developed from the vision statement.**
The project goals should emanate from the needs and values of the client. The goals need not be specific, but should be broad statements of environmentally based ideas that can be further developed and integrated by the project team. They may include such issues as energy efficiency, indoor and outdoor environmental quality, waste minimization, and general princi-

TYPICAL GREEN BUILDING GUIDELINE ISSUES

■ **Energy efficiency and renewable energy**
- Building orientation to take advantage of solar access, shading, and natural lighting
- Effects of micro-climate on building
- Thermal efficiency of building envelope and fenestration
- Properly sized and efficient heating, ventilating, and air-conditioning (HVAC) system
- Alternative energy sources
- Minimization of electric loads from lighting, appliances, and equipment
- Utility incentives to offset costs

■ **Direct and indirect environmental impact**
- Integrity of site and vegetation during construction
- Use of integrated pest management
- Use of native plants for landscaping
- Minimization of disturbance to the watershed and additional non-point-source pollution
- Effect of materials choice on resource depletion and air and water pollution
- Use of indigenous building materials
- Amount of energy used to produce building materials

■ **Resource conservation and recycling**
- Use of recyclable products and those with recycled material content
- Reuse of building components, equipment, and furnishings
- Minimization of construction waste and demolition debris through reuse and recycling
- Easy access to recycling facilities for building occupants
- Minimization of sanitary waste through reuse of graywater and water-saving devices
- Use of rainwater for irrigation
- Water conservation in building operations
- Use of alternative wastewater treatment methods

■ **Indoor environmental quality**
- Volatile organic compound content of building materials
- Minimization of opportunity for microbial growth
- Adequate fresh air supply
- Chemical content and volatility of maintenance and cleaning materials
- Minimization of business-machine and occupant pollution sources
- Adequate acoustic control
- Access to daylight and public amenities

■ **Community issues**
- Access to site by mass transit and pedestrian or bicycle paths
- Attention to culture and history of community
- Climatic characteristics as they affect design of building or building materials
- Local incentives, policies, regulations that promote green design
- Infrastructure in community to handle demolition-waste recycling
- Regional availability of environmental products and expertise

Figure 3

BERKELEY UNIFIED SCHOOL DISTRICT

Berkeley, California

In 1994, the Berkeley Unified School District in Berkeley, California, enacted environmental policies that established green building goals. The school district's Materials/Indoor Air Quality Policy states:

It is the intent of the Berkeley Unified School District Facilities Program to minimize building occupants' exposure to uncomfortable and potentially harmful interior environments. This effort starts with design and construction of new and renovated facilities, and continues through the life of the facility with maintenance practices.[1]

The Energy Design Standard Policy states:

The building energy design standards policy of the Berkeley Unified School District seeks to achieve three broad goals. These are:

1) To provide a high quality indoor environment with respect to thermal comfort, lighting, and ventilation, for student, faculty, and staff.
2) To reduce energy consumption and maintenance costs of the District on an ongoing basis.
3) To improve energy conservation awareness and education of students, faculty, and staff.[2]

Both policies provide additional specific green design criteria. The Materials/Indoor Air Quality Policy deals with site layout and landscape, building materials, finishes and furnishings, building systems, and construction practices. The Energy Design Standard Policy establishes specific energy performance criteria and objectives as follows:

1) Improve district-wide energy use/square foot by 40 percent before the year 2000.
2) New and substantially renovated buildings shall exceed State Energy Code (Title 24) standards by a minimum of 35 percent.
3) Buildings which are retrofitted for energy conservation shall, as a minimum, meet the applicable provisions of the State Energy Code even where not required by law.[3]

ples of sustainability. In some instances, clients, such as governmental agencies and private organizations, may already have an environmental policy that informs and supports the project goals.

❑ **Establish green design criteria.**
The design criteria, which are more specific than the goals, should begin to clarify the most important and relevant aspects of the project. For example, they may include a certain level of improvement in energy efficiency over conventional usage, indicate a percentage of renewable energy strategies and equipment to be used in the project, stipulate requirements for sensitive site design, provide guidelines for indoor environmental quality, and indicate levels of resource conservation and recycling. In addition, they may indicate that life-cycle assessment be used to analyze the direct and indirect environmental impacts of building-material selection, and that broad community-related environmental issues, such as preservation of existing green spaces or reuse of historic structures, be addressed.

❑ **Set priorities for the project design criteria.**

– Prioritize design options based on environmental guidelines and project constraints. Priorities should flow from the vision statement, the goals, and the design criteria, and should support of the project's environmental policy. The design team, may, for example, decide that energy efficiency, indoor air quality, or several combined criteria are the main priorities for a project. Design criteria need to be prioritized in the context of the project's budget and scheduling constraints. The realities of these constraints may allow some design criteria to be included, but exclude others deemed less important by the team, or less achievable with current technology. It is also possible that the project design could be flexible enough to allow incorporation of additional criteria at a later, more practical date. Setting priorities will provide the critical direction needed by the design team in making project decisions related to design, products, and systems.
– Seek to incorporate additional green measures through this process. Prioritizing criteria also may allow the design team to justify additional green measures for the project, by using the projected financial savings of one priority, such as energy conservation, to balance the costs of other green measures. Green building materials, for example, though environmentally significant, may not have the same direct financial payback as energy savings and may have higher up front costs than conventional products. Total project costs can remain reasonable, however, if savings from the energy-efficiency measures can offset the costs of other features.

Building Program

❑ **Develop a building program detailing the project's green building requirements.**
A building program develops a clear statement of the building owner's or client's expectations for the building—and the function of the entire building and its various rooms and related structures—within the budget, schedule, and physical constraints of

the project. The building program should include both a general and a room-by-room description of the project. The project's environmental vision and goals and its design criteria and priorities should also be included in the building program. More specifically, the program should state include the criteria for energy efficiency and renewable energy, indoor air quality, materials selection, waste and demolition recycling, and any other clearly defined green requirements. In addition, the building program can take into consideration the broader community context of the building, and strive to reflect local design as influenced by cultural and climatic factors, as well as consider ease of pedestrian and mass-transit access.

Project Budget

❑ **Develop the project and building construction budget.**
Determine relevant design fees and construction costs, including those for all green building measures, for the project.

- Institute life-cycle-cost analysis for the project's green design and construction measures (see Chapter 1, "The Economics of Green Buildings," and Chapter 2, "Selecting Environmentally and Economically Balanced Building Materials").
- Seek the advice of a design professional and cost consultant with green building experience.
- Because many green and sustainable building practices are relatively new to the industry, allocate adequate contingencies for additional research and analysis of options.

Design Team Selection

❑ **Create a design and construction team that utilizes the whole-building integrated design approach.**
Select team members who are committed to the project vision. The project team should include representatives from all aspects of the building project, from site planning to construction to building operations. Team members should be willing to think beyond their own specialty and understand that the building is a system of interrelated processes and products. *Figure 2* illustrates the basic members of a project team.

❑ **Develop a Statement of Work (SOW) and a Request for Qualifications (RFQ), in preparation for hiring appropriate design professionals.**
The SOW includes the project criteria, including green building issues. The RFQ identifies the skills required for participation in the project, including green building expertise.

❑ **Select a team leader and encourage communication and integration among team members.**
The team leader's role is to integrate the design team process. The leader must have good communication skills and be well-grounded in the principles of sustainable design and construction. Additionally, the building owner, working with the team leader, can be a strong resource by supporting and emphasizing the importance of green building goals to the project.

❑ **Determine the most appropriate method for contractor selection, given the project goals.**
This includes determining the construction contract type, such as public bid, invited bid, negotiated contract, and design-build. Green building goals may be more easily achieved with negotiated contracts than with bids, as the contractor can be carefully selected and hired at an earlier stage and can be actively involved in the building design team process. Prequalification of contractor and pre-selected or invited bids are other options for achieving these results. By prequalifying contractors, the owner can select those with experience and interest in green building practices.

Whichever contract type is selected, very carefully defined specifications, including environmental procedures, need to be developed and implemented. Contract or bid documents should clarify rules for submissions and substitutions of green products and systems. (See Chapter 17, "Specifications," for further discussion.)

Partnering

- ❑ **Implement a partnership-oriented process for the project.**
  Partnership is the best way to pursue established project goals and criteria, following the whole-building integrated design approach; to establish and maintain communication among the team members; and to resolve issues related to design changes, problems with product availability, and other issues quickly. It is also a forum to discuss new techniques and strategies for green building design and to develop new and creative solutions that benefit from the skills and knowledge of all team members. A partnering process should be in place throughout the project, starting with the design phase and continuing through the construction and pre-occupancy phases.

Project Schedule

- ❑ **Develop a project schedule that incorporates the additional steps of an environmentally responsive design process, illustrated in *Figure 1*.**
  The schedule should be sensitive to additional research, unconventional techniques or materials, additional systems testing, pre-occupancy commissioning, or other green practices that may be used for the project in connection with its green design criteria.

Laws, Codes, and Standards

- ❑ **Prepare and review a list of the appropriate and applicable laws, codes, local ordinances, statutes, and industry-related standards relevant to the project.**
  In addition to the typical laws and guidelines followed on most projects, some will be relevant specifically to a green building. Examples include:
  - Local or state environmental quality and energy efficiency laws, such as the California Environmental Quality Act (CEQA), which requires an environmental analysis for any project that may have a significant effect on the environment.
  - Standards produced by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), which address energy efficiency, indoor air quality, thermal comfort, ventilation rates, and building commissioning, and are useful when developing designs and specifications for systems and products related to space conditioning.
  - Other standards, such as the American Society for Testing and Materials (ASTM) life-cycle standards and the Illuminating Engineering Society's lighting standards, and specification guidance from the Construction Specification Institute (CSI). (See Chapter 17, "Specifications," for more information on green specifications, and Chapter 25, "The Future of Green Building," for more information on standards.)

Research

- ❑ **Research green projects that are complete or about to be completed.**
  Prepare a binder of information about these projects for reference. As appropriate, visit the projects and meet with their design teams. This exer-

cise can produce valuable information about existing green building practices and feedback on current green design and construction procedures and products. It is also a good way to educate a team, and the building owner, about green buildings prior to starting a project.

Site Selection

❑ **Evaluate project site selection, based on green criteria.**

In many projects, the site is selected prior to commencement of the design phase. Ideally, the design team should be involved in site selection and should assess the appropriateness of the site relative to green design criteria. A team may decide if the site takes maximum advantage of solar access, existing vegetation, and natural geological features, as well as analyze the site's accessibility from existing transportation corridors and its ability to meet other needs of the building owner, tenants, and visitors. (See Part III for additional site information and selection criteria.)

NOTES

1 Materials/Indoor Air Quality Standards Committee, "Materials/Indoor Air Quality Policy" (Berkeley, Calif.: Berkeley Unified School District Office of Facilities Planning, June 15, 1994).

2 Energy Design Standards Committee, "Energy Design Standards Policy" (Berkeley, Calif.: Berkeley Unified School District Office of Facilities Planning, June 15, 1994).

3 Ibid.

CHAPTER 4

Local Government Information: Pre-Design Issues

Author
Michael Myers

IMPLEMENTATION ISSUES

Local governments have the unique ability to be both owners and clients in designing the form and function of their community buildings. The pre-design phase allows local government to incorporate sustainable building criteria in its determination of where a building should be built, the function of the building, the materials used for construction, and the building's relationship to the local community.

It is during the pre-design phase that green building guidelines need to be developed and used in an integrated approach to building design. This approach encourages local governments to evaluate such factors as future energy usage, environmental impacts, water usage, site impacts, indoor air quality, waste reduction, transportation and parking, community access, operations and maintenance costs, and local economic impacts. It is also an opportunity to establish guidelines that require life-cycle costs be used to evaluate energy and water systems, as well as building products. Life-cycle cost analysis involves calculating the total costs and savings of conventional versus higher-efficiency systems or environmentally sound products.

Local governments can also require design and construction teams to have expertise in resource-efficient design and construction and to ensure that citizens and building occupants have an opportunity during the pre-design phase to contribute their ideas on building use, building design, and access to the site.

LOCAL ACTIONS

➤ The city of Austin, Texas, passed a local resolution in 1994 that requested city staff to develop sustainable building guidelines for municipal buildings, encourage voluntary private sector compliance with the city's sustainable building guidelines through education and promotional endeavors, and promote opportunities to involve at-risk youth in green building projects. The ultimate goal of the resolution is to make Austin a model sustainable city.

By December 1994, the city's Departments of Environmental and Conservation Services and Public Works developed Volume I of the *Sustainable Building Guidelines.* The guidelines are based on Austin's successful Green Builder Program for residential buildings, which received international honors at the 1992 United Nations Conference on Environment and Development.

Volume I, *Principles of Sustainable Building Design,* encourages the broad goals of energy efficiency, water conservation, and healthy structures; the use of recycled-content materials; the integration of environmental concerns, green construction, and waste-reduction practices; and procedures and guidelines for building longevity. Specifically, it aims to:

- Reduce aggregate energy use over the base line by 10 percent.
- Reduce electrical energy demand over the base case by 20 percent.
- Reduce water consumption for similar building type and site square footage by 30 percent.
- Optimally recycle or reuse construction and demolition materials generated by the project.
- Recycle 75 percent of operational waste.
- Select building materials that emphasize sustainability standards.
- Increase building longevity through durable construction elements and adaptable design.
- Achieve a healthy indoor air quality.

Volume I outlines a design process that features a team-oriented and integrated design approach. Steps in Austin's design process include: 1) development of a program-specific base line; 2) site analysis; 3) characterization of energy needs; 4) economic analysis; and 5) development of project-specific goals.

An appendix to the *Sustainable Guidelines* document includes other useful information, such as a preferred plant list for the region, materials suppliers, and resources. Volumes II and III will focus on specifying for sustainability and operations and maintenance for city facilities, respectively.

➤In 1994, the city of Portland, Oregon, also adopted Sustainable City Principles that encourage elected officials and municipal staff to develop connections between environmental quality and economic vitality, to include long-term effects and cumulative environmental impact in decision-making, to ensure commitment to equity, to use resources efficiently and prevent additional pollution, to purchase products based on long-term environmental and operating costs, and to educate citizens and businesses about their role in implementing these principles.

Putting policy into practice, Portland developed a design services Request for Proposals (RFP) for a new municipal building. The RFP designates environmentally sensitive design and construction as priorities of the city and indicates that design and siting decisions will be based on long-term environmental impact. Areas of special focus in the RFP include recycled construction and building materials, energy efficient systems and fixtures, and water-conserving plants in the landscape. Portland also made recommendations for the composition of the design team, including specific expertise in energy-efficient design, and provided mechanisms for input from a Citizens' Task Force and city staff. These groups will meet during the design process to provide direction on siting, building design, and programs offered at the facility.

➤The city of Santa Monica, California, is formulating a set of Sustainable Development Guidelines for construction and development projects within the city. These guidelines are intended to foster environmental responsibility without unreasonable increases in building cost or limits on construction practices. When complete, Santa Monica's guidelines should be beneficial to the environment and conducive to the future growth of the city.

➤The American Institute of Architects (AIA) has carried out a series of design charrettes in communities around the country to increase public and professional awareness of, and involvement in, environmental design projects. These intensive, short-term workshops bring together design professionals, builders, policymakers, financiers, and community organizations to explore the benefits of sustainable development practices. AIA design charrettes have examined a range of projects, including the environmentally sound development of a water aquifer; redevelopment of neighborhoods, inner-city areas, and downtown commercial areas; and reuse of a historic courthouse and a closed landfill site. The charrettes provide an opportunity to develop community support at all levels for implementation of green building practices in community projects.

LOCAL OPTIONS

- Adopt a resolution or policy to direct future building toward green practices.
- Institute life-cycle cost analysis for procurement of building systems and materials for municipal projects.
- Build local public support for green buildings by establishing a green building task force or support activities of existing local organizations.
- Hold a design charrette to focus attention on local green design efforts for public or private building projects.
- Establish a pre-design green team for municipal buildings that includes green design professionals, community members, and building occupants.
- Conduct an environmental scan of existing buildings to assess baseline energy and water usage, indoor air quality, and site characteristics, and to estimate future resource needs and costs.
- Conduct a baseline analysis of institutional issues that affect green building policy implementation—for example, procurement policies, zoning, building codes and standards, operations and maintenance policies, recycling policies, and economic policies.

➜ RESOURCES

Resources for the Local Government Information chapters are located in the Appendix.

PART III

Site Issues

Introduction

Sustainable site planning and design do not impose building design on the site. Rather, they identify the ecological characteristics of the site, determine whether it is appropriate for its proposed use, and design ways to integrate the building with the site. The intent is to lessen the environmental impact of human activity, while using natural characteristics of the site to enhance human comfort and health, and potentially provide a significant portion of the building's energy requirement. Preservation of site resources and conservation of energy and materials in construction and building operations are important results of good site design.

This section of the manual emphasizes the need to consider the regional and global effects of building and development. Far from being merely a location for construction, each site consists of interconnected living systems, all linked to the environment beyond the site's boundaries. The connected outdoor spaces—garden, plaza, greenbelt, and wilderness—also link people, both physically and socially. Keeping a building site in harmony with its surroundings is vital not only to our environment, but also to our sense of community.

The chapters in this section provide practical guidelines for developing site-integrated buildings and maintaining the ecological integrity of the site. Chapter 5, "Sustainable Site Design," covers pre-design planning: assessment of existing natural and cultural site characteristics, existing infrastructure, and building requirements. Chapter 6, "Water Issues," suggests specific methods of protecting natural watersheds, reducing water usage and pollution, and setting up systems to use gray- and blackwater. Chapter 7, "Site Materials and Equipment," discusses environmentally responsible methods of site modification. Practices discussed in Chapters 6 and 7 will be developed during the design phase and carried out during the construction and occupancy phases of a building construction project. Chapter 8 provides examples of local government initiatives related to sustainable issues.

CHAPTER 5

Sustainable Site Design

Author

Nicholas T. Dines

★ SIGNIFICANCE

This chapter focuses on green site-planning strategies and practices that specifically relate to assessing and selecting a site for uses such as office buildings and parks, institutional and research structures, retail businesses, and industrial facilities. The purpose of sustainable site planning is to integrate design and construction strategies by modifying both site and building to achieve greater human comfort and operational efficiencies. Sound site planning is prescriptive and strategic. It charts appropriate patterns of use for a site while incorporating construction methods that minimize site disruption and the expenditure of financial and building resources.

Site planning assesses a particular landscape to determine its appropriate use, then maps the areas most suitable for accommodating specific activities associated with that use. The process is based upon the premise that any landscape setting can be analyzed and studied as a series of interconnected geological, hydrological, topographic, ecological, climatological, and cultural features and systems. An ideal site plan is one in which the arrangement of roads, buildings, and associated uses is developed using site data and information from the larger macro-environment, including existing historical and cultural patterns of the community.

Selecting a building site begins the process of calculating the degree of resource use and the degree of disturbance of existing natural systems that will be required to support a building's development. The most environmentally sound development is one that disturbs as little of the existing site as possible. Therefore, sites suitable for commercial building should ideally be located within or adjacent to existing commercial environments. Building projects also require connections to mass transit, vehicular infrastructure, and utility and telecommunication networks. Sound site planning and building design should consider locating building-support services in common corridors, or siting a building to take advantage of existing service networks. This consolidation can minimize site disruption and facilitate building repair and inspection.

The use, scale, and structural systems of a building affect its particular site requirements and associated environmental impacts. Building characteristics, orientation, and placement should be considered in relation to the site so that proper drainage systems, circulation patterns, landscape design, and other site-development features can be determined.

☞ SUGGESTED PRACTICES AND CHECKLIST

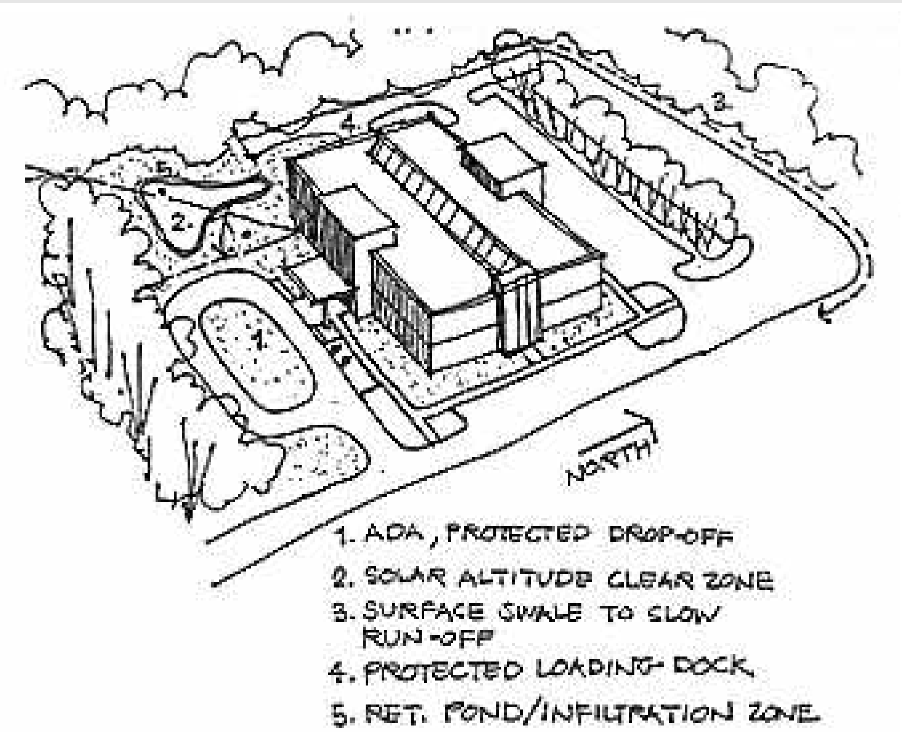
Site Analysis and Assessment

The purpose of a site analysis is to break down the site into basic parts, to isolate areas and systems requiring protection, and to identify both off-site and on-site factors that may require mitigation. Site assessment is a process that examines the data gathered and identified in the site analysis, assigns specific site factors to hierarchies of importance, and identifies, where possible, interactive relationships. For example, an analysis may identify specific soils and their properties, vegetation types and their distribution, or various slope and slope-orientation conditions to name a few site factors. An assessment applies evaluation criteria that allow the comparison of various sites' suitability for a specific use.

Sustainable design practices assess both site and building program to determine the site's capacity to support the program without degrading vital systems, or requiring extraordinary development expenditures. The result of analysis and assessment is a blueprint for the most appropriate ecological and physical fit between site, building, and the resulting cultural landscape.

Figure 1

TYPICAL TEMPERATE CLIMATE BIOCLIMATIC BUILDING AND SITE LAYOUT



Data Collection

Technical Site Data

- ❑ **Perform a site analysis to determine site characteristics that influence building design.**
  The following site characteristics influence building design elements, including form, shape, bulk, materials, skin-to-volume ratio, structural systems, mechanical systems, access and service, solar orientation, and finished floor elevation:
  - *Geographical latitude (solar altitude) and microclimate factors, such as wind loads*—Affect building layout, including solar orientation and location of entrances, windows, and loading docks *(Figure 1)*.
  - *Topography and adjacent landforms*—Influence building proportions, wind loads, drainage strategies, floor elevations, and key gravity-fed sewer-line corridors *(Figure 2)*.

TYPICAL BUILDING ZONES FOR SITE USE WITH REGARD TO TOPOGRAPHY, DRAINAGE, AND SOLAR ACCESS

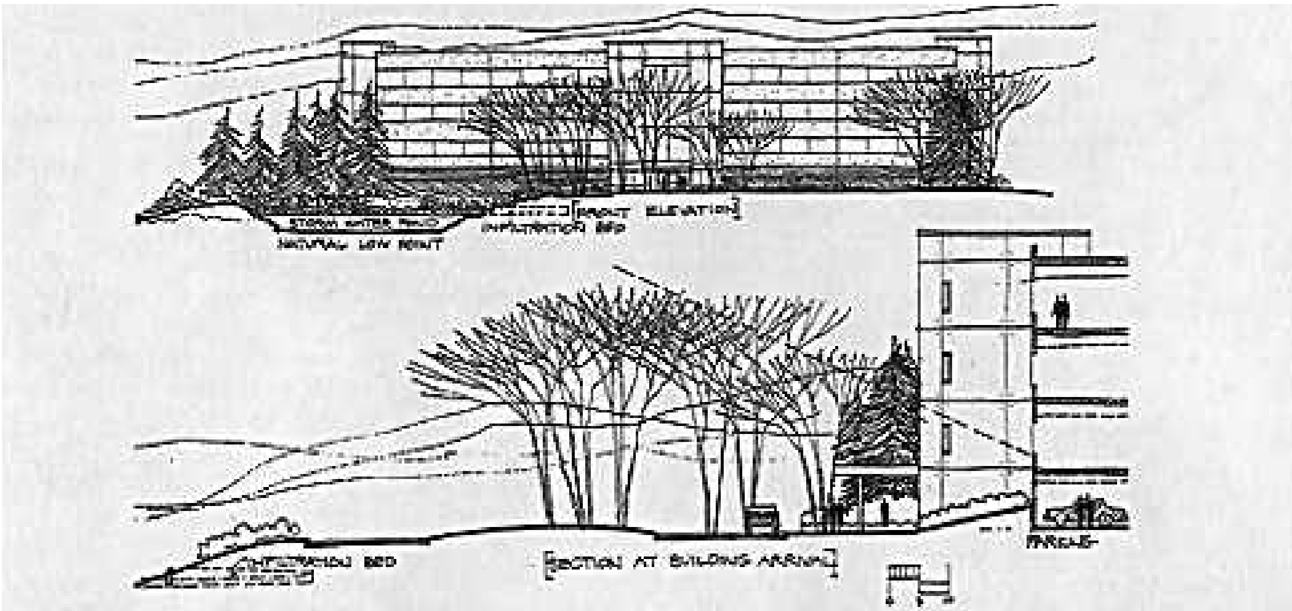


Figure 2

- *Groundwater and surface runoff characteristics*—Determine building locations as well as natural channels for diverting storm runoff and locations of runoff detention ponds *(Figure 3).*
- *Solar access*—Determines position of building to take maximum advantage of natural solar resources for passive solar heating, daylighting, and photovoltaics.
- *Air-movement patterns, both annual and diurnal*—Particularly influence siting of multiple structures to avoid damming cold moisture-laden air, or blocking favorable cooling breezes during periods of overheating. Properly measured wind loads and pressure differentials are essential for designing interior air-handling systems or use of passive solar cooling strategies (see Chapter 11, “Renewable Energy”).
- *Soil texture and its load-bearing capacity*—Determine building location on the site and the type of footing required. Identify site-grading processes by the soil’s potential for erosion by wind, water, and machine disturbance.
- *Parcel shape and access*—Affect a site’s capacity to accommodate a proposed development, even if its size and environmental factors are favorable. Potential access points should not burden lower-density or less compatible adjacent land use. Zoning setbacks and easements can also affect development potential *(Figure 4).*
- *Neighboring developments and proposed future developments*—Affect proposed project and may lead to requisite design changes.

DRAINAGE AND GRADING DIAGRAM OF A TYPICAL COMMERCIAL DEVELOPMENT

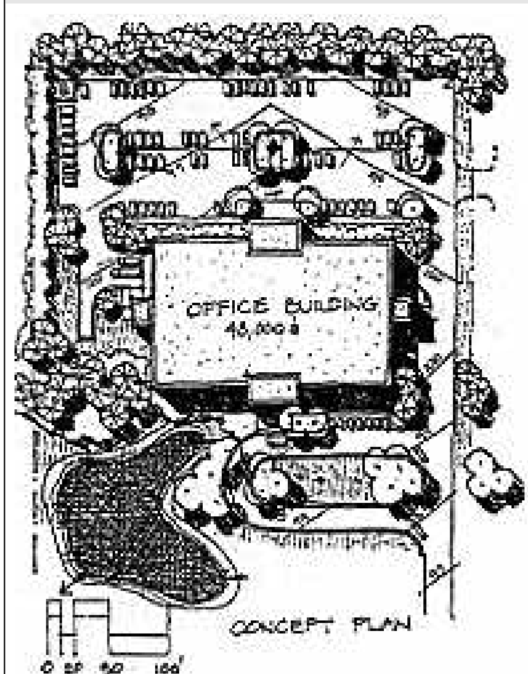


Figure 3

RELATIONSHIP OF LOT SHAPE AND SET-BACKS TO BUILDING ZONE AND SITE LAYOUT

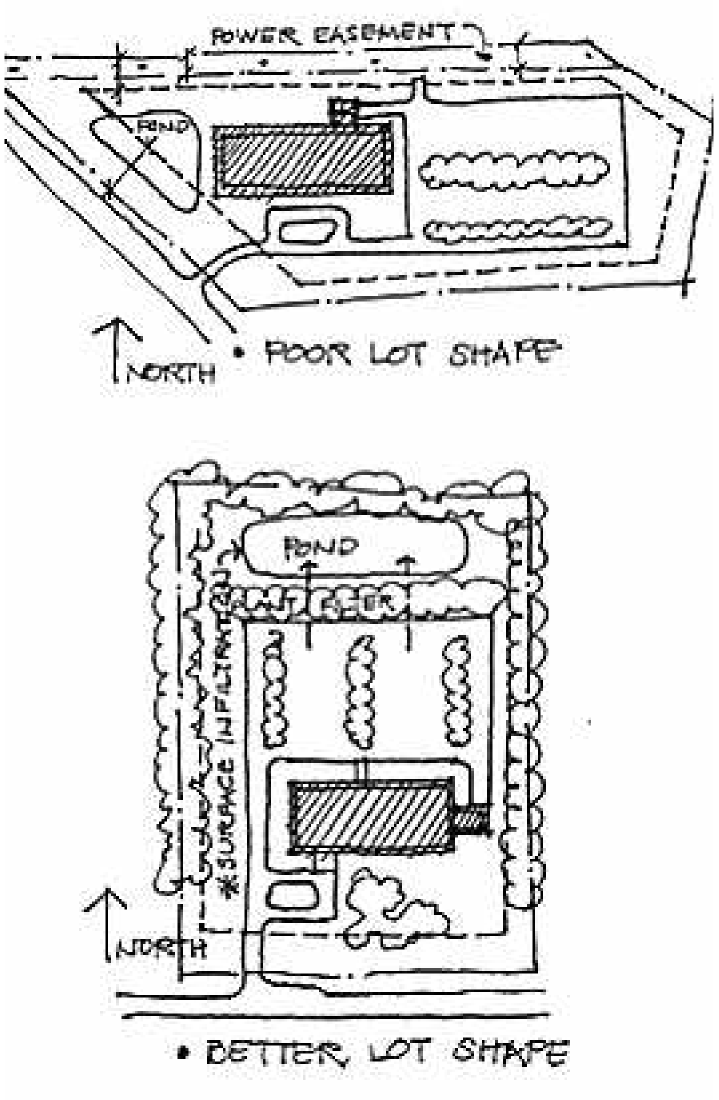


Figure 4

- ❑ **Analyze specific characteristics of climate zones.**
  Climate zones (hot-humid, hot-arid, temperate, and cold) have specific characteristics requiring mitigation, augmentation, and exploitation (*Table 1*). Each climate zone suggests historically amenable siting and building practices.

- ❑ **Analyze the site's existing air quality.**
  Most state and federal projects require an environmental impact statement (EIS) outlining the potential negative impacts of a proposed development and how they might be alleviated. Site planning requires two kinds of air-quality analysis regarding: (1) assessment of the existing air quality of the site to determine the presence of noxious chemicals and suspended particulates, and (2) projection of the negative consequences (if any) of the proposed development on existing air quality. In primarily commercial or industrial areas, poor air quality should be a key factor in determining site suitability and use, especially for such facilities as schools, parks, or housing for seniors. Testing should anticipate seasonal or diurnal wind patterns to make certain that the worst possible case is tested. Certified labs should perform testing to determine both chemical and particulate pollution.

- ❑ **Perform soil and groundwater testing.**
  Perform soil tests to identify the presence of chemical residues from past agricultural activities (arsenic, pesticides, and lead); past industrial activities (dumps, heavy metals, carcinogenic compounds and minerals, and hydrocarbons); and any other possible contamination both on or in the vicinity of the subject site. Also, the possibility of water contamination, in areas where the native rock and substrata are radon-bearing deserves specific attention. These tests are crucial to determine both site feasibility and/or the construction methods required to either mitigate or remove contaminants.

- ❑ **Test soil suitability for backfills, slope structures, infiltration.**
  The native soil should be tested to determine bearing, compactability, and infiltration rates, and, in turn, structural suitability and the best method for mechanical compaction (i.e., clay soils require non-vibrating compaction and non-erosive angles of repose for cut-and-fill slopes).

- ❑ **Evaluate site ecosystem for existence of wetlands and endangered species.**
  In addition to wetland regulations governing vegetative-cover removal, grading, drainage alterations, building siting, and stormwater runoff mitigation, there are endangered species regulations designed to preserve specific plant and animal species. Preservation and restoration strategies require thorough economic analysis, specialized expertise, and sound baseline data gathered through both remote and on-site sensing methods.

❑ **Examine existing vegetation to inventory significant plant populations.**
This will enable the developer or owner to later specify vegetation that is susceptible to damage during construction, so that protective measures can be developed and implemented.

❑ **Map all natural hazard potentials (such as winds, floods, and mudslides).**
Historic flood data, wind-damage data, and subsidence data should be mapped along with current annual wind and precipitation data. It is important to indicate if the proposed development is within a statistically significant probability of sustaining impacts within the near future. Often, evidence of past occurrences is not visible. Subsurface investigation may yield data on surficial rock strata or uncharted previous excavations. Such evidence may require that a different site be selected, or an architectural modification be made.

❑ **Diagram existing pedestrian and vehicular movement and parking to identify patterns.**
Existing traffic and parking patterns in areas which are adjacent to or near the site may need consideration in relation to proposed building design and site circulation patterns.

❑ **Review the potential of utilizing existing local transportation resources.**
Explore the sharing of existing transportation facilities and other resources, such as parking and shuttles, with existing institutions. This can lead to greater site efficiencies.

❑ **Identify construction restraints and requirements.**
Special construction methods may be required because of local soil condition, geology, earth-moving constraints, and other site-specific factors and constraints.

Cultural and Historical Data

❑ **Review site's cultural resources for possible restoration.**
Historical sites and features can be incorporated as part of the project site, thereby increasing ties with the community and preserving the area's cultural heritage.

❑ **Review architectural style of the area for incorporation into building.**
If desirable, the architectural style that is historically predominant in an area can be reflected in the building and landscape design, enhancing community integration.

❑ **Explore use of historically compatible building types.**
There may be building types that are historically matched to the region. Consider integrating such types into building development.

Infrastructure Data

❑ **Analyze site for existing utility and transportation infrastructure and capacity.**
There may be insufficient existing infrastructure for the proposed project. The cost for required additional capacity and associated disruption to the surrounding area could make the project unfeasible. Existing infrastructure should be analyzed for integration into the building and facilities.

Data Assessment

❑ **Identify topographic and hydrological impacts of proposed design and building use.**
Measure cut-and-fill potential and assess potential for erosion, siltation, and groundwater pollution.

❑ **Develop general area takeoff and overall building footprint compatibility with site.**
For example, measure total site coverage of impermeable surfaces to determine thresholds of run-off pollution potential (i.e., over 20 percent impermeable coverage of gross site requires mitigation to clean stormwater before it enters drainage system off-site). Footprint should also maximize site efficiencies with regard to required road, utility, and service access.

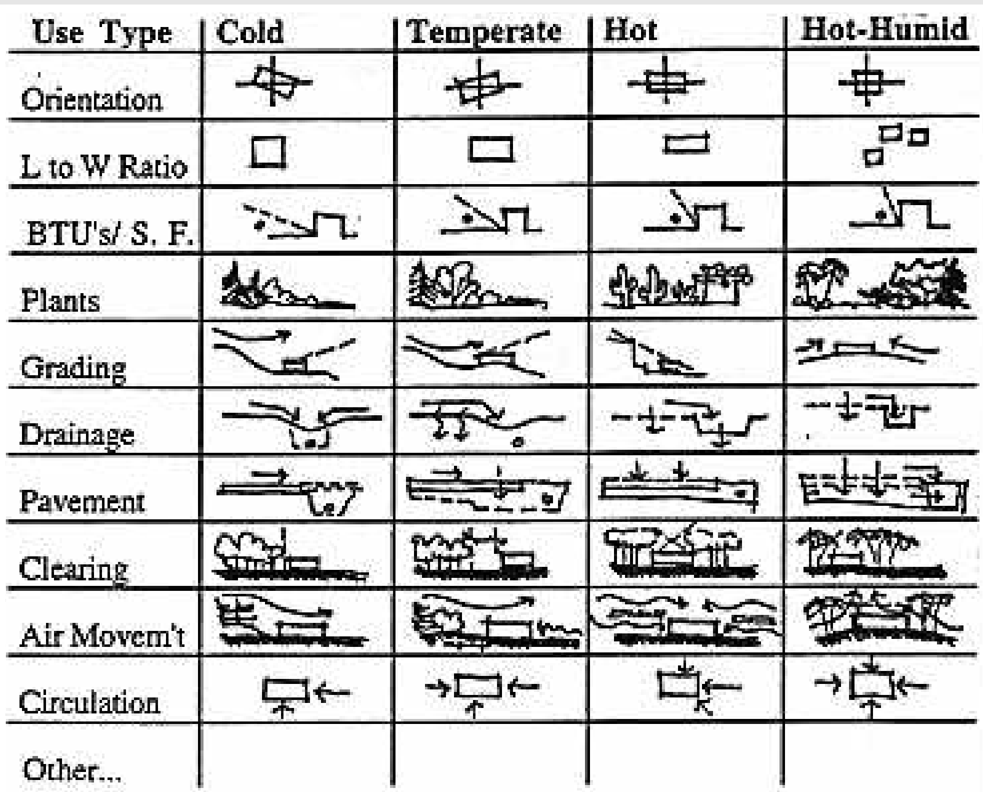
- ❑ **Identify alternative site design concepts to minimize resource costs and disruption.** Develop several alternatives to explore optimal pattern with regard to factors such as grading and tree-clearing consequences and resulting infrastructure costs.
- ❑ **Review financial implications of site development, building, and projected maintenance costs.** Total cost of the project must factor in ongoing costs associated with the site design, development, and operations, as well as hidden embodied energy costs associated with specific materials.
- ❑ **Develop matrix of use and site compatibility index.** *(Table 1).* Each site may be assessed to reveal its development compatibility index with regard to a specific type of development. This index may reveal a pattern of incompatibilities, suggesting that either a different site be chosen or specific appropriate mitigation measures be undertaken.

Site Development and Layout

After the site has been selected on the basis of a thorough analysis and assessment, ideal diagrammatic concepts are laid out on the topographic survey with the objective of organizing all proposed built elements to achieve an efficient and effective site and development fit. The main goal of the concepts should be to minimize resource consumption during construction and after human occupation. It should be noted that during reclamation of disturbed sites, initial expenditures may be higher than normal and should be balanced by ongoing landscape management strategies. The following practices serve to guide the initial concept diagramming process.

Table 1

MATRIX OF REGIONAL BIOCLIMATIC, SITE USE, AND SITE DESIGN FACTORS



Infrastructure

Utility Corridors

- ❑ **Design the site plan to minimize road length, building footprint, and the actual ground area required for intended improvements.**
  Such planning decreases the length of utility connections. Consult local codes regarding separation requirements for water, sewer, electrical, and gas lines.
- ❑ **Use gravity sewer systems wherever possible.**
  Avoid pumped sewer systems because of ongoing power consumption.
- ❑ **Reuse chemical-waste tanks and lines.**
  Existing chemical-waste tanks and lines should be inspected, protected, and reused to avoid creation of additional hazardous-materials problems.
- ❑ **Aggregate utility corridors when feasible.**
  Where possible, common site utility corridors should be consolidated along previously disturbed areas or along new road or walk construction, both to minimize unnecessary clearing and trenching and to ensure ease of access for ongoing repairs.

Transportation

- ❑ **Support reduction of vehicle miles traveled (VMT) to the site.**
  Where applicable, existing mass-transit infrastructure and shuttle buses should be supported, or a new line developed. Carpooling strategies should be encouraged in addition to mass-transit use. To foster the use of bicycles, showers and lockers should be considered. All of these transportation methods reduce parking and transportation costs for employees.
- ❑ **Use existing vehicular transportation networks to minimize the need for new infrastructure.**
  This practice can increase site efficiencies associated with reduced ground coverage, parking requirements, and related costs.
- ❑ **Consider increased use of telecommuting strategies.**
  Telecommuting and teleconferencing can reduce commute time and VMT to and from worksites. Plan for adequate telecommunications infrastructure and access in building design. (See Chapter 25, "The Future of Green Building" for further discussion).
- ❑ **Consolidate service, pedestrian, and automobile paths.**
  To minimize pavement costs, improve efficiency, and centralize runoff, the pattern of roads, walkways, and parking should be compact. This not only is a less expensive way to build, it also helps to reduce the ratio of impermeable surfaces to the gross site area.

Building and Site Requirements

Land Features

- ❑ **Develop previously disturbed sites such as unused urban lots and commercial sites.**
  These sites may already be affecting the environmental quality of neighboring properties, the watersheds, and other features, therefore redevelopment requires minimal disturbance of natural systems. Furthermore, redevelopment is likely to improve the immediate community, potentially create jobs, and increase land values that have been affected by the abandoned or blighted property.
- ❑ **Avoid stream channels, flood plains, wetlands, steep erodible slopes, and mature vegetation.**
  To avoid high site-preparation costs, and to preserve important visual and ecological features, development activity should be configured to occupy "interstitial site space," or those spaces between critical resources.

Building and Site Orientation (see Figure 1)

❑ **Plan site clearing and planting to take advantage of solar and topographic conditions.**
Solar orientation, sky conditions (cloudy versus clear), and topography are interrelated. A site's latitude determines the sun's altitude and associated azimuth for any given time of day, each day of the year. Site-clearing and planting strategies, which partially determine solar access, are influenced by those requirements.

❑ **Orient building to take advantage of solar energy for passive and active solar systems.**
The building should be oriented to take advantage of shade and airflows for cooling in summer, and of passive solar energy for heating and wind protection in winter. If solar collectors or photovoltaic systems are proposed, orientation should allow maximum access to sunlight. (See also Part IV, Section A, "Passive Solar Design" for more information.)

❑ **Minimize solar shadows.**
Landscaped areas, open spaces, parking, and septic fields should be aggregated to provide the least solar shadow for southern orientations of the building project and adjoining buildings. Calculating total site shadow can prevent the creation solar voids and cold-air-drainage dams. This is especially helpful in cold and temperate climates.

❑ **Minimize earthwork and clearing by aligning long buildings and parking lots with landscape contours; take up excess slope with half-basements and staggered floor levels.**

❑ **Provide a north-wall design that minimizes heat loss.**
Provide entrances with airlocks, and limit glass to prevent heat loss in human-occupied areas. Large buildings in cold or temperate climates require air-handling system compensation for balancing interior building pressure in such circumstances.

❑ **Provide a building-entrance orientation that maximizes safety and ease of access.**
The building should be positioned on the site so that its entrance provides maximum safety and ease of access, as well as protection from the elements.

Landscaping and Use of Natural Resources

❑ **Harness solar energy, airflow patterns, natural water sources, and the insulating quality of land forms for building temperature control.**
Existing water sources and landforms can be used to create winter heat sinks in cold climates, and temperature differentials for cooling air movement in hot climates. Existing streams or other water sources can contribute to radiant cooling for the site. Color and surface orientation may be used to favorably absorb or reflect solar energy.

❑ **Use existing vegetation to moderate weather conditions and provide protection for native wildlife.**
Vegetation can be used to provide shade and transpiration in the summer and wind protection in the winter. Additionally, vegetation can provide a natural connection for wildlife corridors.

❑ **Design access roads, landscaping, and ancillary structures to channel wind toward main buildings for cooling, or away from them to reduce heat loss.**

Public Amenities

❑ **Modify microclimates to maximize human comfort in the use of outdoor public amenities such as plazas, sitting areas, and rest areas.**
Figure 5 provides examples of typical commercial buildings and associated sites.

– Modulate sun and wind. In planning outdoor public amenities, the designer needs to consider seasonal weather patterns and climate variables such as vapor pressure in hot-humid zones, desiccating winds and diurnal extremes in hot-arid zones, and annual temperature extremes in temperate and cold zones.

– Introduce structures and plantings that provide shelter from harsh elements and highlight desirable features. Modulation of tree-canopy heights and inclusion of water fountains and other built structures can fine-tune an exterior site by accelerating or decelerating site winds, casting shadows, or cooling by evapotranspiration or evaporative cooling.

❑ **Consider sustainable site materials for public amenities.** Materials should be recycled, if possible, and have a low life-cycle cost. Albido (solar reflectance index attributed to color) should also be considered when choosing site materials (see Chapter 7, "Site Materials and Equipment").

Construction Methods

❑ **Specify sustainable site construction methods.** The construction methods employed should ensure that each step of the building process is focused on eliminating unnecessary site disruption (e.g., excessive grading, blasting, clearing) and resource degradation (e.g., stream siltation, groundwater contamination, air-quality loss). The strategies can harness features such as ventilating breezes, solar gain, and microclimates, and can mitigate unfavorable features such as cold, moist air drainage; desiccating winds; and increased stormwater runoff.

❑ **Develop sequential staging to minimize site disruption.** The building process should be strategically charted in stages to avoid unnecessary site disruption, and to achieve an orderly construction sequence from site clearing to site finish. Such a strategy reduces costs and damage to the site. It requires close coordination between all sub-contractors. (See Chapter 7, "Site Materials and Equipment," and Chapter 19, "Environmental Construction Guidelines".)

➜ RESOURCES

Architects' First Source for Products. Atlanta: 1995. A comprehensive illustrated product catalog of professional organizations that may be useful for further information and site and building products.

Groesbeck, Wesley A., and Jan Stiefel, ASLA. *The Resource Guide to Sustainable Landscapes.* Salt Lake City: Environmental Resources, Inc., 1994. A specific compilation of specification language tied to a Construction Specification Institute (CSI) format with a comprehensive listing of manufacturers specializing in environmentally friendly products, devices, and processes.

U.S. Department of the Interior, National Park Service. *Guiding Principles of Sustainable Design.* Denver: GPO, 1993. A useful general introduction to sustainable design factors affecting site planning and architecture from the perspective of those charged with stewardship of public lands. It contains useful charts and diagrams with regard to site selection, assessment, and design.

BIOCLIMATIC SITING WITHIN CONTEXT OF NORTHERN, SOUTHERN, OR EASTERN SITE ENTRANCE

Figure 5

CHAPTER 6

Water Issues

Watershed Protection

Authors
Lucia Athens and
Bruce K. Ferguson

★ SIGNIFICANCE

Every building site is in a watershed, and everything people do on a site has an impact on the watershed's condition. Sediment from soil disturbance, oil leaks, and fertilizers pollute streams; excessive runoff aggravates flooding and erosion; and deflection of rainwater from its natural paths dries out streams and wetlands in summer.

Watershed protection must occur both during and after construction. Clearing and earthmoving increase erosion by as much as 40,000 times the rate occurring in undisturbed sites.[1] Many states and regions have legal requirements for erosion and sediment control. These laws have been supplemented by national standards for stormwater discharges that regulate all non-point-source pollution—water pollution resulting from urban sources including, for example, nutrients from lawn fertilizers and hydrocarbons from highways and parking lots.

After construction, any building development is physically a mosaic of roofs, pavements, and pervious soil areas. Every impervious surface deflects rainwater away from its natural course—soil pores, native plants, and groundwater reservoirs—and into surface channels. Rainwater then concentrates into downstream floods, eroding as it goes. Carried with it are oils from cars, parking lots, maintenance yards, and storage areas; de-icing salts from roads; metals from construction and industrial materials; and herbicides, pesticides, and nutrients from overmaintained landscapes. These substances can destroy aquatic life and pollute water supplies.

In a protected watershed, soils absorb rain and make it part of the ecosystem. Pollutants are transformed as they filter through porous, humus-rich soil. Soil moisture percolates to the groundwater, which drains slowly out to streams long after the rain has fallen.

Sustainable development can solve watershed problems at the source. Its purpose is to (1) restore the infiltrating, cleansing, and storing functions of soils, plants, and groundwater by preserving natural systems; (2) restore the permeability of constructed pavements; and (3) capture and treat excess runoff by means of natural soil and biological processes. Water conservation, efficiency, and management arise from preserving, restoring, taking advantage of, and working with the site's natural systems.

☞ SUGGESTED PRACTICES AND CHECKLIST

Preservation of Soils and Drainage Ways

❑ **Emphasize preservation of mature vegetated soils and lowland areas.**
These natural systems make the watershed work by allowing rainwater and runoff to infiltrate the soil. In lowland areas, groundwater discharges into surface drainage ways, streams, and wetlands.[2] Stable vegetation around drainage ways and streams filters inflowing runoff, prevents channel erosion, and creates habitats for functioning aquatic ecosystems. Siting construction and earthwork away from drainage courses preserves vegetated buffers and protects stream quality.

❑ **Minimize pavement area.**
Minimizing pavement affords some preservation of mature native soils. Also, preserving existing vegetation generates less runoff. Good practices include:
– Concentrate and cluster development to reduce road paving.
– Double-load parking lots to share traveling and turning lanes.
– Minimize widths of road pavements.

❑ **Install silt fences to hold sediment on-site during construction.**
Silt fences should be installed before construction begins and should be maintained until construction is complete and all soil surfaces are vegetated.

❑ **Minimize use of landscape irrigation, herbicides, pesticides, and fertilizers.**
In disturbed and landscaped areas, lawn and landscape maintenance can generate a high concentration of pesticides, nutrients, and other pollutants.[3]

Porous Paving Materials

❑ **Consider use of permeable paving materials (subject to existing codes or obtained variances).**
Permeable paving materials, such as porous asphalt *(Figure 1)* or porous cement concrete, are some of the most powerful tools available for maintaining and restoring natural cycles on development sites by allowing for water infiltration close to the source. Most of the impervious portion of a typical development is in pavements for cars, not buildings for people. In the United States we are paving or repaving a half million acres per year. A variety of permeable paving materials, available since 1970, can be used for the vast majority of paved surfaces. Impervious pavements can be reserved for special situations, responding to specific on-site hazards such as swelling soils, highly plastic soils, or steep slopes (see Chapter 7, "Site Materials and Equipment").

❑ **Use permeable vegetated surfaces for occasionally used vehicular surfaces such as overflow parking and emergency-access lanes.**
Permeable vegetated surfaces can be designed with reinforced turf and open-celled pavers, concrete or plastic grids with voids that are filled with topsoil or aggregate.[4]

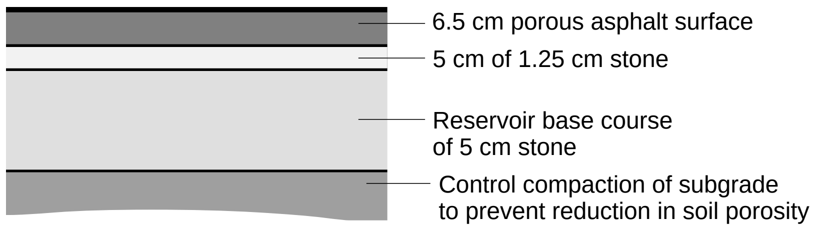
❑ **Build pedestrian surfaces, such as walkways and patios, with loose aggregate, wooden decks, or well-spaced paving stones.**[5]

Figure 1

POROUS ASPHALT

Porous asphalt has been proven in the field in hundreds of pavements of every type, from driveways to highways.[6] The distinctive porous surface layer is constructed with an "open-graded" aggregate, which leaves the voids between large particles unfilled by small particles. An open-graded stone base holds water until it infiltrates the underlying soil. Compared to impervious asphalt, porous asphalt is better-draining, has better traction and visibility in wet conditions, and produces less glare and vehicular noise.

POROUS ASPHALT SECTION



Source: Edmund Thelen and L. Fielding Howe, Porous Pavement (Philadelphia: Franklin Institute Press, 1978)

Drainage of Concentrated Runoff

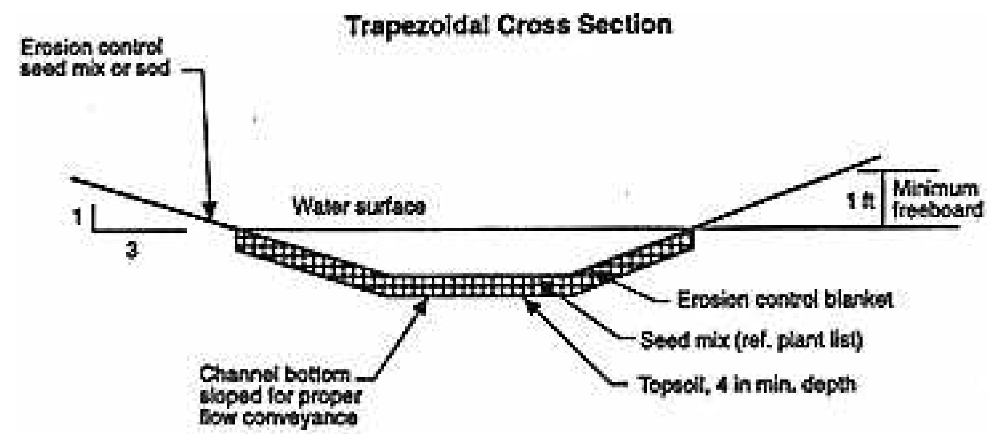
If drainage controls are implemented at the beginning of site planning, they can be integrated economically in the overall development. Detailed information on hydrologic analysis and design can be found in some of the references at the end of this chapter.

❑ **Consider disconnecting pre-existing downspouts and storm sewers from sanitary sewers.**
- Discharge downspouts into an earthern depression or gravel-filled pit for infiltration.

❑ **Moderate and treat runoff from roofs and unavoidable impervious pavements, and, to the degree possible, return it to its natural path in the soil.**
- Design every conveyance, pool, and drainage basin to match the requirements of its specific location and drainage area.
- Disperse runoff from impervious surfaces over adjacent vegatative soils with level spreaders, which change concentrated stormwater flow to sheet flow.
- Convey concentrated runoff in vegetated swales, not structural gutters or pipes. When runoff contacts vegetation and porous soil, its volume and velocity are reduced, and pollutants are filtered. Compared to closed structural systems, this open drainage system increases vegetative variety, reduces need for irrigation water, and reduces drainage velocity and erosion. In addition, it decreases downstream peak flow and runoff volume, increases infiltration, supports wildlife habitat, symbolizes interaction with nature, and requires little single-purpose maintenance *(Figure 2)*.
- Stabilize soil and reduce scouring velocity. Rock or timber checkdams, linings of sod and erosion-control fabrics, and bioengineering with quickly rooting riparian plants are effective where preexisting stream channels are unstable, or where new swales may cause erosion after grading. Swales with broad bottoms reduce velocity.
- Moderate discharge through use of constructed pools and wetlands along drainage courses. Formed by excavation of a shallow reservoir and installation of a low dam and controlled flow outlet, such pools and wetlands can temporarily store storm flows and improve water quality by allowing for settling, filtration, and biodegradation of pollutants.[7] Effective water treatment is a result of providing sufficient area for the water body and providing diverse depth zones for different plant habitats and biophysical processes.

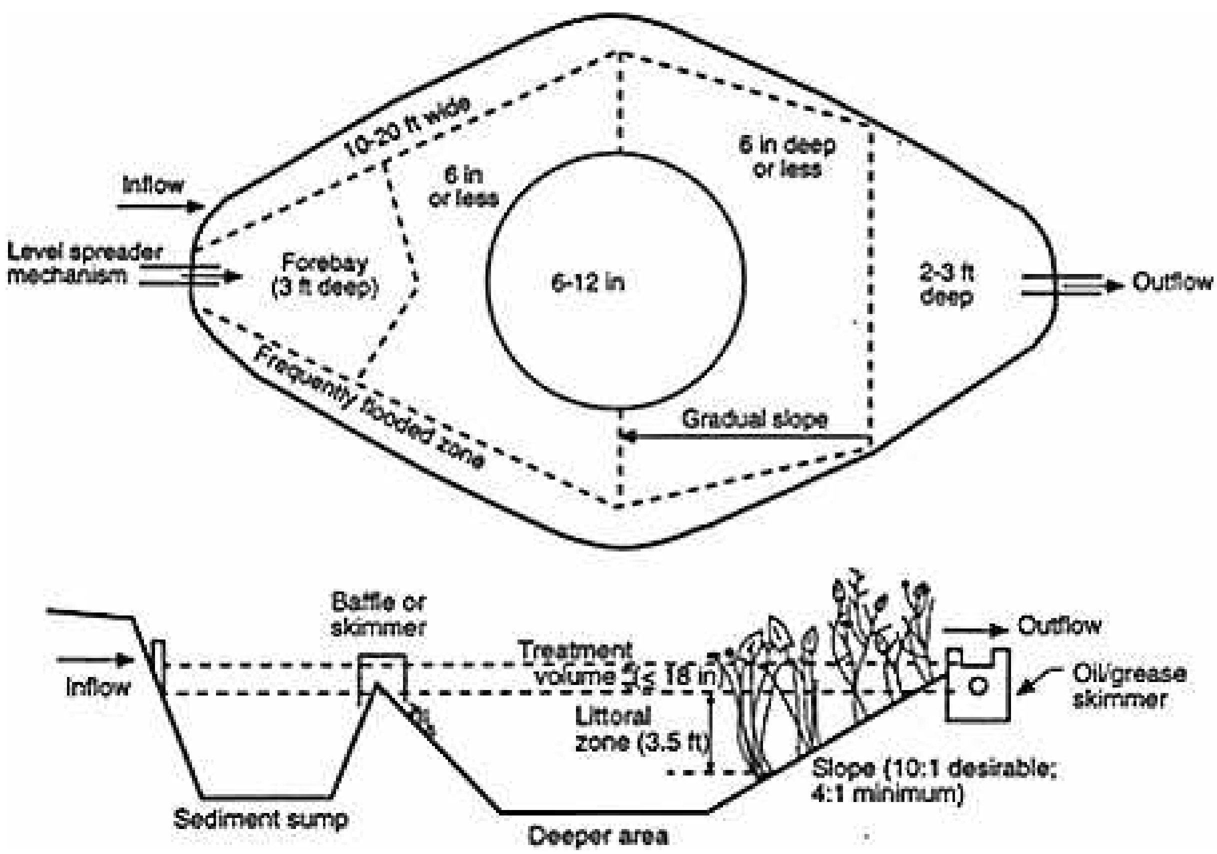
Figure 2

SAMPLE GRASS-LINED SWALE



Source: R. Horner, "Biofiltration Systems for Urban Runoff Water Quality Control" (Seattle: Washington State University, 1988), in U.S. Environmental Protection Agency, Office of Research and Development, Urban Runoff Pollution Prevention and Control Planning, EPA/625/R–93/004 (Washington, D.C.: GPO, 1993).

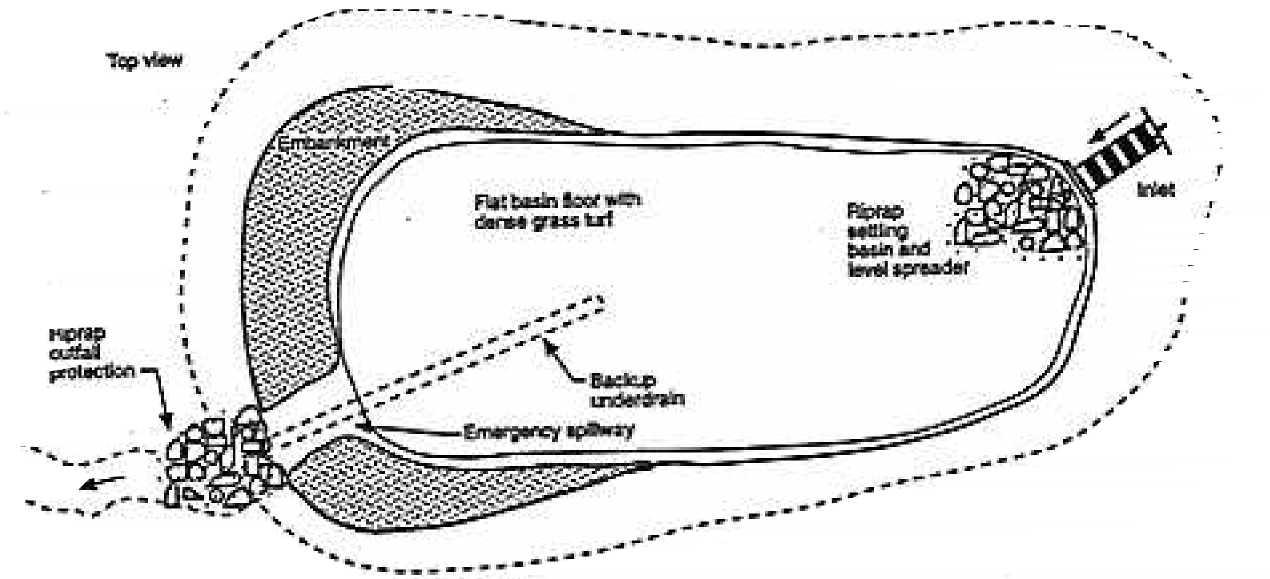
EXAMPLE SHALLOW-CONSTRUCTED WETLAND SYSTEM FOR STORMWATER TREATMENT



Source: Maryland Department of Natural Resources (1987), in U.S. Environmental Protection Agency, Office of Research and Development, Urban Runoff Pollution Prevention and Control Planning, EPA/625/R–93/004 (Washington, D.C.: GPO, 1993).

Figure 3

SAMPLE INFILTRATION BASIN



Source: U.S. Environmental Protection Agency, Office of Research and Development, Urban Runoff Pollution Prevention and Control Planning, EPA/625/R–93/004 (Washington, D.C.: GPO, 1993).

Figure 4

a. Shape water bodies with peninsulas and islands to extend flow path and treatment effectiveness.
b. Install sequences of ponds and wetlands along a site's drainage ways, beginning with miniature pools high in the drainage area to provide thorough treatment; redundancy is an asset (*Figure 3*).
c. Where driveways cross roadside swales, use the driveways as checkdams to form small wetlands.

– Use extreme caution when constructing water bodies at the lowest elevations of a site. Lowland construction of water bodies may disturb existing wetlands and riparian buffers just as any other construction would.
– Use vegetative buffer areas around parking lots. The presence of oil and sediment on parking surfaces and roadways can cause non-point-source pollution through runoff. Buffer-strip plantings around these areas can mitigate the problem.

❑ **Construct infiltration basins.**
Infiltration basins are closed depressions in the earth from which water can escape only into the soil. Infiltration is the ideal management and conservation of runoff because it filters pollutants through the soil, eliminates downstream floods and erosion, and restores natural flows to groundwater and downstream water bodies *(Figure 4)*.
– Design infiltration basins as open or closed systems. Some infiltration basins are open and vegetated; the vegetation maintains their porous soil structure. Others are constructed under the land surface with open-graded crushed stone, leaving the surface to be reclaimed for parking or other human or economic use. Their storage capacity is sometimes supplemented with perforated pipes or premanufactured chambers. Most subsurface basins should include access to the basin bottom for monitoring and maintenance. The cost of construction materials for subsurface basins is substantial, so they tend to be installed only where intense land development demands that the surface be reclaimed for double use.
– Place infiltration basins near source of runoff to be most economical and effective.
– Avoid placing basins near building foundations and on steep unstable slopes.

Water Efficiency and Conservation

★ SIGNIFICANCE

The amount of water available for use on the planet is finite, so as population grows, the available supply of water per person drops. Per capita water supplies worldwide have decreased by one-third since 1970, as the world's population has grown by 1.8 billion. Since 1980, global water use has more than tripled and is currently estimated at 4,340 cubic kilometers per year. Demand in every area of water use—urban, industrial, and agricultural—has increased, often because of mismanagement, overuse, and waste.[8] Many parts of the world are now experiencing rising water costs, seasonal shortages, and unpredictable quality and availability of supplies.

As water demands increase and municipalities must fund new water supply and treatment facilities, costs are passed on to the consumer. Many cities are using conservation rate structures in which larger users pay higher rates. Higher water use also adds to maintenance and life-cycle costs of facility operation. Efficiency and conservation in institutional, commercial, and industrial water use can result in impressive savings of both water and money—not just in water-use fees but also in sewage treatment costs, energy use, chemical use, and capacity charges and limits.

☞ SUGGESTED PRACTICES AND CHECKLIST

Water Harvesting

❑ **Collect and use "harvested" water.**

Water harvesting means collecting runoff from the soil's surface, paved surfaces, and other sources, and storing it for future use such as irrigation. Harvested water can include stormwater and irrigation runoff, water from cooling towers and heating, ventilating, and air-conditioning (HVAC) systems, and water from swales and other drainage structures directed into collection areas. After collection in a storage tank or pond, harvested runoff must be pressurized in order to be used in an irrigation system.

- Utilize gravity flow to collect runoff into harvesting areas such as storage tanks, open ponds, or detention basins.
- Direct rainfall from roofs and water from cooling towers into runoff harvesting areas.

Rainwater Harvesting

❑ **Collect and use rainwater.**

Collecting and using precipitation from a roof or other catchment area is an excellent way to take advantage of natural site resources, to reduce site runoff and the need for runoff-control devices, and to minimize the need for utility-provided water. Rainwater collection has long been utilized in arid parts of the world. Particularly in areas where populations are dispersed, rainwater collection offers a low-cost alternative to centralized piped water supply. In moist climate zones, rainwater collection is an excellent supplemental source of water.[9]

❑ **Consider quality of rainwater.**

Areas with extremely poor air quality may yield rainfall of poor quality. Rainfall in some areas is highly acidic, and therefore, undesirable for reuse. If the collection area has many overhanging tree branches, the collected rainwater will contain more debris and may appear brownish in color (caused by tannic acids drawn from plant debris). In areas with hard water, rainwater is preferable for its softness, cleaning abilities, and ability to extend the life of appliances such as water heaters and coffeemakers. The use and collection of rainwater is not federally regulated, and guidelines pertaining to its use vary by locality. If rainfall is to be used for potable or irrigation purposes, local health codes may require backflow prevention devices in order to avoid any risk of contaminating the public drinking-water supply. Check with local health-code officials for guidelines for your area.

❑ **Design an appropriate harvesting and storage system.**

The capacity of rainwater harvesting to meet water needs depends on the amount of rainfall in an area, the size of the collection area, the size of the storage area, and water needs. One inch of rainfall translates to 0.6 gallon of rainwater collected per square foot of roof area. Basic components of a rainwater-collection system include the catchment area (usually the roof), conveyance system (guttering, downspouts, piping), filtration system, storage system (cistern), and distribution system. The highest cost in most rainwater-collection systems is for water storage.

- Use appropriate roofing materials. The best roof materials for catchment are metal, clay, and concrete-based (such as tile or fiber cement). Asbestos roof materials are not suitable for potable collection because grit can enter the system. Use of asbestos roof materials may not be permitted under local building codes. Lead-containing materials such as flashing should not be used in catchment roofs.
- Install gutters and downspouts sized for the roof size and rainfall intensity. Install screening so that leaves and debris do not enter the cistern, as well as a "roof-washer" device to divert the first flush of water after a rainfall, preventing it from entering the cistern.
- Construct cistern storage. Cisterns may be constructed from a wide variety of materials. Prefabricated cisterns in steel or fiberglass are available, but tend to be quite expensive. Cisterns also may be constructed on site from concrete, ferro-cement, stone, or compressed earth. Cistern interior surfaces must, of course, be watertight. Health codes require them to be covered to prevent mosquito breeding and contamination. To prevent algae growth, which occurs with exposure to sunlight, use opaque materials only.

❑ **Filter and/or treat rainwater to use it as an irrigation source.**

Simple filtration with graded screens and paper filters can filter harvested rainwater for use in irrigation. With additional treatment, rainwater can also be potable.

Landscaping

❑ **Plant native or well-adapted species.**

In areas with low rainfall or seasonal droughts, up to 60 percent of total seasonal water usage can be attributed to irrigation. Typical urban landscapes consist of non-native or unadapted plant species, lawns, and a few trees. Non-native plants increase demands for water, especially during the growing season, thereby depleting local water supplies and driving the need for larger-capacity centralized facilities that may lie dormant during periods of low water use.

Native plants have become adapted to natural conditions of an area such as seasonal drought, pest problems, and native soils. Landscape designs that emphasize native trees, vines, shrubs, and perennials also help maintain the biological diversity of a region and preserve the character of regional landscapes.

❑ **Preserve native plant populations through careful site planning and protection of existing vegetation.**

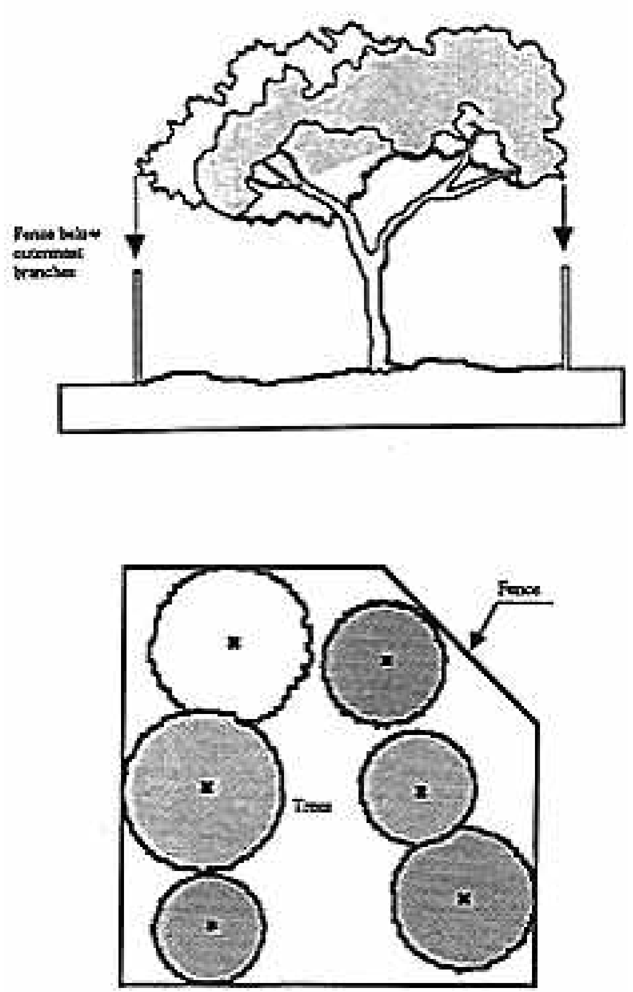
Protect trees by avoiding cut-and-fill in root zones (at a minimum, the area beneath the tree's outermost branches) and preventing heavy equipment from disturbing the area around and under them. The best way to protect existing vegetation is to fence groups of trees off *(Figure 5).*

❑ **Restore the native landscape.**
If disturbance is necessary, restore native plantings by reintroducing the same species. Habitat restoration helps to provide environments for wildlife displaced by development. Constructed landscapes that mimic ecological habitat models can decrease life-cycle maintenance costs, enhance wildlife survival, and blend edges of adjoining urban and rural areas.

❑ **Minimize use of high-maintenance lawns.**
Most turfgrasses typically require more inputs of water, maintenance, and chemicals than other types of plants. Native or drought-tolerant turf species or beds planted with shrubs, groundcover, and perennials can replace non-native lawns. In order to irrigate lawns efficiently, design them with relatively small perimeter areas and in flowing, rounded shapes. Long, skinny, or oddly shaped turf areas are difficult to negotiate with most irrigation equipment.

Figure 5

TREE PROTECTION FENCING



Source: City of Austin, Environmental and Conservation Services Department, Sustainable Building Sourcebook. (Austin: City of Austin, 1993).

❑ **Minimize use of annual plants.**
Annuals often require more irrigation than perennials, as well as higher labor and capital inputs for seasonal replanting. Perennial plantings can be designed to include a wide range of species to ensure staggered bloom cycles for long periods of color interest. Many perennials do require some additional maintenance such as seasonal pruning, which should be taken into account in maintenance plans.

❑ **Establish high and low maintenance zones.**
Group plants with similar water-use needs by determining which areas of the site should receive a higher level of care than others and, during drought periods, more irrigation. Coordinate these areas with the irrigation plan. Higher-maintenance areas should be located around major building entries and high-traffic areas. Lower-maintenance zones are low-traffic areas, buffer zones, and service areas.

Gray- and Blackwater Systems

★ SIGNIFICANCE

Worldwide industrial-sector water consumption totals 973 cubic kilometers per year.[10] Most of the wastewater flow(s) generated from this use is treated through conventional, centralized sewage treatment plants that require large inputs of capital, energy, and chemicals, and then is discharged into waterways, sometimes causing negative environmental conditions such as algae blooms.

The current capital need for new or upgraded sewage treatment plants totals over $66 billion nationally.[11] Alternative sewage systems can help minimize water-quality impacts and are often less costly to operate than conventional treatment plants. They often require less energy, less capital investment, and smaller quantities of chemicals. Alternative methods of dealing with centralized wastewater treatment include land application of reclaimed wastewater, septage lagoon systems, and composting of sewage sludge for use as a soil amendment.

Diverting or reusing wastewater before it enters the centralized wastewater stream minimizes loading of municipal water treatment plants. As an added benefit, the resulting treated effluent can be utilized on-site as an irrigation source that contains valuable plant nutrients or as part of a design feature in an attractive landscape.

Water diverted from the waste stream is either graywater or blackwater, which require different on-site handling. Graywater is wastewater generated from indoor uses such as laundries, showers, and sinks, and can be reused in toilet-flushing or irrigation to help minimize loading on any type of wastewater treatment system and reduce overall water consumption. To utilize graywater, a dual plumbing system must be installed to separate it from blackwater, which is wastewater generated from toilet-flushing. Blackwater can be treated on-site through a variety of conventional or alternative systems.

☞ SUGGESTED PRACTICES AND CHECKLIST

Indoor Water Conservation

❑ **Reduce overall water use.**
Reducing overall water use reduces wastewater. Water-efficient fixtures and appliances are readily available, including toilets that are virtually waterless. Faucet bubblers, low-flow showerheads, and flow restrictors further reduce water consumption.

❑ **Perform a water budget analysis to project the amount and configuration of daily wastewater flows.**
Estimate water usage and wastewater generation based on standard use patterns and the number of building occupants, then analyze the figures to determine opportunities for conservation, sources and amounts of graywater available, and other opportunities for efficiency.

Graywater Systems

❑ **Separate and use graywater generated from indoor uses such as laundries, showers, and sinks.**
Many public and commercial facilities generate relatively small amounts of graywater; other types of commercial and industrial facilities may generate large quantities. For example, a vehicle-maintenance facility that uses large quantities of water to wash trucks can realize considerable savings by recycling washwater. Therefore, volume should be considered in deciding whether it is cost-effective to treat graywater and blackwater separately.

❑ **Check with the local health-code department to learn about regulations governing the use of graywater.**
Usually, irrigation with graywater is required to be subsurface, although some areas permit above-ground irrigation. Factors affecting the approval and use of graywater irrigation systems include soil depth and characteristics as well as drainage and flooding patterns. Other guidelines include setbacks for graywater irrigation lines from property or potable-water lines. Each state has individualized standards for graywater irrigation systems. Two states that have standards encouraging graywater use are Texas and California.

❑ **Install dual plumbing lines in building interiors.**
Dual plumbing separates graywater from blackwater. Dual plumbing is not difficult to install, but is most-cost effective if done during initial construction. If dual plumbing lines are not installed initially, adding a graywater treatment system later can be quite expensive. For this reason, install dual distribution lines in new facilities if a graywater system may be incorporated in the future.

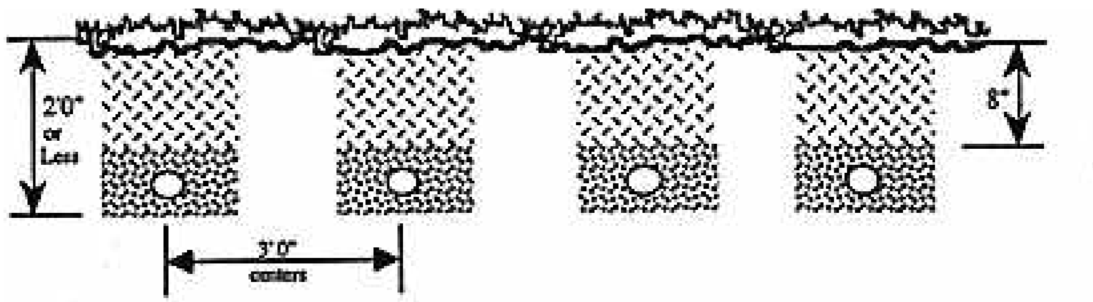
❑ **Utilize graywater for nonpotable purposes.**
Recycle graywater via a dual distribution system, for such nonpotable water uses as toilet-flushing, thereby avoiding unnecessary use of high-quality potable water. Another major use of graywater is for irrigation of areas such as golf courses, ornamental landscapes, and turf areas. A separate tank, filter, and special emitters are necessary in graywater irrigation systems. Types of irrigation systems that can utilize graywater include: (1) drip irrigation with pressure dosing, which uses a pump system to "dose" the irrigation water at regulated intervals; (2) more traditional evapotranspiration systems; and (3) shallow trench systems, which utilize distribution pipes placed close enough to the surface to allow for irrigation of plant roots (*Figure 6*). In some areas, above-ground or spray irrigation is possible.

Blackwater Systems

❑ **When possible, treat blackwater from toilet-flushing with on-site systems.**
- Utilize innovations such as low-pressure dosing systems in conjunction with septic tanks to overcome limitations of soil, geology, or topography.
- Consider biological systems such as constructed wetlands. Constructed wetlands are artificial wetlands used for waste treatment. As wastewater flows through the wetland, plants and naturally occurring microbes remove waste. This technology can be used at a variety of scales, from wastewater treatment for an individual building to treatment for entire communities. Two types of systems, the surface-flow wetland, and the subsurface-flow wetland, can be utilized. Surface flow wetlands, also called wastewater lagoons, usually use a tiered system of ponds with wetland plants to treat wastewater. Subsurface-flow wetlands, also called microbial rock plant filters, are soil-less, and utilize a gravel medium to anchor plants. Wastewater flows through the gravel and is not visible at the surface. Effluent from both types of systems must be handled through irrigation or other methods.
- Consider sand filters and aerobic tank treatment. Sand filters, a low-cost wastewater treatment technology, have been in use for many years. Aerobic tank systems offer advantages over traditional septic tanks, which do not use oxygen to treat waste.
- Consider composting toilets. Composting toilets are a nearly waterless technology for dealing with human waste, combining the waste with organic material, such as lawn clippings, to produce a nearly odorless product that can be used as a soil amendment. Large-scale composting toilets capable of handling large numbers of users are available commercially. This type of technology is being applied at the municipal scale through a practice known as "sludge composting."
- Consider aquaculture systems. In aquaculture systems, wastewater becomes a source of food for plants and fish. In the process, water is purified, as plants and fish ingest pollutants. This type of system requires high management, but produces food and fertilizer in return.

❑ **Check with the local health-code department to learn about regulations governing blackwater systems.**
Treatment and definitions of blackwater vary—in some jurisdictions, blackwater is wastewater generated from toilet flushing; in others, it includes water from kitchen sinks or laundry facilities.

SHALLOW TRENCH SECTION VIEW



Source: City of Austin, Environmental and Conservation Services Department, Sustainable Building Sourcebook. (Austin: City of Austin, 1993).

Figure 6

Water Reclamation

❑ **Use reclaimed water for purposes such as toilet-flushing if dual distribution lines are in place.**

Reclaimed or reused water is wastewater effluent from a centralized water treatment plant that is reused in a variety of ways: for fire protection, in outdoor water features, for street cleaning, for wetlands recharge, or for industrial purposes such as cooling water, boiler-feeder water, or process water.

❑ **Check local regulations on use of reclaimed water.**

No federal regulations regarding water-reuse practices currently exist, although the EPA has published a manual on the subject (see "Resources"). Many states have adopted water-use regulations, but these vary considerably. According to a survey conducted in 1992, 18 states had adopted regulations for reclaimed water reuse, 18 states had guidelines or design standards, and 14 states had no regulations or guidelines. Most of the standards in place pertain to urban or agricultural irrigation. Regulations in some states (Arizona, California, Florida, and Texas) strongly encourage water reclamation as a conservation strategy. Regulatory guidelines for water reclamation usually pertain to reclaimed water-quality and treatment requirements, water-monitoring requirements, reliability of treatment facilities, storage requirements, irrigation application rates, groundwater monitoring, and property-line setback distances for applications. The objective of these regulations is usually to maximize resource benefits while protecting environmental and public health.[12]

❑ **Apply reclaimed effluent to land.**

This technique works best with wastewater treatment of at least 10 million gallons per day. Effluent can be distributed on golf courses, farmland, orchards, or other land. This alternative to discharging treated wastewater into streams and waterways has several benefits, including biological treatment of wastewater, recharging of groundwater, use of the water as a resource, and protection of surface-water quality. In some areas, an hydraulic irrigation-control and -release system is used, diverting effluent to a holding lagoon during wet seasons when irrigation is not needed. Permitted discharges are released from the lagoon to a waterway as necessary. The system can be fully automated and provide for flexible use.

❑ **Establish site-specific monitoring procedures.**

When using reclaimed water for irrigation or land application, monitor to control overwatering and detect buildup of nitrogen, phosphorus, potassium, calcium, iron, and sodium.

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CHAPTER 7

Site Materials and Equipment

Author
Kim Sorvig

Outdoor construction and site modification rely on diverse materials: living plants and soils, raw materials, and manufactured items. The careful selection of site materials is an essential part of environmentally conscious design. Selection variables to be considered include toxicity in manufacture and use; energy consumption in extraction, manufacture, or transport; potential to intensify heat, glare, runoff, wind, or other climatic factors; and, in the case of plant materials, invasiveness, water consumption, and disease susceptibility.

Material performance depends upon bio-regional characteristics: a plant or paving stone suitable in Miami is unlikely to perform well in Anchorage or Albuquerque. Likewise, material selection must be specific to the proposed uses of the site: native grasses or porous asphalt may be ideal for low-traffic locations, but not for heavily used public spaces. Specialized site knowledge is essential to making good choices, and early integration of regionally appropriate, ecologically based principles can significantly enhance project success.

Soils and Soil Amendments

★ SIGNIFICANCE

Soil is an irreplaceable living resource that, once removed or killed, can take decades (in some regions millennia) to re-form.[1] While soil serves many mechanical purposes for construction, regarding it as inert invites problems—from mudslides and cracked foundations to unhealthy landscape plantings. For these reasons, soil characteristics must be respected during design, and the soil itself protected during and after construction. Sustainable development avoids building on prime agricultural soils, and requires that on each site enough undamaged, fertile soil remain after construction to support plant and wildlife diversity, infiltrate precipitation, and filter pollutants that cannot be controlled at their sources.

Soil fertility not only supports plant life but also disperses and filters water, and neutralizes or binds many air and water pollutants. The source of all these benefits is the topsoil, a gossamer-thin blanket over the earth; its depth is a millionth or less of the earth's radius (0.5 inch to 48 inches is typical of most North American soils).[2] Topsoil consists of two parts: a mineral element (sand, silt, and clay in varying proportions, weathered from subsoil) and organic materials (decaying plant and animal remains known as humus). These organic materials are digested and churned by micro- and macroscopic soil organisms whose health is essential to fertile soil.

Soils vary in water-holding ability, nutrient content, pH and salinity, and humus content. They may also be contaminated or, in rare cases, naturally toxic. Each aspect can dramatically affect plant, animal, and human life on the site, as well as construction projects.

Soil's mechanical properties affect what can be built on a site. Depth and strength of bedrock affects structures, excavations, and costs. Percolation affects septic systems and flooding. Erodible soils are vulnerable to foot or vehicle traffic and to changes in vegetative cover. Erosion can damage a watershed's ability to distribute and retain water, contribute to flooding, and contaminate water sources. Performance and review of site-specific soil analysis reveal how these factors affect a building project.

☞ SUGGESTED PRACTICES AND CHECKLIST

❑ **Involve a qualified site-design professional on the design team early in the project.**

❑ **Obtain and evaluate the chemical and physical characteristics of site soils.**
A general picture of soil characteristics is available for most U.S. counties from the U.S. Soil Conservation Service's *Soil Survey*, and is essential for early planning and design work. Before proceeding with detailed design, contract with a reputable soil-testing laboratory. Be sure the service includes a written evaluation of soil suitability for the proposed use, and recommendations for soil remediation and amendment. Use soil analysis to rule out contamination before the site is purchased.

❑ **Amend the soil in planting areas according to professional advice.**
Involve a qualified site-design professional on the team early in the project. Develop a plan to leave as much of the native soil undisturbed as possible. Amendments may include sand or gravel for improved drainage, lime or other pH modifiers, organic manures, and chemicals to improve nutrient availability. Humus is used to increase water-holding capacity, as are proprietary superabsorbent materials. In some cases, amendment may involve specific plowing or irrigation activities—for example, to break a hard-pan or to leach out excessive salts.

❑ **Protect the soil during construction.**
Soil compacted or contaminated by construction activity may become lifeless.

- Design for minimal grading. Where grading is unavoidable, carefully remove and stockpile existing topsoil, replacing it after rough grading. Depending on soil-test findings, the top four to six inches of soil are usually stockpiled.
- Plan construction sequences that minimize heavy-equipment movement over the soil; restrict all equipment, including private vehicles, generators, etc., to areas that will be paved or built over.
- If soil compaction is unavoidable (as with a construction-access road) remediate by tillage and amendments before completing work.

(See Chapter 19, "Environmental Construction Guidelines.")

❑ **Carefully design for grading and excavation.**
In siting facilities, work with the existing topography to save both construction and maintenance costs. Avoid disrupting existing drainage patterns; equalize cut-and-fill; and in general minimize grade changes where possible. Grading for stormwater control

should direct water to planted areas to minimize irrigation needs. Steep sites may benefit from terracing and retaining walls.

❑ **Follow all applicable erosion-control regulations.**
During construction, any exposed soil is susceptible to erosion and contributes to sedimentation downstream. Most jurisdictions require erosion and sedimentation protection.

❑ **Stabilize soil during and after construction.**
Commonly used temporary controls include filtration barriers (straw-bale dams, filter-fabric fences), soil tackifiers, jute netting, hydroseeding with quick-sprouting plants like annual rye-grass, or mulch. More permanent soil stabilization may be required: use geo-textiles (fabrics designed to filter soil from water); soil “cells” separated with masonry, wood, or fabric; and crib- or retaining walls.

❑ **Use bio-engineering.**
One of the most effective, and certainly the most ecological, of soil-stabilization methods is bio-engineering, which weaves live woody cuttings into a living retaining structure that mimics the soil-retention capabilities of matted roots.[3] The flexibility of such live structures protects them from wash-out problems common with rigid constructions.

❑ **Schedule soil-maintenance tasks.**
A site-specific schedule of soil-maintenance tasks, in parallel with planting-maintenance tasks, should be developed.

Plant Materials and Management

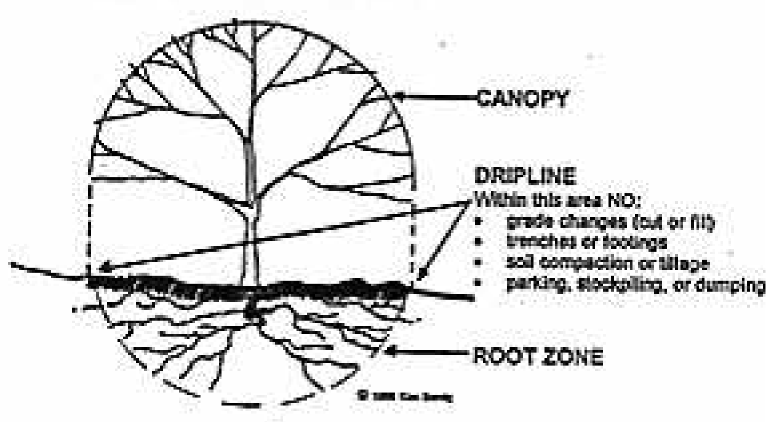
★ SIGNIFICANCE

Without plants, life on earth would cease. Plants provide oxygen; purify air; buffer climatic conditions; and modify shade, sun, wind, temperature, run off, and humidity. Landscape planting can also separate incompatible activities, allowing better use of space. Most cultures treat well-planned, healthy landscapes as important assets; this can add significant resale value to buildings.[4]

Site design and planting affect ecosystem diversity. The average garden contains only a few plant species, less diverse than most native plant communities. Landscapes planted with predominantly non-native species and maintained with pesticides tend to reduce overall diversity and increase water use, thus damaging native ecosystems. Habitat destruction, to which non-native planting can contribute, causes nearly half of all species extinctions.[5] Sustainable development strives to maintain native habitat, and avoids fragmenting it or replacing it with less diverse vegetation.

Figure 1

THE DRIPLINE: A RULE OF THUMB TO PROTECT EXISTING TREES FROM ROOT DAMAGE



☞ SUGGESTED PRACTICES AND CHECKLIST

❑ **Include an ecologically knowledgeable landscape architect as an integral member of the design team.**

❑ **Preserve existing vegetation, especially native plants.**
- Design to avoid sprawl, which destroys native plant communities.
- Use greenbelts and protected wetlands to create a continuous web of native habitats (also serving as bikeways and trails) through which animals can migrate safely. Many communities have greenbelt groups and ordinances, both valuable sources of advice and guidance.
- Decrease parking, paving, and lawns to the minimum that will actually be used.
- Make every space serve several functions; where possible, make the landscapes of public or institutional buildings available to the local community, rather than fencing them off.
- Avoid "replacing" healthy mature trees with small nursery stock.

❑ **Protect existing plants during construction** *(Figure 1).*
Delineate and fence the "dripline" (area directly under the canopy) of all trees. Prohibit parking, stockpiling, heavy-equipment movement, or excessive foot traffic in fenced plant-protection zones within driplines; enforce with a liquidated-damages clause.

❑ **Design new plantings as diverse communities of species well-adapted to the site.**
Use primarily native species: they usually require less maintenance and less water than exotics after establishment (one or more seasons). Do not, however, expect "no-maintenance" landscapes. Reserve exotics for accents. Avoid use of any plant that is invasive: such species overrun native ecosystems. Avoid monocultures (plants of all one species or age), and use plants which attract desirable wildlife.

❑ **Follow Xeriscape™ principles.**
A trademarked term referring to water-efficient choices in planting and irrigation design. The seven basic Xeriscape™ principles for conserving water and protecting the environment are: planning and design, use of well-adapted plants, soil and climate analysis, practical, reduced turf areas, use of mulches, appropriate maintenance, and efficient irrigation by grouping plants with similar water needs. Coordinate plantings with water harvesting systems.[6]

❑ **Use plants to mitigate climate conditions.**
Deciduous plants, when correctly located, provide shade in summer and admit sun when their leaves fall for winter, a natural technique for passive solar design. Evergreen trees can provide year-round sun and wind protection (see Chapter 11, "Renewable Energy"). Windbreak plantings diminish wind within a distance three times their height. To decrease noise significantly, a wide (200-foot) band of plantings is required.

❑ **Use a reputable nursery or contractor to supply and install plants.**
Do not accept wild-dug plants, which may be endangered, and whose removal impoverishes other landscapes. Specify plants grown in the same U.S. Department of Agriculture (USDA) Hardiness Zone as the site, preferably within a 200-mile radius. Seed or seedlings may be cost-effective for mass planting, and tend to develop good hardiness. The planting contract should require the contractor to plant during the correct season (which varies by species), and to maintain all plantings through at least one full growing season after planting, with a warranty to replace any plant that dies within that time.

❑ **Employ integrated pest management (IPM) against insects and weeds.**
IPM uses biological controls as a first defense; if such non-toxic controls fail, carefully timed and targeted pesticides are used. Biological controls include parasitic insects, which destroy pests; pheromone (sex-scent) traps; natural pesticides like pyrethrum; and companion-planting. Artificial pesticides should be chemically targeted to a nar-

row range of pest species, and should be chemically non-persistent in soil, air, or water. They must also be *physically* targeted, using accurate, low-volume applicators to avoid drift and oversaturation. Workers must be trained in proper application.

- ❑ **Use mulching, alternative mowing, and composting to maintain plant health.** Organic mulch around plantings conserves water and maintains favorable soil temperatures. Mulch may be purchased; cleared or trimmed vegetation can be chipped economically for mulch using a rented chipper. Mulching mowers leave fine clippings on lawns as mulch. Any form of mulch eventually breaks down and recycles its nutrient content. Composting plant debris in piles or bins hastens this breakdown; the compost is then used as soil amendment. Many municipalities maintain composting services. Compost maintains soil fertility better than chemical fertilizer, and helps landscape plants resist pests and diseases without pesticides.

- ❑ **Compile and follow a seasonal maintenance task list.** Regular maintenance is essential to a healthy landscape that fulfills the design vision as it grows. The schedule should specify times for pruning, watering, fertilizing, and pest inspection.

Paving Materials

★ SIGNIFICANCE

Thousands of acres of land are paved annually in this country, although much of the paved area is under used: streets deserted except at rush hour, church parking lots barren during the work week, and city-hall spaces vacant on weekends. Underutilized paved surfaces waste materials, energy, and financial resources and eliminate natural habitat for plants and animals.

To create stable surfaces for human activities, most traditional paving excludes water from the soil. This impermeability results in increased run off, erosion, flooding, and loss of soil fertility. Pavement retains heat, contributing significantly to urban "heat sinks" and increased HVAC energy use. It also can cause uncomfortable glare and create harsh, alienating environments.

Zoning laws in some communities limit the creation of new impermeable surfaces. A variety of permeable paving surfaces, as well as non-pavement soil-stabilization methods, can partially overcome the disadvantages of "conventional" paving.

☞ SUGGESTED PRACTICES AND CHECKLIST

- ❑ **Limit paved areas to the strict minimum for their intended purpose.** For example, parking spaces based on the nine- by 18-foot standard save nearly 20 percent more land area than ten- by 20-foot spaces. Many zoning ordinances overcalculate parking "needs." In such cases, seek a variance and consult recent federal laws, like the Intermodal Surface Transportation Efficiency Act (ISTEA), that strike a more reasonable balance between private cars and transportation alternatives. The Act provides funding for state and metropolitan transportation planners to integrate car, bus, train, bicycle, and pedestrian modes of transport, thus reducing dependence on private cars.[7]

- ❑ **Carefully distinguish between light-vehicular, heavy-vehicular, and pedestrian paving.**

  In landscape design, vehicular-strength paving is often used by default even for sidewalks; this unnecessarily eliminates beautiful alternative materials, and wastes materials and money, since many paving materials are non-renewable and energy-intensive, and should not be wasted.

- ❑ **Use water-permeable or "porous" paving.**

  Porous asphalt and concrete are made with aggregates carefully sorted to eliminate "fines" (small particles). Removing fines opens voids that allow drainage, yet porous paving retains most of the strength of conventional paving. Porous paving is suited to parking and lightly used roads; in high-traffic areas, combine it with conventional paving.[8]

  Other permeable systems include block-lattices, which permit drainage but give stability (grass grows in the lattice spaces, while the blocks support vehicles). Lattices are best used for occasional access (fire lanes, overflow parking); constant traffic may kill the grass, as may harsh climates. Some permeability can also be achieved by setting traditional stone or masonry pavers on sand instead of on concrete.

- ❑ **Design paving to serve dual purposes.**

  Porous paving is often constructed over a gravel reservoir sized to hold stormwater volume, thus combining parking and a retention basin within a single area. Such space saving is both economically and environmentally sound.

- ❑ **Design to minimize runoff.**

  Curbed pavement edges concentrate runoff, which increases potential for erosion and flooding. Where possible, porous gutters and curbless designs spread run off more usefully. In general, runoff should be infiltrated as close as possible to its source; flow concentrated over long distances picks up speed and erosive power, and disrupts the distribution patterns of natural precipitation. Infiltration at the source is also more cost-effective (see also Chapter 6, "Water Issues").

- ❑ **For light-duty roads and paths, stabilize *without* pavement.**

  Correctly installed, crushed stone or brick is a stable, porous surface. Proprietary chemical additives can bond soil particles for stability. Geotextile webs and strips are used, much like the straw in traditional adobe, to increase soil strength without affecting its drainage or growing characteristics. Such surfaces are slightly flexible, which minimizes cracking and decreases maintenance costs.

- ❑ **Locate pavement where solar heat gain is desirable.**

  Texture, type, and color of pavement can reduce or concentrate heat or glare if coordinated with prevailing climate conditions. Coordinate paving design with plantings and shade structures to avoid glare and unwanted heat gain. These factors are particularly important in hot and cold environments.[9]

Materials for Site Construction and Furnishings

★ SIGNIFICANCE

Careful selection of site construction materials can reduce energy consumption and waste, increasing human comfort without excessive environmental costs. Inappropriate selection of materials can cause resource depletion and environmental contamination, either at the site or at the source of the material. Many environmental effects of resource use are indirect. Only a few common site materials are directly toxic to soils or plants;

others, not themselves toxic, require toxic processes in their manufacture. Site material extraction (like logging or mining) can also have environmental consequences by increasing erosion and contaminating water bodies.

Site materials face severe conditions, such as exposure to water, freezing, and ultraviolet rays.[10] When site materials fail, resources are wasted and soil or water may be contaminated. Materials must also be physically and psychologically comfortable for outdoor use: for example, metal seating is uncomfortable except in moderate temperatures.

No single rule or practice can guarantee materials that are both environmentally appropriate and suitable to their construction purpose. Materials should be compared not only against other materials, but against the baseline of a "no-build" option. Consider each material's "embodied energy," the known amount of energy expended in its extraction, transportation, production, recycling, and disposal. Selecting products manufactured locally can reduce embodied energy by decreasing transportation. Also important is the product's life cycle. Life-cycle cost (LCC) analysis takes into account purchase, operation, maintenance, replacement, and disposal costs over the expected service life of the product, thus revealing cost/benefits more clearly than conventional cost analysis.[11] Life-cycle assessment (LCA) is a related analysis method that helps compare the environmental consequences of material choices. (See the American Society for Testing and Materials (ASTM) Standards E 917-93 and E-50.06 (Draft); and Chapter 2, "Selecting Environmentally and Economically Balanced Building Materials," for more information on LCC and LCA.)

☞ SUGGESTED PRACTICES AND CHECKLIST

❑ **Reduce material use, reuse, and recycle—in that order of priority.**
- Reduce material requirements through effective site layout. For example, re-routing a walkway or rotating a building can eliminate a costly retaining wall and site grading. Structures designed and sited without careful regard to site-specific conditions create structural, maintenance, and ecological problems.
- Specify reused materials where possible. With the exception of railroad timbers, reuse is rare in landscape materials. In some regions, used brick is a popular commodity, and other durable items like flagstones are reused.
- Specify recycled-content materials for site use, based on life-cycle performance requirements. Wood substitutes made of recycled plastic are now available as lumber and in site furniture. Concrete and asphalt can also be recycled.

❑ **Use new materials thoughtfully; consume the minimum for the purpose; avoid waste.**
Support manufacturers whose product literature includes environmental data. Consider renewability (can the material be *grown* or naturally replenished?), sustainable production (will resources be used up too fast?), and recyclability. For example, wood is renewable and recyclable, but production of some timber species is not sustainable at current rates of consumption. Several natural ecological timber organizations provide useful information about these issues.

❑ **Perform an environmental-impact and cost analysis of all materials based on life-cycle principles.**
(See Chapter 2, "Selecting Environmentally and Economically Balanced Building Materials," and Chapter 17, "Specifications.")

Irrigation Equipment

★ SIGNIFICANCE

In dry regions of the United States, landscape irrigation can constitute half a city's water usage; up to half of that is wasted.[12] Facing such statistics, municipalities are enforcing water-efficiency laws and strictly monitoring commercial landscape irrigation.

Automatic irrigation systems can save water when compared to hand-watering or flood irrigation. However, by definition, any form of irrigation involves addition of surface water beyond what is naturally found on-site. The baseline for evaluating irrigation strategies should be natural precipitation and practices that rely on it. Even efficient irrigation should not be *assumed* to be environmentally responsible without comparison against this baseline.

☞ SUGGESTED PRACTICES AND CHECKLIST

❑ **Base irrigation design on Xeriscape™ principles.**
See "Plant Materials and Management" section of this chapter concerning this approach to water-efficient irrigation and planting design.[13] Always coordinate design of planting and irrigation system.

❑ **Employ water-harvesting techniques.**
Using processed city water for irrigation is wasteful, since plants do not require potable water, and are often vulnerable to chlorine. For landscape purposes, use cisterns or ponds to collect run off from roofs and pavement. Check dams trap runoff in pockets to support plants, as do swales. Diversion of water along key contour lines, or "keylines," efficiently spreads runoff along topographic planes for gradual release[14] (see Chapter 6, "Water Issues").

❑ **Use graywater in irrigation.**
Graywater plumbing (separated from sewage pipes, either by retrofit or in new construction) can save money and reduce water consumption (see Chapter 6, "Water Issues").

❑ **Install drip irrigation systems.**
Drip irrigation systems direct water accurately onto the base of each plant. Drip systems may use less than half the water of conventional systems, which lose water to evaporation and soak areas of soil that may not need water. Uniform drip watering often produces faster, healthier plant growth. Surface drip systems usually use "spaghetti tubing" while underground systems use "leaky" pipe (permeable-walled pipe specific to underground drip irrigation).

❑ **Increase efficiency of irrigation with controllers and sensors.**
Timers and computers provide measured amounts of water at regular intervals. Sensors override the timer in response to rainy or windy conditions, reducing waste. Such controls and the electrical valves they operate require power, either from a transformer or, in some systems, solar electricity.[15]

❑ **Be sure design and layout of the irrigation system are site-specific.**
Topography, structures, and drainage affect the direction, height, and coverage of spray-heads. The site's lowest sprinkler often leaks wastefully after the system is turned off, as water further uphill drains to the low point. Overspray can result either from bad design or from wind. Drip systems avoid these problems, but share the problem of pressure drop: the farther water flows through a pipe, the lower its pressure.

❑ **Maintain irrigation systems regularly for efficiency.**
Poor maintenance causes significant water losses and undermines the value of irrigation systems. Periodically adjust sprinkler output by testing actual performance with a rain-gauge. Inspect for vandalism, accidental damage, and sinkage; reset sprinkler heads flush with the ground. Regularly inspect for leakage. Drain the system for winter, and flush it when reactivating. Recent systems are self-cleaning; older ones may require flushing to remove sediment.

Outdoor Lighting and Electrical Systems

★ SIGNIFICANCE

Lighting consumes about one-fifth of all U.S. electricity; of this, existing efficiency measures could save an estimated 90 percent. Site lighting, one of the fastest-growing sectors of the lighting industry, can be carefully designed to avoid waste. The environmental and social costs of this type of lighting must be carefully weighed against its benefits.

"Light pollution" can disrupt biological cycles in plants and animals, including humans. Glare increases hazards by blinding people and making areas outside the light even less visible. Jurisdictions like Tucson, Arizona, with astronomical observatories and other specialized facilities, have legislated against light pollution, which often hinders effective stargazing by over-illuminating the night sky.

☞ SUGGESTED PRACTICES AND CHECKLIST

❑ **Light the minimum area for the minimum time.**
Limit all-night illumination to areas with actual all-night use or extreme security concerns—simple timers or photocells can be used to turn lights on and off at seasonally appropriate times. For security lighting, motion-sensors can spotlight intruders without beaming constant glaring lights.

- Use cut-off fixtures, shades, or highly focused low-voltage lamps to avoid spillover. Linear "tube lights" and fiber-optics can light the way for pedestrians without illuminating a whole area.
- Question the "brighter is better" myth, especially for security and advertisement.
- Some local ordinances encourage excessive lighting; seek waivers or revisions.

❑ **Clearly identify the actual purpose of lighting to determine minimum acceptable levels.**
Hazard lighting is usually focused on the hazard, bright enough to warn, identify, and allow judgment of distance. Area lighting, seldom as bright or focused, allows a user to choose a safe route.[16] Follow manufacturer's guidance on light distribution and intensity.

❑ **Use energy-efficient lamps and ballasts.**
The most efficient new lamps produce *ten times* as many lumens per watt of power as a conventional incandescent bulb. Most newer bulbs are designed to fit old fixtures; some require a conversion kit. Operating-cost savings (including deferred bulb replacement, labor, and equipment rental for inefficient, hard-to-reach parking-lot lamps) quickly recover the cost of re-lamping. New fixtures are often miniaturized, allowing design flexibility.

❑ **Use low-voltage lighting.**
Increased efficiency has made 12-volt or 24-volt lighting effective and popular for site lighting.[17] Lower-voltage fixtures are safer and often less expensive to install than typical 120-volt options. They can decrease power and energy usage.

❑ **Use renewable energy sources for lighting and other outdoor power.**

Photovoltaic (PV) power is generally cost-effective if a site is over 200 yards from the utility grid, and is an attractive alternative to power lines running through a site.[18] PV power is low-maintenance and very reliable. Its design *must* be specific to both the region and the site. It is possible to incorporate PV panels attractively into architectural elements like windows and roofs. Photovoltaic power requires storage batteries for nighttime lighting. Manufacturers offer solar path-lights, streetlights, and security lights. Extremely bright all-night lighting is difficult to achieve with PV power; however, as noted above, it is desirable to avoid such lighting strategies. Solar electricity is also ideal for running pumps, including irrigation systems. Solar-powered water purification and even solar lawn-mowers are becoming available, and deserve consideration.[19] For daytime uses, batteries are not usually needed, except where long cloudy periods are common (see Chapter 11, "Renewable Energy").

→ RESOURCES

SOILS

Brady, Nyle C. *The Nature and Properties of Soils*. 8th ed. New York: Macmillan, 1974. Classic text on the make-up, fertility, and mechanics of soils.

Carter, Vernon Gill, and Tom Dale. *Topsoil and Civilization*. Rev. ed. Norman, Okla.: University of Oklahoma Press, 1974. Sobering account of human dependence on soil.

Davidson, Donald A. *Soils and Land Use Planning*. New York: Longman, 1980. How soil characteristics can make or break zoning and development policies.

Olson, Gerald W. *Field Guide to Soils and the Environment: Applications of Soil Survey*. New York: Chapman and Hall, 1984. Unlocking the wealth of information found in USCS *Soil Surveys*.

Schiechtl, Hugo. *BioEngineering for Land Reclamation and Conservation*. Edmonton: University of Alberta Press, 1980. Detailed techniques of soil stabilization and protection using live plant structures.

U.S. Soil Surveys map soils by county and give information on engineering and ecological characteristics of site-specific soils. Contact the U.S. Soil Conservation Service, P.O. Box 2890, Washington, DC 20013, 202/447-4543 (Canada: 306/695-2284).

PLANT MATERIALS

Regional native-landscaping books are essential for ecologically appropriate planting design. If a garden design book does not state which geographic region it covers, assume that it focuses on the Eastern Deciduous Forest region. It is also likely to include many British horticultural imports without noting that these are non-native.

Cornell University. Bailey Hortorium. *Hortus Third: A Concise Dictionary of Plants Cultivated in the United States and Canada*. New York: Macmillan, 1976. Standard reference on plants cultivated in the U.S., including origin. Third or later editions recommended.

Druse, Ken. *The Natural Garden*. New York: Potter, 1989. How to design minimal-maintenance gardens with native plants.

Harker, Donald, et. al. *Landscape Restoration Handbook*. Boca Raton, Fla.: Lewis, 1993. Region-by-region reference (continental U.S.) listing best plants for restoring damaged ecosystems; maps and plant-category tables aid selection.

Hightshoe, Gary L. *Native Trees, Shrubs, and Vines for America: A Planting Design Manual for Environmental Designers*. New York: Van Nostrand Reinhold, 1988. Each native species illustrated; its growing needs, natural range, and landscape value charted.

Smyser, Carol A. *Nature's Design: A Practical Guide to Natural Landscaping*. Emmaus, Penn.: Rodale, 1982. Includes regional plant lists and a brief introduction to biological pest controls, plus excellent design methodology.

PAVING MATERIALS

Jacobs, Allan B. *Great Streets*. Cambridge, Mass.: MIT Press, 1993. Illustrated examples of successful streetscapes.

Paine, Jon E., ed. *Pervious Pavement Manual*. Orlando, Fla.: Florida Concrete and Products Association. Construction manual for porous concrete. Contact the Florida Concrete and Products Association, 649 Vassar St., Orlando, Fla. 32804, 800/342-0800.

Sorvig, Kim. "Porous Paving" *Landscape Architecture*, February 1993; and "The Path Less Traveled," *Landscape Architecture*, December 1994. Washington, D.C.: American Society of Landscape Architects. Porous asphalt and concrete, soil-cement, stabilized soil, and crushed traditional pavements are discussed.

Untermann, Richard K. *Accommodating the Pedestrian: Adapting Towns and Neighborhoods for Walking and Bicycling*. New York: Van Nostrand Reinhold, 1984. Strategies for existing developments or new ones to become less car-centered and more people-friendly.

U.S. Department of Energy. Lawrence Berkeley National Laboratories. *Cooling Our Communities*. U.S. Government Printing Office Document no. 055-000-00371-8. Paving and planting strategies to avoid heat build-up.

Vance, Mary A. *Garden Walls, Walks and Steps: A Bibliography*. Monticello, Ill.: Vance Bibliographies, 1986. Source-listing of information on paving and outdoor construction from many authors.

SITE CONSTRUCTION MATERIALS

American Society for Testing and Materials. Standard E 917-93. *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems.* Philadelphia, Penn.: ASTM, March 1993.

American Society for Testing and Materials. Subcommittee on Green Buildings. *Standard Practice for Green Buildings*. Standard E-50.06, draft document, 1993. Contact ASTM, 100 Barr Harbor Drive W., Conshohocken, PA 19428, 610/832-9500.

Fisk, Pliny. *Bioregions & Biotechnologies* and *Sustainable Design Compendium*. Austin, Tex.: Center for Maximum Potential Building Systems, n.d. How to use native resources to produce ecologically intelligent development. Contact the Center for Maximum Potential Building Systems, 8604 F.M. 969, Austin, TX 78724, 512/928-4786.

Landphair, Harlow C., and Fred Klatt. *Landscape Architecture Construction*. New York: Elsevier, 1978. Standard reference on hardscape techniques.

Robinette, Gary O. *Landscape Architectural Site Construction Details*. Reston, Va.: Center for Landscape Architectural Education and Research, 1976; distributed by Environmental Design Press. Illustrated with construction detail drawings.

Sorvig, Kim. "Brave New Landscape." *Landscape Architecture*, July 1992. Washington, D.C.: American Society of Landscape Architects. Emerging and experimental materials in landscape construction. *Landscape Architecture*'s "Technique & Practice" column runs monthly updates on materials.

IRRIGATION EQUIPMENT

Ellefson, Connie; Tom Stephens; and Doug Welsh. *Xeriscape Gardening: Water Conservation for the American Landscape*. New York: Macmillan, 1992. Detailed instructions on irrigation and planting design; low-water plant-lists for all U.S. regions.

Gates, Jane Potter. *Drip, Trickle and Surge Irrigation*. Beltsville, Md.: National Agricultural Library, updated periodically since 1992. Review of irrigation technology and products.

Mollison, Bill. *Permaculture: A Designer's Manual*. Tyalgum, Australia: Tagari, 1988. Sourcebook of sustainable living techniques; includes many water-harvesting methods.

Sorvig, Kim. "Sun on the Water." *Landscape Architecture*, September 1994. Washington, D.C.: American Society of Landscape Architects. Solar-powered landscape irrigation.

Watkins, James A. *Turf Irrigation Manual: The Complete Guide to Turf and Landscape Sprinkler Systems*. Dallas, Tex.: Telsco Industries, 1987. Discusses irrigation hardware. Most irrigation manufacturers also offer detailed design manuals.

OUTDOOR LIGHTING AND ELECTRICITY

Moyers, Janet Lennox. *The Landscape Lighting Book*. New York: Wiley, 1992. Complete treatment of design, equipment, installation, and maintenance of outdoor lighting.

Post, Hal, and Vernon Risser. *Stand-Alone Photovoltaic Systems: A Handbook of Recommended Design Practices*, Albuquerque: Sandia National Laboratories, 1988. Complete manual for planning and installing solar-electric power for any purpose.

Schaeffer, John, ed. *Alternative Energy Sourcebook: A Comprehensible Guide to Energy Sensible Technologies*. Ukiah, Calif.: Real Goods Trading Corporation, updated annually. Catalog with detailed technical explanations; items can be purchased through Real Goods.

Sorvig, Kim. "Low-Voltage Lighting," "New Light on the Landscape," "Transformations of Light," *Landscape Architecture,* January 1994; August 1993; and February 1994. Washington, D.C.: American Society of Landscape Architects. Reviews of current lighting for landscape use, including fiber optics and other unusual equipment.

NOTES

1 Nyle C. Brady, *The Nature and Properties of Soils*, 8th ed. (New York: Macmillan, 1974), 309.

2 Ibid., 9–10.

3 Hugo Schiechtl, *BioEngineering for Land Reclamation and Conservation* (Edmonton: University of Alberta Press, 1980), 37–139. This comprehensive source should be read thoroughly by anyone interested in bioengineering.

4 Lloyd W. Bookout, *Value by Design: Landscape, Site Planning, and Amenities* (Washington, D.C.: Urban Land Institute, 1994), 1–125. Detailed study of the value-added aspects of site design.

5 Daniel Chiras, *Environmental Science* (Redwood City, Calif.: Benjamin/Cummings, 1994).

6 Connie Ellefson, Tom Stephens, and Doug Welsh, *Xeriscape Gardening: Water Conservation for the American Landscape* (New York: Macmillan, 1992), esp. 3–130.

7 See Architectural Graphic Standards or similar reference works for national standards, and use minimum sizing possible, unless barred by local code. For information on ISTEA (Federal Law PL 102–240 enacted 1991) call your state Department of Transportation or the American Society of Landscape Architects Government Affairs Office, (202) 686–8351.

8 Kim Sorvig, "Porous Paving," *Landscape Architecture*, February 1993.

9 US Department of Energy. Lawrence Livermore Labs, "Cooling Our Communities," US Government Printing Office Document #055–000–00371–8 (Washington, D.C.: GPO, n.d.).

10 For discussion and examples, see Janet Lennox Moyer, *The Landscape Lighting Book* (New York: Wiley, 1992). Chapter 7 concerns corrosion of materials in contact with soil and weather; Moyer notes that several manufacturers experienced serious losses by merely adapting indoor fixtures for outdoor use (interview with the author, Albuquerque, 1994).

11 See Post and Risser, *Stand Alone Photovoltaic Systems* (listed in Resources) for clear examples of life-cycle costing, with worksheets.

12 Ellefson, Stephens, and Welsh, 3.

13 Ibid., 9. Principles of design and irrigation, and regional plant lists, are included.

14 Bill Mollison, *Permaculture: A Designer's Manual* (Tyalgum, Australia: Tagari, 1988), 155–170, 336–358.

15 Kim Sorvig, "Sun on the Water," *Landscape Architecture*, September 1994.

16 Jot. D. Carpenter, ed., *Handbook of Landscape Construction* (Washington, D.C.: Landscape Architecture Foundation, 1976), 191–200. Includes table of desirable illumination levels for various functions.

17 Kim Sorvig, "Low-Voltage Lighting," *Landscape Architecture*, January 1994.

18 Hal Post, and Vernon Risser, *Stand-Alone Photovoltaic Systems: A Handbook of Recommended Design Practices* (Albuquerque: Sandia National Laboratories, 1988), 2, 7–86. Excellent detailed discussion, in clear language, of all aspects of photovoltaic use.

19 For information, consulting services, and supply of these and other alternative-power systems, see John Schaeffer, ed., *Alternative Energy Sourcebook: A Comprehensible Guide to Energy Sensible Technologies* (Ukiah, Calif.: Real Goods Trading Corporation, updated annually).

CHAPTER 8

Local Government Information: Site Issues

Sustainable Site Design

Author
Michael Myers

IMPLEMENTATION ISSUES

Environmentally sound site selection and design are evolving processes that integrate local needs with the existing natural environment and pre-existing infrastructure. Designers of local government projects should be especially aware of such issues as access to the site by public transportation, impact of development on the surrounding community, and inclusion of public amenities, such as recreational green space.

Fortunately, local governments are well-positioned to address these issues. They can influence the direction of development, for example, by promoting the redevelopment of urban areas, including abandoned industrial properties (or brownfields). This development strategy takes advantage of existing infrastructure, including sewers, roads, mass transit, and utility corridors; encourages environmental cleanups; and brings jobs to under-employed communities. It also reduces urban sprawl, which contributes to eroding urban tax bases, regional air-quality problems, and the destruction of farmland and natural resources. Local governments can encourage such reuse of existing or abandoned properties and develop green building strategies to promote revitalization of existing urban communities by working with state and federal agencies to revise zoning regulations and provide financial assistance and incentives to development initiatives.

Local governments can also consider and implement development options that utilize telecommunications technology to reduce transportation needs. Telecommuting, including the establishment of telecommuting centers, is being tested in communities across the United States. In addition, the redevelopment of older urban centers can be enhanced by the addition of telecommunications capacity in existing buildings.

As local governments consider site selection for and design of municipal, commercial, and residential structures, they also need to consider disaster resistant planning. Choices that keep in mind possible long-term weather trends can help jurisdictions avoid costly post-disaster relief and rebuilding measures. (See also Chapter 25, "The Future of Green Building.")

LOCAL ACTIONS

- ➤ The Stapleton Redevelopment Project, approved in March 1995 by the Denver, Colorado, Planning Board, is developing a mixed-use plan for the 4,700-acre site of the city's former international airport. The project is based on sustainable principles. It strives not only to integrate urban development, transportation, natural systems, and wildlife habitat, but also to create a balanced mix of uses and densities—including parks, housing, and businesses—for efficient, accessible, and diverse neighborhoods and communities.

  The city's planning team is using a geographic information system (GIS) to assemble data on climate, water resources, land use, transportation, infrastructure, and community energy resources. This information will be used with the computer-based PLACES methodology to model present and future development options. Denver will be able to predict the impact and cost of development and design resource-efficient sites before any new structures are built.

  The Stapleton Redevelopment Project also plans to reuse the airport terminal itself, turning the building into a site for new green businesses, as well as a center for established companies focusing on national and international business opportunities in the environmental and technology fields. Finally, the project will tap nearby community and academic resources to sponsor sustainable educational and training opportunities at the airport-terminal site.
- ➤ The Pennsylvania-based Slippery Rock Foundation, with a grant from the Howard Heinz Endowment, has developed *Guidelines for Sustainable Development* that provide design, construction, and operations suggestions. The guidelines provide basic green site-development recommendations, for example, the reuse of existing structures and already disturbed areas, evaluation of site resources, minimization of paving and impervious surfaces, and analysis of the future impact of a site within the broader context of community.
- ➤ The town of Carrboro, North Carolina, has instituted an architectural process that allows flexibility in site design and development. Carrboro's Arcardia neighborhood, for example, is in the process of developing 33 lots on 16 acres that have narrower-than-usual streets and homes built to satisfy passive solar guidelines. The homes feature radiant-heated floors and some photovoltaic hot-water systems; their landscape design reflects attention to water conservation and use of native plants.
- ➤ The city of Austin, Texas, *Sustainable Building Guidelines* encourage habitat preservation and site restoration, landscape designs that provide passive solar cooling, and the addition of plants and fountains to municipal buildings with main lobbies or to "front yards" of municipal buildings to create pleasant public gathering places.
- ➤ The new Clark County, Nevada, Government Center boasts landscaping that is both drought-tolerant and complementary to the building design and the natural environment. The center's planners have concentrated turf in a single multipurpose, functional area that provides a visual oasis as well as a community space for theater, music, and public gatherings.
- ➤ The village of Charlotte, North Carolina, is developing a mixed-use building project of 164 dwellings on 22 acres—while minimizing additional roads. Sustainability and ecological concepts, including construction-waste recycling and the use of graywater for irrigation, are part of the development process.

- ➤ The city of Chicago, Illinois, has launched a brownfield redevelopment program to promote new investment in older neighborhoods and inner suburbs. In 1993, Chicago formed an interdepartmental working group on brownfields to devise more responsive environmental and economic development policies, to develop economic models that account more accurately for the environmental and social costs and benefits of development decisions, and to implement pilot projects. Initial work on five brownfield sites has already resulted in remediation of the sites and buildings so that redevelopment can occur. These efforts will create local employment opportunities and improve the appearance and safety of the neighborhoods they target.
- ➤ After undertaking a regional planning effort, the city of Portland, Oregon, decided to concentrate development along mass-transportation corridors, encourage infill through zoning and loan incentives, and strive to retain green areas around the urban center.
- ➤ The city of Chula Vista, California, has developed telecommuting centers at decentralized neighborhood locations to reduce traffic congestion and air pollution. These centers offer fully equipped office and meeting rooms, videoconferencing and Internet access, and interactive video classrooms. The city encourages commuters to walk or cycle to the centers.
- ➤ To spur redevelopment in downtown Manhattan, the city of New York, the Alliance for Downtown New York, and other public and private development partners have established the New York Information Technology Center. Equipped with fiber optics; maximum band width, high-speed copper wire; Internet connectivity; state-of-the-art voice, video, and data transmission; and advanced telecommunications and data security, the building is a high-technology hub for the city's redevelopment efforts.
- ➤ The towns of Valmeyer, Illinois, and Pattonsburg, Missouri, following devastating floods in 1993, have taken the opportunity to replace and rebuild their communities, using sustainable development principles. To help avoid future flood disasters, the town of Valmeyer decided to relocate on higher ground, and, with resources from the U.S. DOE and state of Illinois, to incorporate energy efficient designs in its private and public buildings. Pattonsburg, working with the U.S. DOE and Federal Emergency Management Agency, developed a new town vision for the future that includes active public education and participation and passive solar land use plans.

LOCAL OPTIONS

- ■ Develop a sustainable development plan for the community by scanning local resources and environmentally sensitive areas, mapping commercial and industrial areas, and identifying areas with the highest potential for public or private development or redevelopment.
- ■ Promote the reuse of buildings by assessing existing structures to evaluate their suitability for physical renovation or for upgrades of utilities and telecommunications infrastructure to match current needs.
- ■ Provide incentives for the redevelopment of inner-city areas, including brownfield sites, and for the use of resource-conserving practices when building on undeveloped greenfield areas.
- ■ Assess transportation access—bus, bicycle, and pedestrian—when considering a site for development or redevelopment of municipal buildings.
- ■ Assess the addition of information technology in new or existing buildings to reduce transportation needs and increase economic viability.
- ■ Integrate transportation planning, including mass-transit and transportation-reduction measures, with long-range urban and regional land-use plans.
- ■ Integrate sustainable landscaping principles, including retention of native plants, pleasing aesthetics, and multiple recreational uses, into the design of public outdoor areas.

- Provide guidelines for building orientation and siting that take advantage of solar access and other natural features.
- Integrate sustainable siting and building principles into disaster redevelopment projects.

Water

IMPLEMENTATION ISSUES

By regulation, education, and example, local governments are preventing water pollution, boosting water efficiency, protecting native vegetation, and using rainwater and graywater to meet water needs more resourcefully.

Local governments are implementing ordinances governing water runoff from construction and completed building sites to protect watersheds and the water quality of local creeks, streams, and lakes. Through public construction projects, cities and counties are also demonstrating to their communities that bioswales, semi-permeable pavement, and vegetative buffers can reduce non-point-source pollution.

Aware that efficient water usage impacts utility costs, wastewater treatment, and the quality of local water resources, jurisdictions are also promoting implementation of water-efficiency measures in all buildings: residential, multifamily, institutional, and commercial. Federal regulations have made indoor water-conserving fixtures, including 1.6-gallon toilets and efficient water-flow devices, readily available through most plumbing retailers; outdoor water conservation products are equally widespread. Local governments can recommend or require other water efficiency practices in their municipal projects.

Just as effective for cost-savings and the management of water resources are landscaping practices that use water-conserving or native plants. Public construction projects in many jurisdictions are educating residential and commercial builders about the use of native plants, plant-protection measures, and habitat preservation and restoration. Jurisdictions can compile an inventory of native plants to be used for public and private landscaping projects or direct builders to local nurseries or landscape architects that specialize in these plants.

Rainwater and graywater collection, despite their technical simplicity, are less easily implementable, but no less effective, strategies for water conservation. Communities may find these systems difficult to implement because of regulatory restrictions. Local governments can both provide examples of the effectiveness of these systems in public projects, and ensure that codes and permitting processes help, not hinder local builders from trying these alternatives.

A range of rainwater-collection systems, used for centuries in various forms, remain a practical option to collect water for irrigation and, in some communities, supply indoor water usage, including drinking water. Storage tanks or cisterns can be purchased in various sizes and colors and are available regionally.

Graywater systems for surface and subsurface applications are in place in many rural and in some urban areas. Many urban areas, however, may not allow installation of graywater systems, and if so, only as subsurface irrigation systems following specific health and usage regulations. Graywater systems can most easily be utilized during new construction, when separate collection and distribution lines can be installed most cost-effectively.

LOCAL ACTIONS

- Prince George's County, Maryland, has used bioretention practices in several revitalization, urban retrofit, and capital improvement projects designed to reduce urban runoff pollution entering waterways and, ultimately, the Chesapeake Bay. In one stormwater management project, the county added vegetation and settling ponds to an existing concrete drainage system; planted vegetative buffers between a parking area and the storm drain; and developed a constructed wetland to test the effectiveness of these practices in cleaning water runoff. The county has investigated, with the University of Maryland, ways to reduce non-point-source pollution resulting from pedestrian traffic and grounds-maintenance and storage practices at the university. Both partners explored improved practices for stormwater management and wildlife habitat retention. The university agreed to implement recommendations from the study as part of its normal maintenance operations.
- The city of Bellevue, Washington, has passed an ordinance tying stormwater bills to the amount of impermeable surface on each property within its jurisdiction. Each property in Bellevue is assessed in direct relation to its size and degree of development; fees from these assessments help fund water-quality protection. The city has established six categories of development, each assigned a coefficient for bill calculation purposes (wetland = 0.0, undeveloped = .25, light development = .40, moderate development = .50, heavy development = .75, very heavy development = 1.0). Any property can be downgraded one category if a water-detention area is constructed.
- The city of Portland, Oregon, Bureau of Environmental Services will build a new Water Pollution Control Laboratory to enable early detection of substances potentially harmful to operations of the city's wastewater treatment facility, and to reduce contaminants entering the Willamette River. The laboratory site will feature a state-of-the-art experiment in stormwater treatment: the Water Demonstration Garden, a pool with wetland plant life specially designed to clean stormwater naturally. The site will also feature a bio-engineered riverbank to stabilize the area, and a greenway along the waterfront.
- The city of Vancouver, Washington, is addressing limited water resources and rapid urban growth through the Climate Friendly Plant Program. This plant identification and marketing project, initiated by Vancouver's two primary water utilities, aims to reduce outdoor water usage by encouraging wide planting of native and non-native water-conserving vegetation commonly sold at local nurseries. These plants are often disease-and pest-resistant, reducing chemical pesticide use and resulting water pollution. Local utilities and nurseries market the city program.
- The city of San Diego, California, offers a free Residential Water Survey Program in which city technicians audit a home's indoor and outdoor water use and recommend specific conservation methods. The survey includes installation of low-flow showerheads, Xeriscape™ information, and a supply of native flower seeds. A typical household can reduce water consumption by 13 percent. Over 10,000 residents have participated in the program to date.
- The city of Austin, Texas, has developed three major watershed-protection ordinances to address urban runoff pollution of local waterways. Included in the ordinances are measures limiting impervious surfaces, encouraging buffer zones, limiting disturbances of natural streams, implementing erosion controls, and promoting construction of sedimentation and filtration basins. Integrated pest management plans that reduce outdoor chemical use are specifically required for projects in areas covered by the city's watershed ordinances, restrictive covenants, or zoning variances. Additional ordinances mandate protection of trees and natural areas, monitoring of water quality, and retrofits of pollution controls in areas identified as polluting.
- In another sustainable move, Austin has set a goal of reducing water consumption in municipal buildings by 30 percent. The city's plumbing codes require efficient fixtures, and suggest conservation practices for cooling towers, Xeriscape™ practices for landscapes, and use of rainwater, reclaimed-water, and graywater systems. Staff recommend

the collection and use of rainwater for irrigation, and the potential use of reclaimed water for irrigation, toilet-flushing, vehicle-washing, and cooling-tower make-up. Austin's Water and Wastewater Utility provide additional assistance in water-quality, health, and regulatory issues, particularly as these relate to the use of reclaimed water.

➤ Austin's *Sustainable Building Guidelines* are a valuable source of information on graywater and blackwater systems, as well as harvested rainwater collection. The guidelines include ordinances and regulations affecting use, a licensing and approval process, design considerations, and information on local experts and sources of systems components for storage and irrigation.

➤ Jordan Commons, a Habitat for Humanity housing development under construction in south Metro Dade County, Florida, is a model ecological community. Water conservation is one hallmark of its builders' efforts: all 187 homes will be fitted with water-efficient fixtures and 40 homes will feature graywater systems that use treated wastewater to recharge the aquifer and promote subsurface irrigation.

LOCAL OPTIONS

- Conduct an analysis of the non-point-source pollution impact of local water runoff from the built environment.
- Develop local guidelines to reduce non-point-source pollution and disruption to natural water cycles in the urban environment by reducing non-permeable surfaces and constructing vegetated drainage channels.
- Develop guidelines that require the collection of water runoff that may pollute local water resources during the construction or rehabilitation of buildings.
- Establish municipal landscape guidelines that promote local plants, which have low maintenance and water requirements.
- Design harvested-rainwater collection systems to supply irrigation water to local parks and recreation areas.
- Establish a water-fixture replacement program to upgrade equipment in existing municipal facilities, commercial buildings, and homes.
- Promote water conservation efforts and reduce water end-use in the design of new municipal facilities through water-conserving fixtures and graywater or harvested-water systems. Review local ordinances and modify them to allow the collection and use of harvested water, graywater, and reclaimed wastewater.
- Educate municipal, commercial, and residential building occupants about water conservation, pollution prevention, and construction-related practices—as well as pertinent local, state, and federal regulations—to ensure that water quality is maintained.

Materials and Equipment

IMPLEMENTATION ISSUES

Local governments that integrate sound soil maintenance and landscaping practices and efficient irrigation systems can reduce their use of natural resources, such as water, and maintenance supplies, such as pesticides or fertilizers. In doing so, they not only cut costs, but also benefit the environment—especially by restoring native plants and wildlife habitat.

Green building projects (and green buildings themselves) also offer local governments opportunities to educate their communities. By limiting permeable surfaces; using recycled-content outdoor equipment, such as trash cans or benches; and installing renewable-energy-powered lighting in outdoor public areas, cities and counties can demonstrate to their public the availability, durability, and practical application of green materials. For example, businesses, citizens, and public employees can work together in advisory committees to help shape green landscaping plans and environmentally sensitive choices of equipment and furnishings for public buildings, parks, and recreational areas.

LOCAL ACTIONS

- ➤ The city of Austin, Texas, suggests using ground-up wallboard (gypsum) as an amendment for clay soils; chipped wood from demolition for mulch; and recycled asphalt, concrete, and bricks for fill or aggregate.
- ➤ Codes in Metro-Dade County, Florida, allow demolition materials, such as concrete and bricks, to be used as fill in construction sites. They require the demolished material to be free of other substances, such as wood, that would contribute to sink holes. By reusing the material, builders avoid the landfill fees associated with demolition-waste disposal.
- ➤ The Health House '95, sponsored by the American Lung Association and built in Hennepin County, Minnesota, and the '95 Health House built in Orlando, Florida, both reflect a design concept called "naturescaping," used to incorporate native plants and recycled materials on the house sites.
- ➤ Metro-Dade County, Florida, offers property-tax breaks to commercial developers as incentives for preservation of existing vegetation on environmentally sensitive sites. Developers are required to actively maintain existing vegetation for 10 years in return for a tax break that is better, in some cases, than an agricultural exemption.
- ➤ The city of Austin, Texas, Nature Center, which provides a natural habitat for indigenous plants and animals, is a living learning tool for those who study the science and natural history of the area. Its educational resources include a pond trail exhibit and a hands-on compost demonstration area.
- ➤ The city of Durham, North Carolina used plants and recycled products for the landscape restoration of a park following the expansion of a road interchange. The city's Water Resources Department and its Parks and Recreation Department worked with citizen groups to plant several "pods" of trees and shrubs, reintroducing native species and eliminating labor-intensive turf.
- ➤ The city of Austin, Texas, offers the expertise of landscape architects from its Environmental Services and Conservation Department's Water Conservation Program to help other municipal departments design resource-efficient landscape and irrigation systems. The architects have developed a Preferred Plant List for municipal projects that emphasizes native and low-water plants, and recommended integrated pest management practices. Xeriscape™ landscapes in Austin, studies have shown, use 30 to 50 percent less water than traditional landscapes use.
- ➤ The city of Sarasota, Florida used a permeable pavement to allow public access to and parking on a parcel of land in a pineland marsh reserve. The pavement, a six-inch plastic cellular confinement system, known commercially as GEOWEB, is covered with six inches of stone in-fill and one inch of stone cover to allow both permeability and access, even during the rainy season. The system's cost is only one-third that of a traditional paved road.
- ➤ The cities of Atlanta, Georgia; Baltimore, Maryland; Miami, Florida; Milwaukee, Wisconsin; and Austin, Texas, are participating in the "Cool Communities" program, in partnership with American Forests and the U.S. Environmental Protection Agency. This program seeks to reverse heat-island effects of urban areas, to reduce energy usage

and global warming, by the strategic planting of trees and use of light-colored surfaces for roads, parking lots, and building roofs and walls.

➤ The city of San Diego, California, Park and Recreation Department developed efficient turf-irrigation systems to minimize water use. Irrigation system replacements, retrofits, and performance checks have resulted in a combined total reduction in water usage for 1990 to 1994 of 1,700,000 hundred cubic feet (HCF), a cost savings of over $2 million for the department despite the addition of over 40 new parks since 1989.

➤ Communities in Chittenden County, Vermont, have begun to set standards and guidelines for exterior lighting to preserve the region's natural nighttime beauty. The goal is to increase energy efficiency, provide clear standards and guidelines for lighting designs, and preserve nighttime landscapes. The municipalities of Burlington, Shelburne, and Richmond, key players in the effort, are all concerned about the control of overall illumination levels, glare, and color distortion from outside lighting. Other concerns include balancing aesthetics, safety and security, and the capital or operating costs of lighting fixtures; the impact of high-pressure sodium street lights on the natural and built environment; and, in some cases, discouraging the installation of new lighting in neighborhoods.

LOCAL OPTIONS

- Develop site-maintenance plans for municipal properties that include soil upkeep with mulch and composted materials, integrated pest management, reduced fertilizer use, and native plants with low irrigation needs. Use drip irrigation and programmable timers for irrigation systems with rain shut-off valves.
- Sponsor site design competitions. *Landscape Architecture* magazine, for example, sponsors an annual competition for innovative, ecologically sensitive residential landscape designs.
- Develop a native plant list for the region. Indicate a preference for native plants for landscaping projects on public property and make the list available for private developers.
- Involve the public in identifying and mapping trees of significance to the community. Develop a Tree Preservation Plan for municipal construction projects, and encourage commercial and residential projects to adopt it as a model.
- Designate the use of products with recycled content for the construction of park benches, fences, storage sheds, and walkways for municipal projects, when economically feasible. Locate regional sources for equipment and furnishings featuring recycled content or reusable materials.
- Require municipal projects to use semipervious parking pavers or no paving, where feasible, or require them to match a percentage of parking spaces with a certain number of new trees. Encourage these practices in commercial projects also.
- Develop lighting guidelines that balance safety, aesthetics, and community values. Consider renewable energy resources, such as photovoltaic systems, for outside lighting along landscapes, trails, and walkways, and for other electrical needs.

➜ RESOURCES

Resources for the Local Government Information chapters are located in the Appendix.

PART IV

Building Design

Introduction

Building design is moving into an extraordinary phase of evolution in this decade. Strategies that have been considered "cutting-edge" in the recent past—such as passive solar design, environmentally sensitive design, and design that emphasizes indoor environmental quality—are now becoming prominent and economically feasible. In Part IV, these strategies are applied to the design process to offer a new perspective on buildings—one that exceeds conventional practice in a variety of ways.

In Section A, the chapters deal with passive solar design through a discussion of daylighting, building envelope, and renewable energy—the basic strategies of green design that adapt a building to its site and climate. Section B focuses on building systems—heating, ventilating, and air-conditioning (HVAC) systems; lighting; and electrical technologies that support and must be integrated with the passive design in an efficient and appropriate manner. Other chapters in Section B address indoor environmental quality, including air quality and acoustics, and building commissioning. Section C provides a decision process and criteria for selecting environmentally sound materials for a construction project, and the means to incorporate environmental components into construction specifications.

An integrated approach is required for successful application of these strategies. The whole picture is one of a building as a complete system, with the building siting, form, envelope, systems, and contents simultaneously interacting together and fitting their setting in nature. The resulting building will perform as a resource-efficient and cost-effective system designed to enhance occupants' productivity and health. A whole-team approach, commencing early in the design process, is necessary to achieve this.

The greening of public and commercial buildings is a large agenda, perhaps too large for any individual or organization to undertake in one step. It is a real challenge to include or optimize all of these design strategies in one project, but every renovation or new building project can emphasize at least some of these strategies and achieve higher-than-normal levels of efficiencies and performance. The process is evolutionary and progresses incrementally.

SECTION A

Passive Solar Design

Passive solar design is a broad term used to encompass a wide range of strategies and options resulting in energy-efficient building design and increased occupant comfort. The concept emphasizes architectural design approaches that minimize building energy consumption by integrating conventional energy-efficient devices, such as mechanical and electrical pumps, fans, lighting fixtures, and other equipment, with passive design elements, such as building siting, an efficient envelope, appropriate amounts of fenestration, increased daylighting design, and thermal mass. Many passive buildings are compatible with active components such as solar hot water systems. In short, "passive solar design balances all aspects of the energy use in a building: lighting, cooling, heating, and ventilation. It achieves this by combining, in a single concept, the use of renewable resources and conventional, energy-efficient strategies."[1]

The basic idea of passive solar design is to allow daylight, heat, and airflow into a building only when beneficial. The objectives are to control the entrance of sunlight and air flows into the building at appropriate times and to store and distribute the heat and cool air so it is available when needed. Many passive solar design options can be achieved at little or no additional cost. Others are economically viable over a building's life-cycle.

The U.S. Department of Energy has shown that passive solar buildings use 47 percent less energy than conventional new buildings and 60 percent less than comparable older buildings. Passive solar design strategies can benefit most large buildings and all small buildings.[2] It has been used effectively in an estimated 17,000 commercial buildings in the United States—ranging from offices and warehouses to schools, health care centers, libraries, and airport terminals. Passive solar design is best suited to new construction and major renovation because most components are integral elements of the building. Depending on siting, the range of improvements planned, and the building's characteristics, a number of passive strategies can potentially be incoporated into existing buildings. For example, designers can consider using advanced glazings when replacing windows during a renovation.[3]

Properly designed and constructed passive solar buildings offer many benefits to building owners and occupants, including:[4]

- **Energy Performance:** Lower energy bills year-round.
- **Investment:** High economic return on the incremental investment on a life-cycle cost basis and greater financial independence from future rises in energy costs. These can lead to higher tenant retention and satisfaction, which can correlate to higher building value and lower risk (see Chapter 1, “The Economics of Green Buildings”).
- **Comfort:** Greater thermal comfort, less reliance on noisy mechanical systems, solid construction (more thermal mass), sunny interiors, and open floor plans.
- **Productivity:** Increased daylighting, higher quality lighting systems, and reduced glare can increase worker productivity and reduce absenteeism (see Chapter 1, “The Economics of Green Buildings”).
- **Low Maintenance:** Reduced building maintenance costs resulting from less reliance on mechanical systems.
- **Environmental:** Reduced energy usage and reliance on fossil fuels.

Successfully integrating passive solar design strategies requires a systematic approach that begins in the pre-design phase and carries throughout the entire design process. It is critical that the building owners and the design team agree to integrate passive solar design considerations during the appropriate project phases. The following passive solar design strategies should be included during the building-design process.[5]

- **Site Selection:** Evaluate building site options/positions for solar access and use of landscaping elements.
- **Programming:** Establish energy-use patterns and set priorities for energy strategies (e.g., daylighting versus efficient lighting); determine base-case conditions and conduct life-cycle cost analysis; establish an energy budget.
- **Schematic Design:** Maximize site potential by considering orientation, building shape, and landscaping options; conduct a preliminary analysis of representative building spaces as they relate to insulation, thermal mass, and window type and location; determine the available daylighting; decide on the need for passive heating or cooling load avoidance, lighting, and HVAC systems. Determine the preliminary cost-effectiveness of options and compare the budgets.
- **Design Development:** Finalize the analysis of all individual building zones, including analysis of design element options and life-cycle costs.
- **Construction Documents:** Simulate total building projections and develop specifications that meet the intent of energy-efficient design.
- **Bidding:** Use life-cycle cost analysis to evaluate alternates or “equals.”
- **Construction:** Communicate to the contractor the importance of adhering to design elements and ensure compliance.
- **Occupancy:** Educate occupants on the intent of the energy design and provide an operations manual for maintenance staff.
- **Post-Occupancy:** Evaluate performance and occupancy behavior for comparison with goals.

The optimal combination of passive solar design features is not always intuitively obvious. In order to analyze the choices, a base case is established—a building that corresponds to the overall architectural program but does not use passive solar strategies. Energy and economic comparisons are made between the base case and various combinations of passive and energy-efficient design strategies. The final design is checked to confirm that energy performance goals established earlier have been met.

Passive building design starts with consideration of siting and daylighting opportunities and the building envelope; then building systems are considered. Almost every element of a passive solar design serves more than one purpose. Landscaping can be aesthetic while also providing critical shading or direct air flow. Window shades are both a shading device and part of the interior design scheme. Masonry floors store heat and also provide a durable walking surface. Sunlight bounced around a room provides a bright space and task light. Critical design areas include the following:[6]

- **Thermal Protection:** Provides appropriate levels of insulation and minimal air leakage.
- **Windows:** Transmit heat, light, and air between interior space and the outside environment.
- **Daylighting:** Reduces lighting and cooling energy use; creates a better working environment, leading to increased comfort and productivity.
- **Thermal Mass:** Stores excess heat in winter; in summer, cools down during the night and absorbs heat during the day. This can help to shift peak cooling and heating to off-peak hours.
- **Passive Solar Heating:** Allows heat to enter the building during the winter months and rejects it during the summer months through the use of appropriate amount and type of south-facing glazing and properly designed shading devices. Most valuable in cooler climates.
- **Energy-Efficient Lighting:** Uses efficient lamps, ballasts, controls, and luminaries coordinated with daylight and color of interior space to provide the requisite level of light.
- **Internal Heat-Gain Control:** Minimizes heat gain generated by lights, people, and equipment through the use of daylighting, thermal mass, efficient equipment selection, and venting.
- **Passive Cooling with Natural Ventilation:** Incorporates controlled air exchanges through natural or mechanical means. Helps to increase energy performance of buildings in most locations.
- **Energy-Efficient HVAC System:** Reduces system load by integrating above-listed design strategies and using measures such as efficient motors, heat pumps, variable speed drives, and sophisticated building controls.

Section A of the manual contains three chapters that address areas of primary importance for passive solar design: daylighting (Chapter 9), building envelope (Chapter 10), and renewable energy systems (Chapter 11). Although discussed in individual chapters, these three elements need to be considered in an integrated and simultaneous manner, along with energy-efficient mechanical and electrical systems, discussed in Chapter 12, "HVAC, Electrical, and Plumbing Systems." Review of such measures in isolation can lead to a reduction of the overall energy efficiency potential.

NOTES

1 Passive Solar Industries Council (PSIC) and National Renewable Energy Laboratory (NREL), *Designing Low Energy Buildings—Integrating Daylighting, Energy-Efficient Equipment, and Passive Solar Strategies* (Washington, D.C.: Passive Solar Industries Council, n.d.), 10.

2 Ibid., 2, 7.

3 U.S. Department of Energy, National Renewable Energy Laboratory, Federal Energy Management Program, "Renewable Energy Technologies for Federal Facilities" (brochure)(Golden, Colo.: National Renewable Energy Laboratory, September 1995).

4 PSIC and NREL, *Designing Low Energy Buildings*.

5 Ibid., 20-21.

6 Ibid., 11-18.

CHAPTER 9

Daylighting

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★ SIGNIFICANCE

Daylighting is the practice of bringing light into a building interior and distributing it in a way that provides more desirable and better-quality illumination than artificial light sources. This reduces the need for electrical light sources, thus cutting down on electricity use and its associated costs and pollution. Studies substantiate that daylighting creates healthier and more stimulating work environments than artificial lighting systems and can increase productivity up to 15 percent.[1] Daylighting also provides changes in light intensity, color, and views that help support worker productivity. Surveys have shown that 90 percent of employees prefer to work in spaces with windows and a view to the outside.[2] In one study, 75 percent of office and factory workers stated that daylight provides better quality illumination than artificial light.[3]

Daylighting significantly reduces energy consumption and operating costs. Energy used for lighting in buildings can account for 40 to 50 percent of total energy consumption. In addition, the added space-cooling loads that result from waste heat generated by lights can amount to three to five percent of total energy use. Properly designed and implemented daylighting strategies can save 50 to 80 percent of lighting energy.[4]

Greater use of daylighting can also provide advantages for the environment by reducing power demand and the related pollution and waste byproducts from power production. Lighting—and additional building cooling requirements from lighting—use an estimated 20 to 30 percent of total United States energy production.[5] About three-quarters of this amount is used to light commercial and industrial buildings. If extensive daylighting measures achieved only a 40 percent lighting energy savings, total national electricity consumption would be reduced by six to nine percent.[6] In addition, the greatest savings from daylighting occur during periods when sunlight is most intense, which coincides with periods of peak demand for heating, ventilating, and air-conditioning (HVAC) and refrigeration loads. Therefore, wider use of daylighting would reduce both the need for new peak demand capacity and overall power demand.

Daylighting requires the correct placement of openings, or *apertures,* in the building envelope to allow light penetration while providing adequate distribution and diffusion of the light. A well-designed system avoids excessive thermal gains and excessive brightness resulting from direct sunlight, which can impair vision and cause discomfort.[7] To control excessive brightness or contrast, windows are often equipped with additional elements such as shades, blinds, and light shelves. In most cases, the daylighting system should also include controls that dim or turn off lights when sufficient natural light is available to maintain desired lighting levels. It is also often desirable to integrate daylighting systems with the artificial lighting system to maintain required task or ambient illumination while maximizing the amount of lighting energy saved (see Chapter 12, "HVAC, Electrical, and Plumbing Systems").

Recent daylighting innovations offer a wide range of advanced, highly efficient, and, in some cases, highly engineered systems. In reviewing these options, the practitioner should recognize that higher efficiency and improved daylighting performance may entail additional costs. The benefits of daylighting include improved visual quality, better lighting-color rendition, reduced solar heat gain, and improved visual performance and productivity. These benefits can make any increased engineering and installation costs a worthwhile investment for the building owner or employer.

☞ SUGGESTED PRACTICES AND CHECKLIST

Design Process

Programming Phase

❑ **Establish daylighting performance objectives and requirements.**
Performance objectives may include savings in lighting-energy costs, cooling-load reductions, visual quality, and views to the outside. The designer should establish required illumination levels to meet the needs of the building occupants and the tasks they perform. *Table 1* provides illumination standards established by the Illuminating Engineering Society (IES). These levels have been reduced significantly over the past decades because it is now generally accepted that illumination can be reduced in situations where the quality of light is high and background surface reflectance is optimal. See *Table 2* for recommended interior surface reflectance values.

❑ **Analyze lighting performance needs using the following procedures:**
- Perform a solar-path analysis for the latitude at the site;
- Perform preliminary aperture-optimization studies (optimal window-to-floor ratio, optimal skylight-to-floor ratio);
- Determine the design illumination levels for various program functions based on IES standards (see *Table 1*); and
- Perform a preliminary life-cycle cost-benefit analysis. (Refer to Moore in "Resources" section.)

Preliminary Design Phase

❑ **Establish basic daylighting parameters as part of the building design.**
- Establish the location, shape, and orientation of the building on the site based on daylighting performance objectives as part of an integrated passive solar heating and cooling strategy.
- Establish fenestration design objectives based on optimization studies.
- Establish energy-efficient artificial illumination systems based on design illumination levels and energy-efficiency targets.
- Perform a preliminary life-cycle cost-benefit analysis of daylighting systems as an integrated part of the total building system. Consider qualitative benefits such as increased productivity and reduced absenteeism, as well as the direct costs of design systems when assessing costs and benefits. (Refer to Moore, in "Resources" section.)

RECOMMENDED ILLUMINATION LEVELS

Type of Activity	-3,-2 weight (footcandles)	-1 to +1 weight (footcandles)	+2,+3 weight (footcandles)
Public spaces with dark surroundings	2	3	5
Simple orientation for short, temporary visits	5	7.5	10
Working spaces with occasional visual tasks	10	15	20
Visual tasks of high contrast or large size	20	30	50
Visual tasks of medium contrast or small size	50	75	100
Visual tasks of low contrast or small size	100	150	200
Visual tasks of low contrast and very small size over prolonged periods	200	300	500
Exacting and prolonged visual tasks	500	750	1000
Very special visual tasks of extremely low contrast and small size	1000	1500	2000

Weight Factor Determination*

	Weight		
Task and Worker Characterisitcs	-1	0	+1
Worker Age	Under 40	40-55	Over 55
Speed and/or Accuracy	Not Important	Important	Critical
Reflectance of Background	> 70%	30-70%	< 30%

***Note: Use the Weight Factor Determination to establish the range of values as part of the design illumination requirements.**

Source: Illuminating Engineering Society. Lighting Handbook. (New York: IES, 1979.)

Table 1

RECOMMENDED SURFACE REFLECTANCE VALUES

Surface	Range of Surface Reflectance (low - high)
Ceiling	80% - 90%
Walls	60% - 65%
Floor	20% - 50%

Source: Illuminating Engineering Society. Lighting Handbook. (New York: IES, 1979.)

Table 2

- Determine the optimal effective aperture for toplighting strategies.
- Incorporate fenestration into the basic building geometry.
- Perform daylighting studies using computer-simulation tools and physical-model evaluation. Conduct studies of both direct-beam irradiance on a heliodon and diffuse sky illuminance under an artificial sky, if possible. (Refer to Evans, Hopkinson, Moore in "Resources" Section.)
- Establish lighting-control strategies, including the use of logical zoning and selection of either continuous dimming, stepped, or on-off switching.

Design Development Phase

❑ **Specify details for lighting systems and products.**

- Specify glazing materials based on climate, fenestration position, and solar orientation, maintaining the highest possible luminous efficacy (k-factor or ratio of visible transmittance to shading coefficient) and daylight factor (ratio of visible transmittance to total solar transmittance).
- Specify finishes based on the desired reflectance values for walls, ceilings, and floors (see *Table 2*).
- Based on a heliodon study or other solar-path analysis, determine the type and location of, and control methods for, shading systems that minimize or eliminate direct sun in work areas and moderate excessive brightness.
- Specify control systems, including photosensors, control zones and occupancy sensors, based on control strategies.
- Seek opportunities to integrate controls with other building energy-management systems.
- Incorporate flexible, ongoing capabilities for monitoring lighting conditions, including lighting-energy consumption and lighting operation hours by zone.
- Determine the method for reviewing and analyzing field-monitoring data and performing associated responsibilities.

Construction Phase

❑ **Confirm that specified practices and materials are installed properly.**

- Monitor direct sunlight penetration through fenestration and fine-tune the solar shading systems as required.
- Observe skylight installations and related flashing and sealants to verify that each installation is watertight and has been performed according to standard practices.
- Observe the final calibration and testing of lighting-control systems to verify that the installation functions as specified.

Post Occupancy Phase

❑ **Ensure that the building's daylighting features are in place and maintained for optimum performance.**

- Walk through the entire project and review all fenestration, solar controls, and lighting-control systems to verify that they are operational and as specified. Identify any potential visual-quality problems such as glare from excessively bright source or background illuminance. Monitor light levels in all spaces with a hand-held photometer and follow up on any variations from the design illuminance levels. Prepare a checklist of problems that need to be corrected and submit it to the contractors and building owner.
- Verify with the building owner that a glass-cleaning and systems-maintenance schedule is in place.
- Review the data collected from monitoring systems, analyze energy use, and compare the results with design targets.
- Identify individuals who are responsible for maintaining and making modifications to the lighting-control systems and ensure that they are familiar with proper procedures.

Lighting Systems

General Daylighting Principles

❑ **Avoid direct sunlight on critical tasks and excessive brightness.**
Direct sunlight in certain non-task areas can be helpful because it provides building occupants with information about outside weather conditions and the time of day. These factors can actually relieve the stress associated with being in a windowless space for long periods of time. However, when a critical task is performed in direct sunlight, the light can cause unacceptable contrast ratios, disability glare, or veiled reflection. In this situation, the work surface or computer screen reflects the light source so that it is difficult to see the intended task. The recommended maximum background-to-task ratio is 10 to one; the recommended maximum light source-to-background ratio is 40 to one.[8]

❑ **Bring the daylight in at a high location.**
The four basic types of daylight apertures are windows, skylights, roof monitors, and clerestories. Skylights, roof monitors, and clerestories tend to be more effective than windows because their high location in a building affords penetration of light into the building core. Windows, unless fitted with light shelves or venetian blinds, can sometimes cause unacceptable brightness levels and excessive contrast ratios of background to foreground, thereby creating visual problems.

❑ **Filter the daylight.**
Trees, plants, draperies, screens, translucent shades, and light-scattering glazings diffuse and distribute light while reducing its intensity.

❑ **Bounce daylight off of surrounding surfaces.**
Light shelves, louvers, blinds, and vertical baffles reflect and distribute light throughout a building interior. In general, the larger and softer the light source, the better the visual quality, the less the resulting eye strain, and the easier it is to function and perform a given task. In addition, when the light is nondirectional—that is, reflected from countless surfaces—shadows are avoided or eliminated, again improving visual quality.

❑ **Integrate daylight with other building systems and strategies.**
The most effective daylighting solutions work in concert with and not against other building systems or design strategies, for example, HVAC systems, including natural ventilation, passive solar heating and cooling, acoustic control systems, electrical lighting systems incorporating occupancy sensors, photocells and dimmable electronic ballasts, and building energy management systems (see Chapter 11, “Renewable Energy,” and Chapter 12, “HVAC, Electrical, and Plumbing Systems”).

Traditional Daylighting Strategies[9]

Sidelighting

❑ **Maintain a favorable room aspect ratio—the ratio of ceiling height and window height to depth of room from window** *(Figure 1).*

❑ **Establish an appropriate building footprint.**
For sidelighting strategies to work in the majority of building spaces, establish an appropriate building footprint. The ideal building depth is limited by the dimension required for a double-loaded corridor (that is, exterior window/wall-daylit room-corridor-daylit room-exterior window/wall). Frank Lloyd Wright prescribed the ideal width of a wing for daylighting as 13 meters, about 42 feet. This guideline offers almost infinite flexibility to explore various floor configurations (for example “L,” “O,” “U,” “E,” “X,” and others). In addition, these configurations for sidelighting can be any number of stories high.

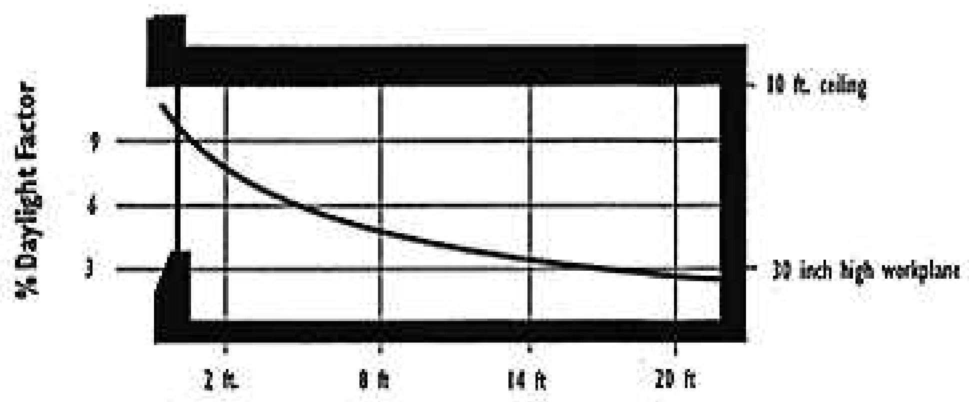
❑ **Specify the appropriate room reflectivity (surface reflectance).**
The amount of light that can be reflected to the back of a space from an outside wall with windows, and thus the comparative illumination levels between front and back, is

controlled by the reflectivity of the interior surfaces. The higher the reflectivity, the greater the illuminance values at the back of the space. Reflectance values also affect background brightness levels and therefore contrast ratios of task to background (refer to *Table 2*).

❑ **Rely on clerestories in addition to windows.**
In this strategy, which combines sidelighting and toplighting, vertical windows in a higher space are positioned adjacent to other windows, creating in a sense a "clear story" *(Figure 2)*. This method provides an excellent means of delivering daylight deep into an interior space.

Figure 1

ILLUMINATION RELATIVE TO DISTANCE INTO ROOM FROM WINDOW

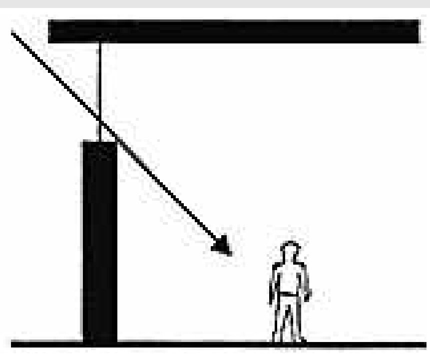


Toplighting

❑ **Consider a sawtooth roof form.**
A sawtooth roof uses a series of repetitive clerestories to provide uniform illumination over a large area *(Figure 3)* and is best designed in concert with passive solar heating and cooling strategies. The glazed openings in the sawtooth commonly face north, thereby providing a diffuse and uniform source of daylight. To take advantage of solar gains for heating purposes in colder climates, it may be advisable to face the openings south. In this case, however, solar controls may be needed to prevent glare, high contrasts, and veiling reflections. Overhangs, diffuse glazing materials, interior or exterior baffles, louvers, blinds, and shades are all effective means of accomplishing the required solar control.

Figure 2

CLERESTORY



❑ **Consider the use of roof monitors.**
Monitors are a type of clerestory that usually involves a stepped roof, allowing light to enter from two or more directions at once *(Figure 4)*. Monitors usually benefit from an overhang on the southern, eastern, and western exposures. An inherent advantage of using monitors is that the roof tends to act as a reflector or a light shelf for the monitor above. Extension of the roof plane to the interior of the glazing can sometimes enhance this effect while providing additional relief from direct sunlight penetration. In addition, monitors are less likely to leak than skylights.

Figure 3

SAWTOOTH ROOF

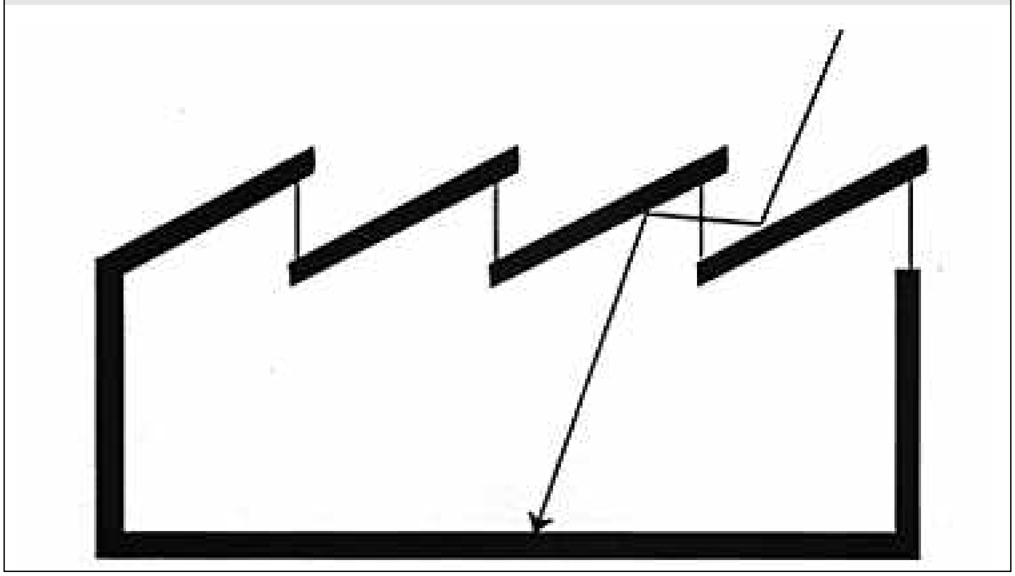
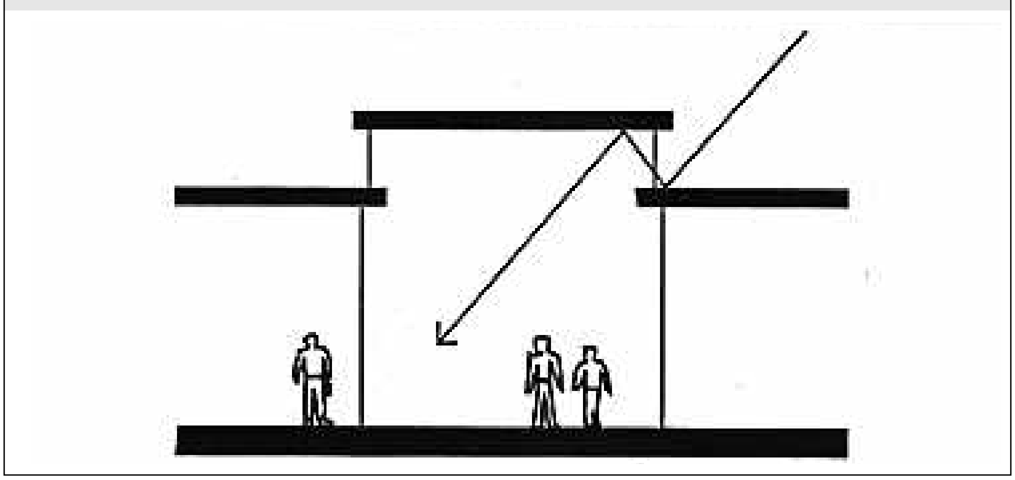


Figure 4

MONITOR



❑ **Use skylights.**

Skylights, horizontal openings in a roof, are the most common daylighting strategy in single-story buildings. When used judiciously, they offer the most efficient means of bringing light into a building because they generally have a 180-degree view of the sky. They are usually laid out on a grid so that the distance between the skylights is roughly 1.5 times the distance between the floor and ceiling planes. Optimal skylight-to-floor ratios may range from 5 to 10 percent or higher depending on the transmittance of the glass, the efficiency of the skylight design, the required illuminance level, the ceiling height, and whether the space is mechanically air conditioned.

Some problems with skylights include the potential for water leakage, the loss of some thermal insulation at the skylight locations, and the generally higher cost of the roof structure. Another drawback is the potential for heat gain during the warmer seasons, causing thermal discomfort or increased cooling costs. Because most skylight installations require diffuse glazing for solar control, they do not provide views to the outside. When skylights are used in a daylighting strategy, be sure to:

- Angle light wells to prevent loss of efficiency. The finished vertical surfaces below the skylight opening are known as the “light well.” As the depth of the construction or the distance from the roof to the ceiling plane increases, it becomes more important that the light well be angled to prevent loss of efficiency of the skylight system.
- Use baffles below the skylight to reflect some of the incident light up onto the ceiling surface. This technique reduces the ratio of source-to-background contrast by making the ceiling a relatively large indirect light source.
- Consider roof design. When a skylight is used in conjunction with a sloped roof surface, the efficiency of the skylight is reduced in proportion to the slope of the roof, and the light distribution pattern becomes more like that of a sidelighting strategy. If the slope of the roof is to the north, solar control is less of a concern; if it is to the east, south or west, it is more of a concern.

Light Distribution Strategies

❑ **Use sloped or curved ceiling planes.**

Ceiling shape is the simplest mechanism for distributing light in a space. Sloping the ceiling from a high point at the window or skylight essentially has the same impact as maintaining a high ceiling throughout the space. Curving the ceiling can produce dramatic effects. The light from the window or skylight can be focused or collimated in the case of a concave surface or further diffused and spread in the case of a convex surface.

❑ **Optimize overhangs based on window height and latitude (solar altitude).**

Although usually necessary to exclude light and solar gain at unwanted times, overhangs always reduce the overall amount of daylight in the space and should therefore be designed with care, including an analysis of their year-round effect.

❑ **Incorporate light shelves with windows where appropriate.**

The light shelf is an extremely useful tool when used in conjunction with sidelighting strategies. This mechanism, a horizontal surface at or above eye level, serves to reflect light falling above the vision window up onto the ceiling and therefore deeper into the room *(Figure 5)*. At the same time, it reduces illumination immediately adjacent to the window, where illumination levels are typically too great to work comfortably. This has the effect of creating more even illumination throughout the space, even though the overall amount of light flux into the space is reduced.

❑ **Employ baffles, louvers, and reflectors as appropriate in conjunction with any of the above mentioned strategies for solar control.**

❑ **Integrate daylighting with luminous ceiling systems.**

Locating clerestories and skylights above luminous ceiling systems provides a unique method of integrating natural and electrical light sources. However, increased maintenance may be a concern.

Innovative Sidelighting Systems

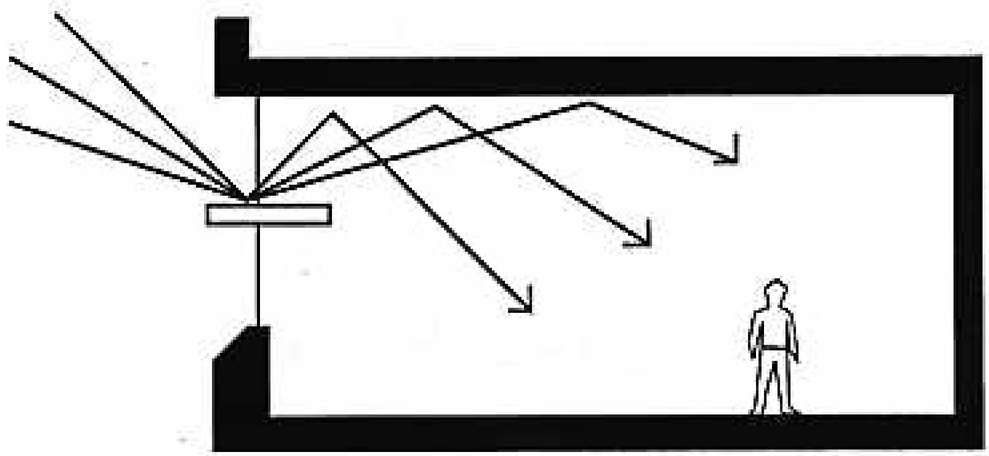
The primary challenges in sidelighting applications are: (1) the need for control of solar light and heat gains near windows; and (2) the transfer of light to the deeper zones away from the windows in order to extend the effective depth to which daylighting may be achieved. The following innovations can address these issues.

❑ **Consider using the currently available techniques:**

- Solar optic lens film (SOLF) applied to acrylic panels;
- Molded acrylic prismatic glazings or prismatic panels;
- Specular blinds or mirror panels;
- Holographic or diffraction-grating glazings; and
- Reflective films.

Figure 5

LIGHT SHELF



- ❑ **Consider solar shade and awning systems.**
  These systems often project out from the building surface above the window or are in the same plane as the window glazing (usually in the upper portion of the window). They are engineered to collect light from a variety of angles and redirect it by specular reflection toward the deepest portion of the room and generally upward toward the ceiling plane.
- ❑ **Consider optical venetian-blind systems.**
  These systems work like standard venetian blinds except that they have diffraction gratings or micro-fresnel lens surfaces and some have individual slats that are shaped like collapsed prisms. Like their standard miniblind counterparts, they can be operated manually with a wand-type actuator or automatically with new photosensor light-angle measuring systems and computer software control algorithms.
- ❑ **Consider advanced light-shelf systems.**
  These systems utilize many of the same advanced glazing technologies as solar shading systems; however, they are arranged in projecting configurations that look and act like standard light shelves but offer much better control of light direction and higher efficiencies. While typical light shelves may be expected to maintain relatively even daylight illumination for a depth of up to 2.5 times the distance to the top of the window into the room, advanced light shelves (*Figure 6 and Figure 7)* should maintain even illumination up to four times the distance from the floor to the top of the glass opening under certain conditions.[10] Tracking systems have an advantage over passive systems in that they maintain more uniform efficiencies and resulting light-distribution patterns but have greater potential for problems and associated maintenance costs.

Innovative Toplighting Systems

The primary challenges to toplighting applications are the need for collimation of light vertically deeper into the interiors of high-rise buildings and the need for higher efficiency and better distribution control allowing greater distance between skylights in single-story applications.

- ❑ **Consider advanced systems such as active concentrating heliostats, passive collimating systems, and high-performance optical skylights.**[11]
  Technologies that may be applied in these strategies are similar to those mentioned above for innovative sidelighting systems.

ADVANCED LIGHT SHELF

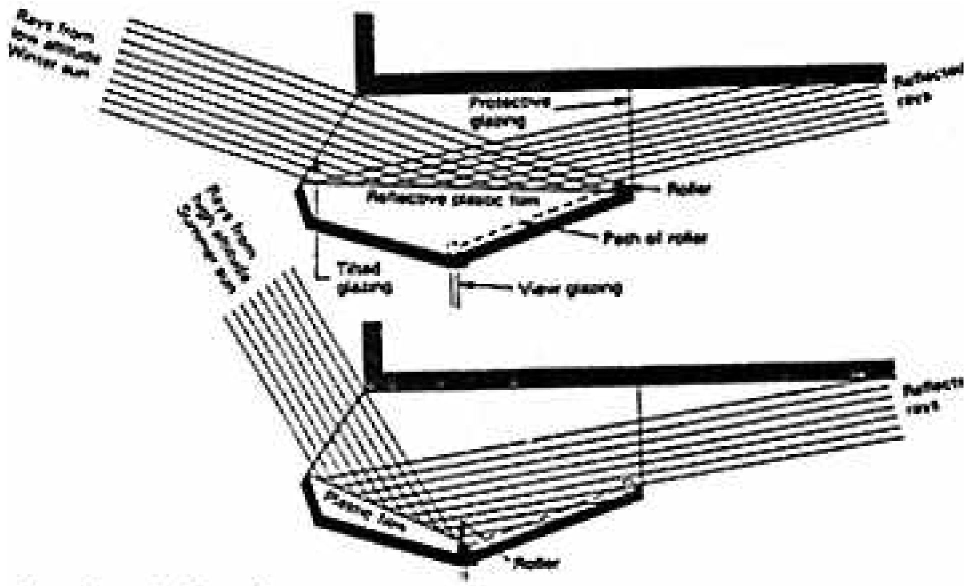
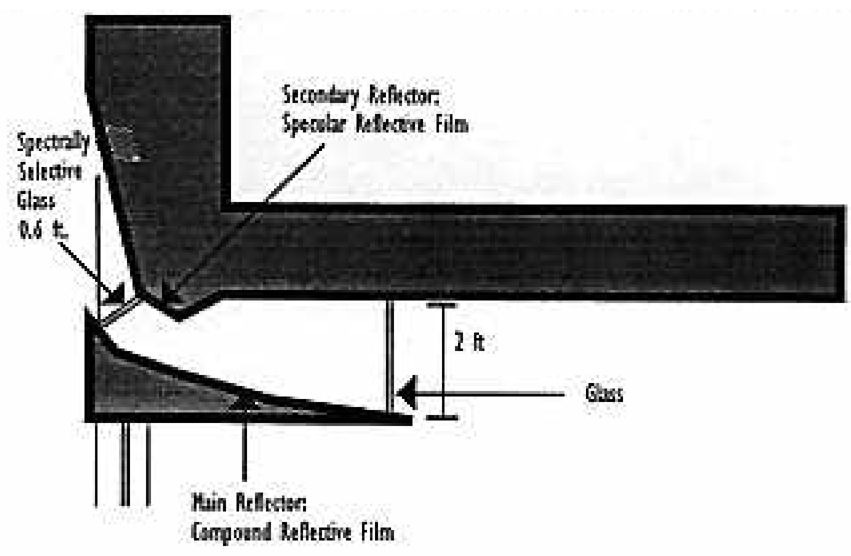


Figure 6

ADVANCED LIGHT SHELF



Source: Lawrence Berkeley National Laboratory, University of California at Berkeley

Figure 7

Innovative Core Daylighting Systems

❑ **Consider light-pipe distribution.**

Light-pipe distribution has been commercialized for use with high-output luminaires in commercial buildings where special security requirements, difficulty of access, or explosive or corrosive environmental conditions are present. The efficiency of light-pipe distribution is approximately 50 percent from source to delivered illumination.[12] Available systems include those where the light transfer is internal only, or where the pipe itself is a continuous light source.[13] Daylighting applications using this technology for light distribution use concentrating collectors or heliostats as high-intensity light sources.

Control Strategies

❑ **Integrate lighting controls to respond to available daylight.**

To capitalize on the potential energy savings associated with daylighting strategies, it is usually necessary to automate the reduction of electrical lighting operation. This can be accomplished in a variety of ways; however, hardware complexity, cost, wiring complexity, and types of lighting systems are all affected by desired control strategies. In addition, the subtlety of the lighting change actuated by the control systems is affected by the mode of controls selected (see Chapter 12, "HVAC, Electrical, and Plumbing Systems").

❑ **Ensure good control-system design.**

The chief failure of daylighting systems lies in the faulty design or installation of lighting controls. Several factors are critical to the correct functioning of daylighting control systems. Consider these practices to improve lighting control:

- Properly locate and calibrate the photosensors. Correct location and calibration of the photosensor for all daylighting control systems is critical. Ordinarily, a single photosensor will control a group or zone of light fixtures in order to reduce system cost. The sensor should "see" a mixture of both natural and electrical light and should not be located so as to be "fooled" by movement of occupants or objects in the space.
- Use proper zoning. Daylight levels vary greatly within a building depending on many factors. Typically, at least two zones—perimeter and core—should be established in a sidelighting situation. Toplighting situations usually require at least two or three zones. Where more sophisticated controls systems are used, calibrate and control each fixture individually based on a common reference photosensor.

❑ **Integrate daylight controls with other control strategies.**

In addition to controlling lighting to respond to levels of daylight, other lighting-control strategies are typically cost-effective in reducing lighting needs and thus reducing lighting and cooling energy consumption. These may include:

- Time or scheduling controls;
- Occupancy-sensor controls; and
- Lumen-maintenance control programs.

Some manufacturers of lighting-control and building energy systems allow daylighting-control strategies to be integrated with these additional control features in a single system with a central control and program terminal.

Emerging Glazing Technologies

❑ **Consider spectrally selective glazings.**

Specifying glazings with high visible-light transmittance is necessary for optimal energy savings. On the other hand, a low shading coefficient reduces relative heat gain through the glass, which lowers cooling loads. The daylight factor is the ratio of visible light transmittance to total solar transmittance; therefore, the higher the daylight factor, the better the choice for daylighting applications in general. Another measure is the luminous efficacy value (k-factor) which is the visible-light transmittance divided by the shading coefficient. A luminous efficacy of greater than 1.5 is excellent for daylighting applications. New glass coatings being engineered, such as the spectrally selective low-emissivity coatings offered by numerous glazing manufacturers, admit higher than 70 percent of visible light while blocking nearly 95 percent of the infrared spectrum.[14] These coatings may not be desirable, however, where passive solar heating is needed.

❑ **Consider switchable glazings.**

Although still in development and rather expensive, switchable glazings offer special attributes and may be appropriate for special applications. The different types of switchable glazings are:

- *Photochromic glass*. This light-sensitive glass darkens at a predetermined intensity level (like light-sensitive sunglasses).
- *Thermochromic glass*. This heat-sensitive glass becomes translucent at a predetermined temperature.
- *Electrochromic glass*. Electrically variable coatings become darkened with the application of current and clear as current is reduced.
- *Liquid crystal (LCD)*. This material becomes clear with the application of electrical current and is translucent otherwise. Tints can be added to the liquid crystal films, giving them greater solar-control capabilities.

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DESIGN TOOLS

AAMASKY, Skylight Design Analysis Tool. Easy-to-use design tool for layout and energy-cost and performance modeling of simple skylit spaces. Developed by Lawrence Berkeley National Laboratory (LBNL). Contact: American Architecture Manufacturers Association (AAMA), (708) 202-1350.

ADELINE. Advanced integrated lighting design and analysis package, incorporating DXF input capability, SCRIBE MODELLER, PLINK, SUPERLIGHT, SUPERLINK, and RADIANCE, for detailed and advanced analysis of complex buildings. Available for MS-DOS 486 platforms. Developed by LBNL. Contact: Steve Selkowitz, (510) 486-5064.

Building Design Advisor (BDA). Easy-to-use design tool for preliminary design phase being developed by LBNL. Alpha version currently available Contact: Constantinos Papamichael, (510) 486-6854.

DAYLITE, Daylighting design tool. Available for MS-DOS 386 and 486. Developed by the Graduate School of Architecture, University of California at Los Angeles. Contact: Murray Milne, (310) 825-7370.

DOE-2. Building envelope, building systems, and daylighting analysis package. DOE Version 2.1E available for MS-DOS and Windows (386 and 486) and UNIX workstations. Developed by LBNL. Contact: Fred Winkleman, (510) 486-4925.

ENERGY-10, Low-Rise Building Design. Design manual and software. Windows-environment program for small commercial buildings allows early design evaluation of 16 energy-saving stategies including daylighting. Developed by National Renewable Energy Laboratory (NREL), Passive Solar Industries Council (PSIC), U.S. Department of Energy, and LBNL. Contact: Blaine Collison at PSIC, (202) 628-7400.

LUMEN MICRO 6.0. PC program that enables calculation of average illuminance, evaluated using the zonal cavity method, and point-by-point horizontal and vertical illuminances; generating tables, iso-contour maps, or perspective renderings of spaces lighted with equipment or daylighting components specified by the user. Available through Lighting Technologies, Boulder, CO.

POWERDOE. Windows-environment version of DOE-2 with user-friendly interface. Available in early 1996. Developed by LBNL. Contact: Fred Winkleman, (510) 486-4925.

RADIANCE. Lighting and daylighting modeling tool for performing accurate photorealistic lighting simulation. Available for UNIX workstations. Developed by LBNL. Contact: Charles Erlich, (510) 486-7916.

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6 E-Source*, Lighting Technology Atlas*, 21; and U.S. Energy Information Service, *Annual Energy Consumption Report* (Washington, D.C.: GPO, 1994).

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12 E-Source, 57.

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14 E-Source, 54.

CHAPTER 10

Building Envelope

Author

William Burke

★ SIGNIFICANCE

The building envelope, or "skin," consists of structural materials and finishes that enclose space, separating inside from outside. This includes walls, windows, doors, roofs, and floor surfaces. The envelope must balance requirements for ventilation and daylight while providing thermal and moisture protection appropriate to the climatic conditions of the site. Envelope design is a major factor in determining the amount of energy a building will use in its operation. Also, the overall environmental life-cycle impacts and energy costs associated with the production and transportation of different envelope materials vary greatly.

In keeping with the whole building approach, the entire design team must integrate design of the envelope with other design elements including material selection; daylighting and other passive solar design strategies; heating, ventilating, and air-conditioning (HVAC) and electrical strategies; and project performance goals. One of the most important factors affecting envelope design is climate. Hot/dry, hot/moist, temperate, or cold climates will suggest different design strategies. Specific designs and materials can take advantage of or provide solutions for the given climate.

A second important factor in envelope design is what occurs inside the building. If the activity and equipment inside the building generate a significant amount of heat, the thermal loads may be primarily internal (from people and equipment) rather than external (from the sun). This affects the rate at which a building gains or loses heat. Building volume and siting also have significant impacts upon the efficiency and requirements of the building envelope. Careful study is required to arrive at a building footprint and orientation that work with the building envelope to maximize energy benefit.

Openings are located in the envelope to provide physical access to a building, create views to the outside, admit daylight and/or solar energy for heating, and supply natural ventilation. The form, size, and location of the openings vary depending upon the role they play in the building envelope. Window glazing can be used to affect heating and cooling requirements and occupant comfort by controlling the type and amount of light that passes through windows.

Decisions about construction details also play a crucial role in design of the building envelope. Building materials conduct heat at different rates. Components of the envelope such as foundation walls, sills, studs, joists, and connectors, among others, can create paths for the transfer of thermal energy, known as thermal bridges, that conduct heat across the wall assembly. Wise detailing decisions, including choice and placement of insulation material, are essential to assure thermal efficiency.

☞ SUGGESTED PRACTICES AND CHECKLIST

Climate Considerations

❑ **Assess the local climate (using typical meteorological-year data) to determine appropriate envelope materials and building designs.**

The following considerations should be taken into account, depending on the climate type.

- In hot/dry climates use materials with high thermal mass. Buildings in hot/dry climates with significant diurnal temperature swings have traditionally employed thick walls constructed from envelope materials with high mass, such as adobe and masonry. Openings on the north and west facades are limited, and large southern openings are detailed to exclude direct sun in the summer and admit it in winter. A building material with high thermal mass and adequate thickness will lessen and delay the impact of temperature variations from the outside wall on the wall's interior. The material's high thermal capacity allows heat to penetrate slowly through the wall or roof. Because the temperature in hot/dry climates tends to fall considerably after sunset, the result is a thermal flywheel effect—the building interior is cooler than the exterior during the day and warmer than the exterior at night.
- In hot/moist climates use materials with low thermal capacity. In hot/moist climates, where nighttime temperatures do not drop considerably below daytime highs, light materials with little thermal capacity are preferred. In some hot/moist climates, materials such as masonry, which functions as a desiccant, are common. Roofs and walls should be protected by plant materials or overhangs. Large openings protected from the summer sun should be located primarily on the north and south sides of the envelope to catch breezes or encourage stack ventilation.
- In temperate climates, select materials based on location and the heating/cooling strategy to be used. Determine the thermal capacity of materials for buildings in temperate climates based upon the specific locale and the heating/cooling strategy employed. Walls should be well insulated. Openings in the skin should be shaded during hot times of the year and unshaded during cool months. This can be accomplished by roof overhangs sized to respond to solar geometries at the site or by the use of awnings.
- In colder climates design wind-tight and well-insulated building envelopes. The thermal capacity of materials used in colder climates will depend upon the use of the building and the heating strategy employed. A building that is conventionally heated and occupied intermittently should not be constructed with high mass materials because they will lengthen the time required to reheat the space to a comfortable temperature. A solar heating strategy will necessitate the incorporation of massive materials, if not in the envelope, in other building elements. Where solar gain is not used for heating, the floor plan should be as compact as possible to minimize the area of building skin.

(See also Chapter 11, "Renewable Energy.")

❑ **Assess the site's solar geometry.**

Solar gain on roofs, walls, and the building interior through window openings can be either a benefit or a hindrance to heating, cooling, and occupant comfort. A thorough understanding of solar geometry specific to the site is crucial to proper envelope design. (See also Chapter 5, "Sustainable Site Design" for further discussion.)

Building Shape and Orientation

❑ **Choose the most compact building footprint and shape that work with requirements for daylighting, solar heating and cooling, and function.**
The greater the amount of building skin in relation to the volume of space enclosed, the more the building is influenced by heat exchanges at the skin. Excluding consideration of window openings and glazing choices, if two building designs under consideration enclose the same volume, the one with the more compact plan will have greater thermal efficiency. A square floor plan is more thermally efficient than a rectangular one because it contains less surface area over which to lose or gain heat. However, this may not be the most efficient or desirable form when other considerations such as daylighting, passive solar heating and cooling, need for temperature variation, and occupant use patterns are included (see also Chapter 9, "Daylighting" and Chapter 11, "Renewable Energy").

❑ **Site and orient the building so as to minimize the effects of winter wind turbulence upon the envelope.**
The shape and orientation of the building shell has an impact upon wind turbulence and opportunities for infiltration through the envelope. However, an orientation that minimizes winter wind may also limit opportunities to make use of cooling breezes in summer. An understanding of the site-specific microclimate is needed. Coniferous trees may be used for windbreaks (see also Chapter 5, "Sustainable Site Design.")

Doors, Windows, and Openings

❑ **Size and position doors, windows, and vents in the envelope based on careful consideration of daylighting, heating, and ventilating strategies.**
The form, size, and location of openings may vary depending on how they affect the building envelope. A window that provides a view need not open, yet a window intended for ventilation must do so. High windows for daylighting are preferable because, if properly designed, they bring light deeper into the interior and eliminate glare. Vestibules at building entrances should be designed to avoid the loss of cooled or heated air to the exterior. The negative impact of door openings upon heating or cooling loads can be reduced with airlocks. Members of the design team should coordinate their efforts to integrate optimal design features. For passive solar design, this includes the professionals responsible for the interactive disciplines of building envelope, daylighting, orientation, architectural design, massing, HVAC, and electrical systems.

❑ **Shade openings in the envelope during hot weather to reduce the penetration of direct sunlight to the interior of the building.**
Use overhangs or deciduous plant materials on southern orientations to shade exterior walls during warmer seasons. Be aware, however, that deciduous plants can cut solar gains in the winter by 20 percent. Shade window openings or use light shelves at work areas at any time of year to minimize thermal discomfort from direct radiation and visual discomfort from glare.

❑ **In all but the mildest climates, select double- or triple-paned windows with as high an "R" value as possible and proper shading coefficients within the project's financial guidelines.**
The "R" value is a measure of the resistance to heat flow across a wall or window assembly (with higher values representing a lower energy loss). Shading coefficient is a ratio used to simplify comparisons among different types of heat reducing glass. The shading coefficient of clear double-strength glass is 1.0. Glass with a shading coefficient of 0.5 transmits one-half of the solar energy that would be transmitted by clear double-strength glass. One with a shading coefficient of 0.75 transmits three-quarters.

❑ **Select the proper glazing for windows, where appropriate.**
Glazing uses metallic layers of coating or tints to either absorb or reflect specific wavelengths in the solar spectrum. In this manner, desirable wavelengths in the visible spectrum that provide daylight are allowed to pass through the window while other wavelengths, such as near-infrared (which provides heat) and ultraviolet (which can damage fabric), are reflected. Thus, excess heat and damaging ultraviolet light can be reduced while still retaining the benefits of natural lighting. More advanced windows use glazings that are altered with changing conditions, such as windows with tinting that increases under direct sunlight and decreases as light levels are reduced. Research is being conducted on windows that can be adjusted by the building occupant to allow more or less heat into a building space.[1] (See Chapter 9, "Daylighting," for further discussion.)

Thermal Efficiency

❑ **Determine the building function and amount of equipment that will be used.**
The type of activity and the amount of equipment in a building affect the level of internal heat generated. This is important because the rate at which a building gains or loses heat through it skin is proportional to the difference in air temperature between inside and outside. A large commercial building with significant internal heat loads would be less influenced by heat exchanges at the skin than a residence with far fewer internal sources of heat generation.

❑ **In general, build walls, roofs, and floors of adequate thermal resistance to provide human comfort and energy efficiency.**
Roofs especially are vulnerable to solar gain in summer and heat loss in winter. Avoid insulating materials that require chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons (HCFCs) in their production, as these are ozone-depleting compounds. Consider insulating materials made from recycled materials such as cellulose or mineral wool, if such items meet the project's performance and budgetary criteria. If the framing system is of a highly conductive material, install a layer of properly sized insulating sheathing to limit thermal bridging.

❑ **Consider the reflectivity of the building envelope.**
In regions with significant cooling loads, select exterior finish materials with light colors and high reflectivity. Consider the impact of decisions upon neighboring buildings. A highly reflective envelope may result in a smaller cooling load, but glare from the surface can significantly increase loads on and complaints from adjacent building occupants.

❑ **Prevent moisture buildup within the envelope.**
Under certain conditions, water vapor can condense within the building envelope. When this occurs the materials that make up the wall can become wet, lessening their performance and contributing to their deterioration. To prevent this, place a vapor-tight sheet of plastic or metal foil, known as a vapor barrier, as near to the warm side of the wall construction as possible. For example, in areas with meaningful heating loads, the vapor barrier should go near the inside of the wall assembly. This placement can lessen or eliminate the problem of water-vapor condensation.

❑ **Weatherstrip all doors and place sealing gaskets and latches on all operable windows.**
Careful detailing, weatherstripping, and sealing of the envelope are required to eliminate sources of convective losses. Convective losses occur from wind loads on exterior walls. They also occur through openings around windows and doors and through small openings in floor, wall, and roof assemblies. Occupants can experience these convective paths as drafts. Older buildings can prove to be a source of significant energy loss and added fuel and pollution costs. Inspect weatherstripping and seals periodically to ensure that they are air-tight.

❑ **Specify construction materials and details that reduce heat transfer.**
Heat transfer across the building envelope occurs as either conductive, radiant, or convective losses or gains. Building materials conduct heat at different rates. Metals have a high rate of thermal conductance. Masonry has a lower rate of conductance; the rate

for wood is lower still. This means that a wall framed with metal studs compared to one framed with wood studs, where other components are the same, would have a considerably greater tendency to transmit heat from one side to the other. Insulating materials, either filled in between framing members or applied to the envelope, resist heat flow through the enclosing wall and ceiling assemblies. Consider the following principles in construction detailing:

- To reduce thermal transfer from conduction, develop details that eliminate or minimize thermal bridges.
- To reduce thermal transfer from convection, develop details that minimize opportunities for air infiltration or exfiltration. Plug, caulk, or putty all holes in sills, studs, and joists. Consider sealants with low environmental impact that do not compromise indoor air quality.

❑ **Incorporate solar controls on the building exterior to reduce heat gain.**
Radiant gains can have a significant impact on heating and cooling loads. A surface that is highly reflective of solar radiation will gain much less heat than one that is adsorptive. In general, light colors decrease solar gain while dark ones increase it. This may be important in selecting roofing materials because of the large amount of radiation to which they are exposed over the course of a day; it may also play a role in selecting thermal storage materials in passive solar buildings. Overhangs are effective on south-facing facades while a combination of vertical fins and overhangs are required on east and west exposures and, in warmer areas during summer months, on north-facing facades. (See also Chapter 11, “Renewable Energy,” for more information.)

❑ **Consider the use of earth berms to reduce heat transmission and radiant loads on the building envelope.**
The use of earth berms or sod roofs to bury part of a building will minimize solar gain and wind-driven air infiltration. It will also lessen thermal transfer caused by extremely high or low temperatures. (See also Chapter 11, “Renewable Energy” for further discussion.)

Building Grounds

❑ **Coordinate building strategy with landscaping decisions.**
Landscape and other elements such as overhangs are integral to a building’s performance. Decisions about the envelope need to be coordinated with existing and new landscaping schemes on a year-round basis.

❑ **Reduce paved areas to lessen heat buildup around the building that will add to the load on the building envelope.**
Consider selection of a paving color with a high reflectance to minimize heat gain. Glare factors should also be considered.

(See also Chapter 7, “Site Materials and Equipment.”)

➜ RESOURCES

Allen, Edward. *How Buildings Work*. New York: Oxford University Press, 1980. Broadly summarizes in simple, graphic fashion what a building does and how it does it. It contains a wealth of information that should be useful to professionals and non-professionals alike.

Passive Solar Industries Council (PSIC) and National Renewable Energy Laboratory (NREL). *Designing Low Energy Buildings—Integrating Daylighting, Energy-Efficient Equipment, and Passive Solar Strategies*. Washington, D.C.: Passive Solar Industries Council, n.d.

U.S. Department of Energy. Energy Efficiency and Renewable Energy. Office of Building Technologies. *Windows and Daylighting: A Brighter Outlook*. Washington, D.C.: GPO, 1994.

Watson, Donald, ed. *The Energy Design Handbook*. Washington, D.C.: The American Institute of Architects Press, 1993. Presents design concepts and methods to create climate-responsive, energy-efficient architecture. It includes introductory explanations, guidelines, examples, and references of energy design strategies appropriate to particular climates and applications.

Watson, Donald, and Kenneth Labs. *Climatic Building Design*. New York: McGraw-Hill, 1983. Provides an introduction and reference guide to climatic design, focusing on the art and science of using the beneficial elements of nature to create comfortable, energy-efficient and environmentally wise buildings. It includes a good discussion of energy exchange through the building envelope, and offers strategies for heat and energy exchange that minimize energy use and maximize occupant comfort.

DESIGN TOOLS

PASSIVE SOLAR DESIGN

BLAST. Calculates building loads, analyzes solar feasibility, predicts life-cycle costs, and helps select the optimal HVAC system for a building. Developed by Civil Engineering Research Laboratories, U.S. Army. Contact: University of Illinois, (800) UI BLAST

ENERGY-10, Low-Rise Building Design (Design manual and software). Windows-environment program for small commercial buildings allowing early design evaluation of 16 energy-saving strategies including daylighting. Developed by National Renewable Energy Laboratory (NREL), Passive Solar Industries Council (PSIC), U.S. Department of Energy (DOE), and Lawrence Berkeley National Laboratory (LBNL). Contact: Blaine Collison at PSIC, (202) 628-7400.

SERI-RES (also known as *SUNCODE)*. Useful for residential and small commercial buildings to analyze passive solar design and thermal performance. Developed by NREL and Ecotope Group. Contact: Ron Judkoff at NREL, (303) 275-3000.

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

ENERGY-EFFICIENT DESIGN

BLAST. See Passive Solar Design. Contact: University of Illinois, (800) UI BLAST

DOE-2. Calculates energy use and life-cycle costs of design options. Includes building envelope, HVAC systems, and daylighting analysis package. DOE Version 2.1E available for MS-DOS and Windows (386 and 486) and UNIX workstations. Developed by LBNL. Contact: Fred Winkleman, (510) 486-4925.

ENERGY-10, *Low-Rise Building Design*. See Passive Solar Design. Contact: Blaine Collison at PSIC, (202) 628-7400.

TRNSYS. See Passive Solar Design. Contact: TRNSYS Coordinator, (608) 263-1589.

DAYLIGHTING DESIGN

ADELINE. Advanced integrated lighting design and analysis package, incorporating DXF input capability, SCRIBE MODELLER, PLINK, SUPERLIGHT, SUPERLINK, and RADIANCE, for detailed and advanced analysis of complex buildings. Available for MS-DOS 486 platforms. Developed by LBNL. Contact: Steve Selkowitz, (510) 486-5064.

RADIANCE. Lighting and daylighting modeling tool for performing accurate photorealistic lighting simulation. Available for UNIX workstations. Developed by LBNL. Contact: Charles Erlich, (510) 486-7916.

SUPERLITE 2.0. Daylighting analysis tool. Available for MS-DOS 386 and 486. Developed by LBNL. Contact: Rob Hitchcock, (510) 486-4154.

NOTES

1 U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Building Technologies, *Windows and Daylighting: A Brighter Outlook* (Washington, D.C.: GPO, 1994) 7, 8.

CHAPTER 11

Renewable Energy

Passive Solar Heating, Cooling, and Thermal Storage

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★ SIGNIFICANCE

Integration of passive solar heating, cooling, and thermal storage features, along with daylighting, into a building can yield considerable energy benefits and added occupant comfort. Incorporation of these items into the building design can lead to substantial reduction in the load requirements for building heating and cooling mechanical systems. The passive solar measures and mechanical systems need to be evaluated on an *interactive* basis during the design process, since an increase in one, can lead to a decrease in the other.

Direct gain through south-facing glass is the most common method of passive solar heating. Sunlight is admitted through the glazing into the space to be heated, and typically absorbed by thermal mass materials. Other methods include indirect gain (e.g., using a sunspace or atrium) and thermal storage walls. Passive solar heating works successfully in many types of buildings, especially residential and smaller commercial, industrial, and institutional buildings. They benefit from passive solar designs because they are "envelope-dominated", that is, their space conditioning loads are determined primarily by climatic conditions and building envelope construction characteristics rather than by internal heat gains. Passive solar heating works particularly well in climates where many sunny days occur during the cold season but is also beneficial in other climates.

Passive solar cooling strategies include cooling load avoidance, shading, natural ventilation, radiative cooling, evaporative cooling, dehumidification, and ground coupling. Passive design strategies can minimize the need for cooling through proper selection of glazings, window placement, shading techniques, and good landscaping design. However, incorrect daylighting strategies can produce excessive heat gain. Minimization of cooling loads should be carefully addressed through proper design for both solar and conventional building design.

Thermal mass and energy storage are key characteristics of passive solar design.[1] They can provide a mechanism for handling excess warmth, therefore reducing the cooling load, while storing heat that can be slowly released back to the building when needed. The thermal mass can also be cooled during the evening hours by venting the building, reducing the need for cooling in the morning.

☞ SUGGESTED PRACTICES AND CHECKLIST

Passive Solar Heating

❑ **Analyze building thermal-load patterns.**
An important concept of passive solar design is to match the time when the sun can provide daylighting and heat to a building with those when the building needs heat. This will determine which passive solar design strategies are most effective. Commercial buildings have complicated demands for heating, cooling, and lighting;; therefore their design strategies require computer analysis by an architect or engineer.

❑ **Integrate passive solar heating with daylighting design.**
A passive solar building that makes use of sunlight as a heating source should also be designed to take advantage of sunlight as a lighting source (see Chapter 9, "Daylighting"). However, each use has different design requirements that need to be addressed. In general, passive solar heating benefits from beam sunlight directly striking dark-colored surfaces. Daylighting, on the other hand, benefits from the gentle diffusion of sunlight over large areas of light-colored surfaces. Integrating the two approaches requires an understanding and coordination of daylighting, passive design, electric lighting, and mechanical heating systems and controls.

❑ **Design the building's floor plan to optimize passive solar heating.**
Orient the solar collection surfaces, for example appropriate glazings in windows and doors, within 15 degrees of true south, if possible. Because of the solar path, the optimum orientation for passive solar buildings is due south. South-facing surfaces do not have to be all along the same wall. For example, clerestory windows can project south sun deep into the back of the building. Both the efficiency of the system and the ability to control shading and summer overheating decline dramatically as the surface shifts away from due south.

❑ **Identify appropriate locations for exposure to beam sunlight.**
Overheating and glare can occur whenever sunlight penetrates directly into a building and must be addressed through proper design. A "direct-gain" space can overheat in full sunlight and is many times brighter than normal indoor lighting, causing intense glare. Generally, rooms and spaces where people stay in one place for more than a few minutes are inappropriate for direct gain systems. Lobbies, atria, or lounges can be located along the south wall where direct sun penetrates. Choose glazings that optimize the desired heat gain, daylighting, and cooling load avoidance. (see Chapter 9, "Daylighting").

❑ **Avoid glare from low sun angles.**
In late morning and early afternoon, the sun enters through south-facing windows. The low angle allows the sunbeam to penetrate deep into the building beyond the normal direct-gain area. If the building and occupied spaces are not designed to control the impact of the sun's penetration, the occupants will experience discomfort from glare. Careful sun-angle analysis and design strategies will ensure that these low sun angles are understood and addressed. For example, light shelves can intercept the sun and diffuse the daylight. Workstations can be oriented north-south so that walls or high partitions intercept and diffuse the sun.

❑ **Locate thermal mass so that it will be illuminated by low winter sun angles.**
Building design should incorporate a sufficient amount of correctly located thermal mass to effectively contribute to the heating requirements and provide cooling benefits in the summer.

Passive Solar Cooling

❑ **Design buildings for cooling load avoidance.**

Minimization of cooling loads should be carefully addressed for both solar building and conventional energy-efficient building design. Design strategies that minimize the need for mechanical cooling systems include proper window placement and daylighting design, selection of appropriate glazings for windows and skylights, proper shading of glass when heat gains are not desired, use of light-colored materials for the building envelope and roof, careful siting and orientation decisions, and good landscaping design.

❑ **Choose one or more shading strategies.**

– Install fixed shading devices, using correctly sized overhangs or porches, or design the building to be "self-shading." Fixed shading devices, which are designed into a building, will shade windows throughout the solar cycle. They are most effective on the south-facing windows. The depth and position of fixed shading devices must be carefully engineered to allow the sun to penetrate only during predetermined times of the year. In the winter, overhangs allow the low winter sun to enter south-facing windows. In the summer, the overhangs block the higher sun.

– Plant trees and/or bushes to shade the windows at the right time of day and season (see Chapter 7, "Site Materials and Equipment"). Deciduous vegetation is often an attractive and inexpensive form of shading, because it follows the local seasons, not the solar calendar. In the warm south, where more shading is needed, trees leaf out earlier, while in the cold north, where solar heat is beneficial late into spring, trees wait until the weather warms up before they leaf out. Trees can be strategically planted on east and west sides to block the rising and setting sun. Bushes can be positioned to block undesirable low sun angles from the east or west, and deciduous vines trained to grow over trellises make easily controlled shading systems. Evergreen trees trimmed so that their canopies allow low winter sun underneath but block the high summer sun can be very effective. Properly placed vegetation can also guide air flows toward buildings for natural ventilation and can block cold winter winds. Vegetation and groundcover also contribute to evaporative cooling around a building.

  Vegetation used for shading should be properly located so as not to interfere with solar gain to buildings in winter. Deciduous trees can reduce winter solar gain by 20 percent or more and should not be placed in the solar access zone. Also note that trees require maintenance, pruning, watering and feeding. As they grow they change their shading pattern, and they can be damaged or killed, leaving the building exposed.

– Consider awnings that can be extended or removed. Movable awnings are an old tradition and an excellent solution to the variation between seasons and the solar year. When rolled out in the summer, they not only provide deep shade but also lend a colorful touch to a building's facade. When rolled up in winter, they allow more sun into the building and avoid snow loads and/or excessive weathering.

– Consider exterior roll-down shades or shutters. An enormous variety of vertical shading devices are readily available. Wooden shutters are the most traditional. Also available are many exterior-grade fiberglass and plastic fabrics that cut out a significant amount of sunlight but still allow a clear view through the window. However, they do not prevent the glare problems caused by low-angle sun. Opaque steel or plastic roll-down shutters have proved reliable and long-lasting. Although expensive, they can also provide additional storm and vandalism protection.

– Limit east/west glass. Glass on these exposures is harder to shade from the eastern morning sun or western evening sun. Vertical or egg-crate fixed shading works well if the shading projections are fairly deep or close together; however, these may limit views. North-facing glass receives little direct solar gain, but does provides diffuse daylight.[2]

❑ **Consider other cooling strategies.**

– Design the building to take advantage of natural ventilation. Natural ventilation uses the passive stack effect and pressure differentials to bring fresh, cooling air through a building without mechanical systems. This process cools the occupants and provides comfort even in humid climates. Buildings using this design will incorporate operable windows or other means of outdoor air intakes. Wingwalls are sometimes used to increase the convective air flow. Other features include fresh air inlets located near floor level, use of ceiling fans, and the use of atriums and stairwell towers to enhance the stack effect. Caution should be used not to increase the latent load (i.e., the increased cooling load resulting from condensation) by bringing in moist outside air.

– Consider radiative cooling in appropriate climates. Radiative cooling, also known as nocturnal radiative cooling, uses design strategies that allow stored heat to be released to the outside. This strategy is particularly effective in climates and during seasons of the year when the daytime-nighttime temperature differences are meaningful. Night flushing of buildings uses radiative cooling principles. Building thermal storage serves as a heat sink during the day, but releases the heat at night, while being cooled with night air.

– Consider ground coupled cooling. Ground coupling is achieved by conductive contact of the building with the earth. The most common strategy is to cool air by channeling it through an underground tunnel. Another strategy provides cool air by installing a tube in the ground and dripping water into the tube. This reduces the ground temperature through evaporation.

– Consider evaporative cooling strategies. This cooling method works when water, evaporating into the atmosphere, extracts heat from the air. Evaporative cooling is most appropriate in dry climates, such as the Southwest.

– Use dehumidification in humid climates. Dehumidification is required in climates having high humidity levels, and therefore latent loads, during portions of the year. Common strategies include dilution of interior moisture by ventilating with less humid air, condensation on cooled surfaces connected to a heat sink, and desiccant systems.

Thermal Storage

❑ **Determine if excess heat should be stored or vented.**

Thermal mass in a passive solar building is intended to meet two needs. It should be designed to quickly absorb solar heat for use over the diurnal cycle and to avoid overheating. It should provide slow release of the stored heat when the sun is no longer shining. Depending upon the local climate and the use of the building, the delayed release of heat may be timed to occur a few hours later or slowly over days. Careful selection of the thermal storage medium, its location in the building, and its quantity are important design and cost decisions. Venting, another solution for handling stored heat, can rid the building of late afternoon heat or exhaust heat when the building's thermal mass is already saturated. Venting can also be viewed as a form of economizer cooling, using outside air to cool the building when the outside air is cooler than the building's thermostat setting[3] Venting requires an exhaust fan tied to a thermostatic control or flushing using natural ventilation.

❑ **Choose one or more thermal storage strategies.**

There are two basic thermal storage strategies using thermal mass. "Direct" thermal storage materials, such as concrete masonry or tiles, are placed directly in the sunlight so that intense solar energy enters them quickly. "Diffuse" thermal storage materials are placed throughout the building. They can absorb heat by radiation, the reflectance of sunlight as it bounces around a room, and via air heated elsewhere in the building (e.g., sunspaces and atria). Several storage strategies are presented below.

– Consider concrete, tile, brick, stone, or masonry floors. Flooring using these materials, exposed to direct sunlight, is probably the most common form of thermal storage selected for passive solar buildings. Masonry materials have high thermal capacity; their natural dark color aids in the absorption of sunlight. They also provide an attractive and durable floor surface, are widely available, and readily accepted by contractors and building occupants. Masonry's effectiveness can be inhibited if occupants place furniture and carpets over the floors. To address this, use masonry floors only in the areas where direct heat gain and storage is required.

– Consider a Trombe wall—a south-facing masonry wall covered with glass spaced a few inches away. Sunlight passes through the glass and is absorbed and stored by the wall. The glass and airspace keep the heat from radiating back to the outside. Heat is transferred by conduction as the masonry surface warms up, and is slowly delivered to the building some hours later.

  Trombe walls can provide carefully controlled solar heat to a space without the use of windows and direct sunlight, thus avoiding potential problems from glare and overheating, if thermal storage is inadequate. The masonry wall is part of the building's structural system, effectively lowering costs. The inside, or discharge, surface of the Trombe wall can be painted white to enhance lighting efficiency within the space. However, the outside large dark walls sheathed in glass must be carefully designed for both proper performance and aesthetics.

– Consider masonry or concrete walls insulated on the outside. Many buildings, especially low-rise commercial buildings, are constructed with concrete or masonry walls that can provide excellent thermal mass to absorb excess solar heat and stabilize indoor temperatures. In most climates masonry walls are most energy-efficient when they are insulated on the outside of the building, which allows them to absorb excess heat within the building, without wicking it away to the outside.

  However, there are barriers to using this technique. It is not common practice for contractors, and it may seem redundant to cover up an existing excellent weather surface. Insulated masonry also adds extra width to a wall, making it difficult to finish at the edges of windows, roofs, and doors.

  Fortunately, new technologies have lowered the cost and increased the options for insulated masonry. Various foam insulations are available in panels that can be adhered directly to the masonry surface and then protected with a troweled- or sprayed-on weathering skin, and masonry insulated structural panels are also available. Manufacturers are also developing self-insulating masonry materials that both increase the thermal capacity of the building and slow the flow of heat through the walls.

– Consider using double gypsum board throughout the building. Increase the thermal capacity of a building by simply increasing the thickness of the gypsum board used on interior wall surfaces of the building or by using thicker gypsum board products. Increasing the thickness of all of the wall surfaces can raise the thermal capacity of the building for little additional material cost and practically no labor cost. It has the added benefits of increasing the fire safety and acoustic privacy of interior spaces. This diffuse thermal mass approach depends on effective convective airflows since room air is the heat-transfer medium. To really "charge" the walls, temperatures within the space must be allowed to fluctuate a little more than standard design assumptions, on the order of 5° F above and below the thermostat setting.

– Consider water-storage containers for thermal mass. Water has a very high thermal capacity, about twice that of common masonry materials. Water also has the advantage that convection currents distribute heat more evenly throughout the medium. Passive solar designers have experimented with a wide variety of water-storage containers built primarily into walls. Creative solutions include enclosing water containers in seating boxes under south windows or using water as an indoor feature such as a large tropical aquarium, pond, or pool.

Active Solar Systems

★ SIGNIFICANCE

Active solar collector systems take advantage of the sun to provide energy for domestic water heating, pool heating, ventilation air preheat, and space heating. Active solar systems should be integrated with a building's design and systems only after passive solar and energy-conserving strategies are considered.

Water heating for domestic use is generally the most economical application of active solar systems. The demand for hot water is fairly constant throughout the year, so the solar system provides energy savings year-round. Successful use of solar water heating systems requires careful selection of components and proper sizing. Major components of a system include collectors, the circulation system that moves the fluid between the collectors and storage, the storage tank, a control system, and a backup heating system.[4]

An active solar water heating system can be designed with components sized large enough to provide heating for pools or to provide a combined function of both domestic water and space heating. Space heating requires a heat-storage system and additional hardware to connect with a space heat distribution system. An active solar space heating system makes economic sense if it can offset considerable amounts of heating energy from conventional systems over the life of the building or the life of the system. The system equipment, which can be costly, should be evaluated on a life-cycle basis, using established project financial criteria acceptable to the building owner.

SUGGESTED PRACTICES AND CHECKLIST

General Considerations

❑ **Determine if the climate and building usage is appropriate for an active solar collection system.**
The energy savings for active solar systems depend upon the amount of available solar radiation, projected uses of the system, and the proper system design.

❑ **Determine the financial feasibility of an active solar system.**
A life-cycle cost analysis should be carried out for the up-front and operational costs, and expected energy savings, of an active solar system compared with conventional systems. The financial analysis should be performed over the projected life of the system—a minimum of 10 years. Based on the resulting estimated calculations, the project owner can make a determination of the financial feasibility of investment in the active solar system.

❑ **Determine an appropriate location for solar collectors on or near the building.**
- Locate collectors to maximize exposure to sun. Numerous solar engineering texts describe criteria for optimizing the orientation (ideally due south) and tilt of the collector according to latitude, climate, and usage. Collectors intended for winter space heating have a steeper slope than collectors designed for year-round hot-water heating. Vertically mounted wall collectors and horizontal roof collectors have also been used in various systems.
- Locate collectors to avoid shading from nearby buildings and vegetation. A study of sun angles and local sky obstructions should help determine the best location on the site. For large commercial buildings, the most common location for good solar access is on the highest level of a flat roof.
- Locate collectors to avoid vandalism and safety hazards. Collectors can be attractive targets for vandals. Their flat surface is well suited to graffiti, and glass cover plates can be broken. The more visible the collectors, the more they may attract the attention of vandals.

– Locate collectors to avoid blinding hazards from reflected sunlight. In addition to absorbing the sun's energy, almost all collectors reflect light at certain angles. This reflection is undesirable when directed at the occupants of another building and can be hazardous if directed toward a road or machine operator.

❑ **Design collectors to withstand all weather conditions.**
Heavy snow loads, ice storms, and especially hailstorms can damage collector glass. Tempered glass or reinforced glass is often used to increase resistance. Structures supporting collectors have to be designed to survive wind loads from all directions. A structural engineer should be consulted to ensure compliance with all structural codes.

❑ **Design and locate collectors to maintain a clean surface and facilitate cleaning.**
Dirt and dust on collector glazing can easily reduce system efficiency by 50 percent or more. Insist upon a location and system materials that minimize dirt collection. A regular maintenance schedule is aided by easy access to the collectors, a source of water, and a nearby drainage system. Very large, tall, or horizontal collectors may need to be designed to support the weight of maintenance personnel. In some cases, rainwater may provide adequate surface cleaning.

❑ **Minimize heat losses from the system.**
– Minimize the distance from collection to the storage source. The longer the run from the collectors to storage, the greater the heat loss and reduced system efficiency. For solar heating, locate storage near the central heating system.
– Optimize insulation of collectors, ducts, pipes, and storage. Greater insulation should be installed for higher-temperature collection levels.
– Place duct and piping runs within conditioned space. This design can be advantageous during the heating season, but may be disadvantageous during the cooling season.

❑ **Avoid over-designing to ensure the longevity of an active solar system.**
– Minimize controls. Control technology, along with computer and sensor technology, has advanced significantly over the past years, making older versions quickly obsolete. New systems provide higher efficiencies and greater returns on investment. In addition, the design and building management team should provide maintenance staff with system controls training to optimize system operations.
– Minimize maintenance. A system that is self-maintaining is likely to have a higher efficiency and lower failure rate, and thus the best economic payback. Generally, the fewer moving parts, the less maintenance required. Active solar space-heating systems generally are not operating year-round, so their moving parts must be reliable enough to work intermittently. Pressure-relief valves, self-cleaning surfaces, and overheating sensors pay for themselves by extending the life of the system.
– Maximize access to collectors, pipes, ducts, and storage areas. Assume that all parts of a system may have to be maintained and replaced in the future, and make sure that maintenance and replacement will not be difficult. Pipes and ducts buried in walls and under concrete slabs will be costly to fix, and thus are more likely to be abandoned.

Active Solar Hot Water

❑ **Select the type of solar hot-water heater according to climate, cost, and operations and maintenance preferences.**
There are five types of solar water-heating systems:
– *Thermosyphon Systems*. These systems heat water or an antifreeze fluid, such as glycol. The fluid raises by natural convection from collectors to the storage tank, which is placed at a higher level. No pumps are required. In thermosyphon systems fluid movement, and therefore heat transfer, increases with temperature, so these systems are most efficient in areas with high levels of solar radiation.
– *Direct-Circulation Systems*. These systems pump water from storage to collectors during sunny hours. Freeze protection is obtained by recirculating hot water

from the storage tank, or by flushing the collectors (drain-down). Since the recirculation system increases energy use while flushing reduces the hours of operation, direct-circulation systems are used only in areas where freezing temperatures are infrequent.

- *Drain-Down Systems*. These systems are generally indirect water-heating systems. Treated or untreated water is circulated through a closed loop, and heat is transferred to potable water through a heat exchanger. When no solar heat is available, the collector fluid is drained by gravity to avoid freezing and convection loops in which cool collector water reduces the temperature of the stored water.
- *Indirect Water-Heating Systems*. In these systems, freeze-protected fluid is circulated through a closed loop and its heat is transferred to potable water through a heat exchanger with 80 to 90 percent efficiency. The most commonly used fluids for freeze protection are water-ethylene glycol solutions and water-propylene glycol solutions.
- *Air System*s. In this indirect system the collectors heat the air, which is moved by a fan through an air-to-water heat exchanger. The water is then used for domestic or service needs. The efficiency of the heat exchanger is in the 50 percent range.

Direct-circulation, thermosyphon, or pump-activated systems, require higher maintenance in freezing climates. For most of the United States, indirect air and water systems are the most appropriate. Air solar systems, while not as efficient as water sytems, should be considered if maintenance is a primary concern since they do not leak or burst.[5]

❑ **Consider a pre-heat or full-temperature system.**

- A low-temperature solar water-heating system can be sized to provide only hot-water preheating. When hot water is needed, the warm water from storage is boosted to full temperature with a conventional gas or electric-based hot-water system. These systems can be relatively simple, with reduced collector size, lower insulation levels, and small boosting system, making them attractive options.
- Higher-temperature solar hot-water systems can be designed to provide full-temperature hot water. A conventional gas or electric backup system is used only when there is no sun for extended periods. A high-temperature system can save more in fuel costs, but with the tradeoff of more expensive equipment.

❑ **For systems using water as a collection medium, consider the following issues:.**

- Prevent stagnation. If a system is allowed to stagnate in direct sun, very high temperatures can quickly result, causing collector materials to deteriorate rapidly. and causing closed piping or storage tanks to burst from excessive pressure. Stagnation can be avoided by venting or slow circulation of some water to keep the collectors cool; a drainback system can also be used.
- Provide freeze protection. Freeze protection is important, even in nonfreezing climates, because an extreme weather event can cause substantial damage to a system. In desert climates, systems can freeze even on relatively warm nights because their heat radiates outward to the cool night sky, dropping the system temperature to freezing. The strategies used to protect a water system from freezing are determined by the main system type (e.g., direct-circulation, draindown, or closed-loop).
- Avoid calcification and corrosion. Calcification is the buildup of minerals inside a collector and its pipes caused by "hard" water circulating through the system. Open systems that circulate city water are especially vulnerable. Mineral scales eventually clog the system, reducing flows and pump efficiency. Water can also be slowly corrosive of both metals and organic compounds. Gaskets and sealants can be quite vulnerable. Closed-loop systems can compensate with buffering chemicals to maintain a neutral pH.
- Plan for leaks. Any failure of a water-based system is likely to result in a leak. Provisions should be made to contain all possible leaks and prevent water from

harming other building components. Electrical equipment, and any personnel working on the electrical equipment, should be protected from exposure to leaking water.

- Select a heat-storage strategy. Almost all water systems involve thermal storage. This is typically done by collecting the heated water in storage tanks for use as needed. The simplest systems circulate the heated water directly. More complex systems use one or more heat exchangers to isolate system components, adding the potential for more sophisticated levels of control.
- Minimize pumps and pump energy. Systems using pumps can require significant energy usage. Each pump also requires control logic that raises the complexity and cost of the system. Failure of a pump by stagnation or freezing can result in significant damage.

Active Solar Heating Systems

❑ **Select an active solar heating system and collection medium appropriate for the building's heating and cooling system.**

A solar heating system should be designed to be compatible and interactive with conventional HVAC systems in the building. Water-based systems tend to be most compatible with HVAC systems that also use water as a distribution mechanism, though some interface with air distribution systems. Air-based systems tend to be most appropriate when the building uses a large, centralized air-distribution system. A central heating system has sophisticated controls and centralized ducts that can interface well with a central solar thermal-storage source.

❑ **Evaluate water-based collectors.**

A water-based system typically uses heat exchangers to move heat from the collection medium to the heat-storage or distribution medium. Heat exchanges can transfer heat to water-storage, water-distribution, and also air-distribution systems. (See also the "Active Solar Hot Water" section for additional issues to consider.)

❑ **Consider air-based collectors.**

Air-based systems are the least complex of active systems; therefore, they avoid many of the problems of water collectors. Air collectors are typically simple, flat-plate collectors with plastic covers. They are easily serviced, and have less extreme and costly failures. While safe from freezing or boiling, they do take up considerably more surface area, and their ducts and fans require more space than water pipes and pumps. In addition, sealing an air system against leakage and finding and repairing leaks are more difficult than repairs in water-based systems. When considering air collectors:

- Determine the use of the system. A very simple air system can provide preheated air for a mechanical system. This is basically a heating economizer, and it can use control logic similar to that of a cooling economizer. The resulting energy savings are significant if sunny weather typically coincides with the hours when the building needs heat.
- Determine heat storage needs. Heating requirements in commercial buildings are greatest in the early morning and evening, when solar heat is not available. These buildings require a thermal-storage system to provide solar heat, on an as-needed basis, after it has been collected.

❑ **Consider ventilation air preheat systems.**

This space heating system uses solar energy to preheat ambient air and bring it into a building's ventilation systems. The system utilizes a dark-colored, perforated, unglazed collector, integrated into the building structure, to preheat the air. These systems have efficiencies as high as 75 percent, require low maintenance, and can be installed economically, depending on the building type, climate, and fuel costs.[6]

Photovoltaics

★ SIGNIFICANCE

Photovoltaic (PV) technology is the direct conversion of sunlight to electricity using semiconductor devices called solar cells. Photovoltaics are almost maintenance-free and seem to have a long life span. The photoelectric conversion process produces no pollution and can make use of free solar energy. Overall, the longevity, simplicity, and minimal resources used to produce electricity via PV systems make this a highly sustainable technology.

PVs are currently cost-effective in small, off-grid applications such as microwave repeaters, remote water pumping, and remote buildings. While the cost is high for typical applications in buildings connected to the electric power grid, the integration of PVs into commercial buildings is projected to greatly increase over time. In fact, worldwide PV manufacturing is growing at a healthy annual rate of more than 20 percent, and the focus of research is to reduce the cost of PV systems, and to integrate PV into building design.

The most common technology in use today is single-crystal PVs, which use wafers of silicon wired together and attached to a module substrate. Thin-film PV, such as amorphous silicon technology, is based on depositing silicon and other chemicals directly on a substrate such as glass or flexible stainless steel. Thin-film PV materials can look almost like tinted glass. They can be designed to generate electricity from a portion of the incoming light while still allowing some light to pass through for daylighting and view. Thin films promise lower cost per square foot, but also have lower efficiency and produce less electricity per square foot compared to single-crystal PVs.

PV panels produce direct current, not the alternating current used to power most building equipment. Direct current is easily stored in batteries; a device called an inverter is required to transform the direct current to alternating current. The cost of reliable batteries to store electricity, and the cost of an inverter, increase the overall cost of a system.

With an inverter creating alternating current, it is possible to transfer excess electricity generated by a photovoltaic system back into the utility grid rather than into batteries for off-grid systems. In this case, the utility grid becomes a virtual storage system. Most utilities are required to buy such excess site-generated electricity back from the customer. Recently, through what is called a “net-metering law,” a few state legislatures or public utility commissions have mandated that utilities pay and charge equal rates regardless of which way the electricity flows. Building owners in such states will find PVs more economically attractive.

☞ SUGGESTED PRACTICES AND CHECKLIST

Installation Sites

❑ **Consider conventional and remote electrical uses for PV power.**

- Conventional uses include communications or testing devices that need to operate continuously without supervision or require direct current. Park districts and transportation departments have installed small PV systems to power emergency telephone stations. Water districts have installed PV systems to power monitoring equipment.
- Remote uses include applications in off-grid areas and for small, isolated electric uses. For example, isolated communities can store medical supplies in refrigerators powered by PVs. Any appliance that can run off a 12-volt battery with direct current is a good application for remote PVs because it does not require an inverter to create alternating current.
- Recreational areas far from utility service, such as parks, beaches, and campsites, are

especially good candidates for PV power. With battery backup and an inverter, public facilities, concessions, and guard stations can be powered with reliable electricity off the grid and without the noise of a generator.

- ❑ **Consider utility-integrated PVs where utility demand charges are very high and there is extensive sunshine during the facility's peak electric loads.**
- ❑ **Consider PV-driven battery backup systems where air-quality restrictions limit the use of gas generators for emergency backup.**

Building Integration

❑ **Rack-mount PV systems or mount them directly on roof and wall surfaces.**
Optimizing the panel's tilt to the sun improves performance. Most existing commercial buildings have large, flat roofs exposed to lots of sun, making them good candidates for PV arrays. New buildings can be designed with sloped surfaces that can optimize PV exposure to the sun. The PV panels can be designed as the primary "weather skin" for sloped roofs or walls and can be integrated into shading devices.

❑ **Watch for the commercial availability in the near future of partially transparent PV panels for use as window-shading devices.**
The panels would allow diffuse light through a window while also producing electricity from energy that would otherwise be rejected from the building.

Landscape Integration

❑ **Consider the use of large PV arrays to generate electricity while shading parking lots or other outdoor areas.**
This application is especially appropriate where the PVs are used to generate electricity for parking lot lighting or recreational uses.

❑ **On a smaller scale, PVs can be used to economically power night-time walkway and landscape lighting.**
A small PV panel mounted above the light collects energy during the day and charges a small battery that powers the light for a preset number of hours at night. This type of stand-alone system saves the cost of underground electrical service (see also Chapter 7, "Site Materials and Equipment").

➜ RESOURCES

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ACTIVE SOLAR DESIGN

American Society of Heating, Refrigerating, and Air-Conditioning Engineers. "Solar Energy Utilization," Chapter 30 in *ASHRAE Handbook, HVAC Applications.* Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 1995. Extensive summary of solar fundamentals and current applications of active solar technology. Good bibliography and additional references.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers. *Active Solar Heating System Design Manual*. Atlanta: ASHRAE, n.d. Provides architects, engineers, and designers of large active solar water and space heating systems with design information for a variety of applications, system types, and locations.

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National Renewable Energy Laboratory. "Solar Ventilation Preheating," *Renewable Energy Technologies for Federal Facilities*. Golden, Colo.: NREL, September 1995.

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DESIGN TOOLS

PASSIVE SOLAR DESIGN

BLAST. Calculates building loads, analyzes solar feasibility, predicts life-cycle costs, and helps select the optimal HVAC system for a building. Developed by Civil Engineering Research Laboratories, U.S. Army. Contact: University of Illinois, (800) UI BLAST

ENERGY-10, Low-Rise Building Design (Design manual and software). Windows-environment program for small commercial buildings allowing early design evaluation of 16 energy-saving strategies including daylighting. Developed by National Renewable Energy Laboratory (NREL), Passive Solar Industries Council (PSIC), U.S. Department of Energy (DOE), and Lawrence Berkeley National Laboratory (LBNL). Contact: Blaine Collison at PSIC, (202) 628-7400.

SERI-RES (also known as *SUNCODE)*. Useful for residential and small commercial buildings to analyze passive solar design and thermal performance. Developed by NREL and Ecotope Group. Contact: Ron Judkoff at NREL, (303) 275-3000.

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

ENERGY-EFFICIENT DESIGN

BLAST. See Passive Solar Design. Contact: University of Illinois, (800) UI BLAST

DOE-2. Calculates energy use and life-cycle costs of design options. Includes building envelope, HVAC systems, and daylighting analysis package. DOE Version 2.1E available for MS-DOS and Windows (386 and 486) and UNIX workstations. Developed by LBNL. Contact: Fred Winkleman, (510) 486-4925.

ENERGY-10. See Passive Solar Design. Contact: Blaine Collison at PSIC, (202) 628-7400.

TRNSYS. See Passive Solar Design. Contact: TRNSYS Coordinator , (608) 263-1589.

DAYLIGHTING DESIGN

ADELINE. Advanced integrated lighting design and analysis package, incorporating DXF input capability, SCRIBE MODELLER, PLINK, SUPERLIGHT, SUPERLINK, and RADIANCE, for detailed and advanced analysis of complex buildings. Available for MS-DOS 486 platforms. Developed by LBNL. Contact: Steve Selkowitz, (510) 486-5064.

RADIANCE. Lighting and daylighting modeling tool for performing accurate photorealistic lighting simulation. Available for UNIX workstations. Developed by LBNL. Contact: Charles Erlich, (510) 486-7916.

SUPERLITE 2.0. Daylighting analysis tool. Available for MS-DOS 386 and 486. Developed by LBNL. Contact: Rob Hitchcock, (510) 486-4154.

SOLAR HOT WATER SYSTEM DESIGN

F-Chart. Used for active solar system design applications, including water storage heating, domestic water heating, and pool heating. Versions for Mac, DOS, and Windows. Contact: F-Chart Software, Middleton, Wisconsin, (608) 836-8531 .

TRNSYS. See Passive Solar Design. Contact: TRNSYS Coordinator , (608) 263-1589.

PHOTOVOLTAIC DESIGN

PV F-Chart. A comprehensive PV system analysis and design program for utility interface, battery storage and stand-alone systems. Contact: F-Chart Software, Middleton, Wisconsin, (608) 836-8531.

NOTES

1 Passive Solar Industries Council. *Designing Low Energy Buildings.* Washington, D.C.: Passive Solar Industries Council, n.d., 60.

2 Ibid.; p. 39.

3 Ibid.; p. 60.

4 Ibid.; p. 96.

5 Ibid.; p. 95.

6 National Renewable Energy Laboratory. “Solar Ventilation Preheating,” *Renewable Technologies for Federal Facilities*. (Golden, Colo.: NREL, September 1995.)

SECTION B

Buildings Systems and Indoor Environmental Quality

Designing and installing environmentally sound and energy-efficient systems have a long-term impact on the cost-effective operations of a building and on the productivity of building occupants. Chapter 12 in this section provides guidance on types of heating, ventilating, and air-conditioning (HVAC) system components that will most effectively meet design goals and also examines lighting and other electrical systems for efficiency in products and practices.

Indoor environmental quality is also reviewed, with a focus on indoor air quality (IAQ) and acoustics as two aspects that can affect building occupants' health and productivity. Chapter 13 outlines strategies to achieve good IAQ through control of contaminant sources and occupant activity and through good ventilation and building maintenance practices. Chapter 14 discusses how desired sound control levels can be reached through design practices, construction techniques, and attention to mechanical systems and surface finishes.

Building commissioning, a practice to ensure building systems are installed, operate, and are maintained to meet design goals, is discussed in Chapter 15.

CHAPTER 12

HVAC, Electrical, and Plumbing Systems

Heating, Ventilating, and Air-Conditioning

Author
Clark Bisel

★ SIGNIFICANCE

The amount of energy used annually by heating, ventilating, and air-conditioning (HVAC) systems typically ranges from 40 to 60 percent of the overall energy consumption in a building, depending on the building's design, the use of renewable energy strategies, climate, the building's function, and its condition. HVAC systems also affect the health and comfort of building occupants. These systems serve an essential function and are identified as problem areas more often than other occupancy issues.

HVAC system requirements increased dramatically in the twentieth century in response to changes in other design practices, such as greater use of glazing, sealed buildings, alternate envelope systems with greater thermal loads, larger building floorplates, and more extensive use of artificial lighting and occupant equipment. As a result, buildings have become more dependent on fossil-fuel energy sources instead of natural energy flows such as climate, temperature, and solar conditions.

Before the first energy crisis in the United States in the 1970s, HVAC systems in many commercial buildings were often designed to maintain comfort by simultaneously heating and cooling, with minimal regard for energy use. Additional inefficiencies caused by lighting that used two to three times the energy of modern systems, minimally insulated building envelopes, and other factors further compounded the growth in energy use. The result was excessive energy loss as heating and cooling plants were operated in "opposition" to each other during most hours when the building was occupied, regardless of climatic conditions. Systems such as constant-volume, double-duct and perimeter-induction systems were predominant and were designed primarily for comfort, not energy conservation.

After the energy crisis, design and operating practice shifted drastically. Outdoor ventilation rates were reduced to very low (and now considered unhealthy) levels, lighting levels were decreased, and building temperatures were kept at the outer limits of the comfort range. This resulted in greater occupant dissatisfaction. Since that time, advancements have led to greater precision in maintaining indoor temperature (and often humidity) and indoor air-quality levels, thus increasing the level of HVAC performance and decreasing energy use.

The goal of environmentally sound HVAC system design is to meet occupant needs through the most efficient and environmentally positive means at the lowest initial and life-cycle costs. Solutions that have evolved provide environmental comfort while accounting for climatic conditions, use of space, and building technology. These green system designs take into consideration factors such as solar orientation, floorplate depth, thermal mass, insulation, selection of architectural materials, placement and type of doors and windows, and natural ventilation.

Heating and cooling needs are affected by the performance of interrelated building systems and characteristics, including passive solar design elements such as daylighting, climate-sensitive envelope, and efficient lighting, as well as user equipment needs and other heating loads. The appropriate HVAC solution should be determined only when the full design team has thoroughly reviewed the requirements and contributing thermal loads of these interrelated systems and has carefully considered all efficiency gains possible through design strategies. The design team should also review the budgetary impact of different options. Decisions made in the pre-design phase using this integrated approach will typically lead to reduced energy requirements and lower HVAC system costs.

☞ SUGGESTED PRACTICES AND CHECKLIST

Pre-Design Process

❑ **Develop a conceptual computer model that illustrates projected energy use and sources.**
This conceptual model can serve as a baseline for comparison of system options. The basic framework of the model is the proposed building design, including architectural and systems information. The computer model should be "tuned" to reflect actual performance data from similar types of buildings. A local utility can be helpful in providing this information. The project team should integrate system options and "packaged" solutions. A parametric process can be used to evaluate the impact that a change in one variable would have on the remaining systems—for example, the impact that a different glazing size and type would have on heating, cooling, and lighting. The model can be used to analyze these options on a case-by-case, integrated basis. Each iteration should be reviewed for its relative energy and financial outcomes.

❑ **Use this suggested approach in performing the analysis.**

- Explore passive solar strategies and non-energy-intensive HVAC and lighting opportunities that harness natural processes. Daylighting, natural ventilation, evaporative cooling, thermal mass coupling, energy recovery systems, and other processes may be appropriate. Free cooling directly with outside air or evaporative cooling with water may offer excellent energy-saving opportunities in certain climates.
- Consider the building envelope and integrate this with general architectural issues such as solar strategies, glazing, daylighting, and access.
- Fine-tune the proposed building footprint and orientation to maximize energy benefits.
- Recognize that thermal mass can be beneficial in providing a flywheel effect to reduce after-hours environmental conditioning and morning warm-up loads in the specific microclimate.
- Optimize the energy benefits of glazing selections, sizing, and locations for each building facade.

– Review the interaction between daylighting and artificial illumination. The benefit of reduced lighting energy needs and the resulting HVAC savings are substantial.
– Consider architectural elements such as louvers, blinds, and horizontal and vertical shades to reduce direct solar radiation into the occupied space when not desired (cooling load avoidance).
– Control the infiltration of unwanted air through window-wall detailing, sealing, and building pressurization.
– Consider increased insulation levels for various systems to reduce loss factors.
– Consider vapor barriers to reduce latent (moisture) loads.
– Reduce internal heat gains from office equipment, appliances, ambient lighting, and task lighting. Review design criteria for occupant needs, including lighting and electric power, comfort, and occupant density. Consider options to reduce the energy needs of user equipment.
– Design systems and components for ease of maintenance.
– Incorporate ventilation for healthy indoor air quality and balanced energy use.

❑ **Design the HVAC system and consider potential options.**
After all systems have been optimized in the model, design the resulting HVAC system and reduce energy requirements. This will lead to lower energy and operational costs.

❑ **Improve control systems by using computer software programs and sensors to operate building systems in accordance with occupancy patterns.**

❑ **Develop accurate pricing.**
Prepare realistic cost estimates for all of the modeling and energy-based decisions. Make final decisions on a life-cycle cost basis, reviewing all up-front and annual operating costs.

(See also Chapter 9, “Daylighting,” Chapter 10, “Building Envelope”, and Chapter 11, “Renewable Energy,” for more information on pre-design considerations.)

HVAC Design Guidelines

❑ **Define the project design criteria.**
The design criteria should reflect an understanding of the building’s use, occupancy patterns, density, passive solar opportunities, office equipment, lighting levels, comfort ranges, and specific needs. Actual operating data from similar buildings is of value in this process. When determining final criteria, the design team should build in flexibility to accept future changes in the design. The design criteria should outline a process and goals for evaluating energy efficiency, based on project economics and owner performance requirements.

❑ **Use advanced design methods.**
Utilize the best design tools available to accurately size and select system components. Specify equipment that meets the calculations and do not oversize. Plan for effective ways to meet future load increases without sacrificing current energy requirements. Use computer-based analysis tools to evaluate building load, select equipment, and simulate complete system performance (such as DOE-2.1, ENERGY-10, TRNSYS, and BLAST). Annual simulations are the best tool for evaluating the complex interaction between building systems. (See “Resources” section for more information on Design Tools.)

❑ **Design for part-load efficiency.**
Select equipment that remains efficient over a wide range of load conditions. Size systems to accommodate multiple stages of capacity that can be activated in sequence. Buildings operate at part-load status most of the time. Peak system loads occur infrequently and are usually caused by the simultaneous occurrence of multiple factors such as peak occupancy, temperature extremes, and use of occupant equipment. HVAC systems need to respond to various loads in order to achieve the greatest overall efficiency.

❑ **Optimize system efficiency.**
HVAC systems consists of several different types of equipment including fans, pumps, chillers/compressors, and heat-transfer equipment. The performance of the overall HVAC system should be optimized over that of any individual component. For example, the cooling system components should be optimized as a system, including the chiller, pumps, cooling tower, cooling coil, and distribution piping.

❑ **Design for flexibility.**
The HVAC design should provide flexibility to address future changes in the building and its functions and use over time. Planning for change includes factoring in potential new users.

Control Systems

❑ **Design a building-management control system.**
The continued development of microprocessor-based building controls and sensors has led to a revolution in control-system applications. Individual equipment components often contain electronic intelligence and the ability to coordinate their operations with those of other system components.

- Consider the use of direct digital control (DDC) electronic systems for all functions, including central equipment control and zone-level management. This provides greater energy-efficiency capabilities, accuracy, and flexibility. Zone-level control features are important because sensors in each zone directly measure factors such as temperature, airflow, lighting, and whether the area is occupied or unoccupied. These control features are linked to the central systems and can be used to optimize system functions.

❑ **Train building engineers to use the control system for greater comfort and efficiency.**
Proper use of the control system's remote reporting, diagnostic, and troubleshooting capabilities allows the building engineer to monitor and modify system operations for optimal energy efficiency, lighting use and HVAC performance.

❑ **Integrate the operation of all components and install a centralized computer interface throughout the project.**
Coordinate various building management functions (energy, lighting, life safety, security, elevators, etc.) by integrating occupancy sensors, daylighting control, temperature control, and ventilation levels.

❑ **Ensure that HVAC control systems include the following functions:**

- Basic features
  a. Comfort control (temperature, humidity)
  b. Scheduled operation (time-of-day, holiday and seasonal variations);
  c. Sequenced modes of operation;
  d. Alarms and system reporting; and
  e. Lighting and daylighting integration.
- Additional capabilities
  a. Maintenance management;
  b. Indoor-air-quality reporting;
  c. Remote monitoring and adjustment; and
  d. Commissioning flexibility.

Air-Delivery Systems

❑ **Use variable-air-volume systems.**
This approach reduces energy use during part-load conditions and takes advantage of each zone's operational characteristics.

❑ **Avoid reheating for zone temperature control.**
Consider a dedicated-perimeter heating system and the use of room return air for heating to minimize outdoor-air reheat penalty.

- ❑ **Reduce duct-system pressure losses.**
  The amount of fan energy used to distribute air throughout a building is significant. Most ductwork sizing does not generally take into account the distribution system as a whole. However, computer-based programs for sizing ductwork are becoming widespread. These programs facilitate improved analysis that can reduce energy losses. A good design should strategically locate balancing dampers to improve energy efficiency. The use of round or flat oval ductwork will reduce energy losses and minimize acoustical radiated noise.
- ❑ **Reduce duct leakage and thermal losses by specifying low-leakage sealing methods and good insulation.**
- ❑ **Consider proper air distribution to deliver conditioned air to the occupied space.**
  Optimal selection and location of air diffusers will save energy and improve comfort control. Select diffusers with high induction ratios, low pressure drop, and good partial-flow performance.
- ❑ **Use low-face velocity coils and filters.**
  Reducing velocity across coils and filters will reduce the amount of energy lost through each component. It also will allow more efficient fan selection, and reduce noise attenuation needs.
- ❑ **Use cold-air systems.**
  Consider a design that supplies air at lower temperatures to reduce airflow requirements and fan energy usage. This offers additional benefits of lower indoor air humidity and potentially higher room temperatures.
- ❑ **Design equipment and ductwork with smooth internal surfaces.**
  This will minimize the collection of dust and microbial growth. Be sure to provide adequate access for inspection and cleaning.

Central Equipment

- ❑ **Evaluate chiller selection.**
  Chiller options are routinely evaluated on larger projects but often are overlooked as a component of smaller, packaged equipment. High-performance chiller equipment is available in all sizes. Integrated controls that work with other HVAC components to increase operating flexibility are also available. Open-drive compressors eliminate one source of loss by not rejecting the compressor motor heat into the refrigerant flow. The energy and cost savings associated with of converting or retrofitting outdated chillers that contain environmentally harmful refrigerant should be assessed. The use of evaporative cooling equipment should be considered for greater efficiency.
- ❑ **Evaluate a multiple-chiller system with units of varying size.**
  Most installations with a chiller plant should have multiple chillers of different sizes. An alternative is to provide variable-speed drives for improved chiller operation during part-load conditions. This approach allows the most efficient chiller operation for low loads.
- ❑ **Consider desiccant dehumidification.**
  These systems are effective where latent loads are significant, such as in humid climates or low-humidity spaces. Adsorbent enthalpy wheels (which use exhaust air to dehumidify or to cool supply air) or heat-regenerated enthalpy wheels can significantly reduce electrical power needs for refrigerant-based dehumidification. (See also Chapter 11, "Renewable Energy.")
- ❑ **Consider absorption cooling.**
  This approach typically changes the energy source from electricity to gas and can reduce energy costs; however, it is not likely to reduce energy use inside the building. Although not as efficient as electrically driven chillers, absorption chillers permit the use of a lower cost fuel. A heat source, such as steam, natural gas, or high-temperature waste heat, usually drives the absorption refrigeration process. Direct-fired gas equipment can also be selected to provide hot water for building heating needs in addition to chilled water.

❑ **Consider thermal energy storage.**
The heating and cooling loads of a building vary on a daily and seasonal basis. Thermal energy storage (TES) makes it possible to manage a building's utility usage, or conduct "load management." A TES system generates and stores thermal energy on a daily, weekly, or longer basis. It can shift the use of more expensive peak utility energy to less expensive off-peak time periods. Ice banks and stratified chilled water are the most common examples.

❑ **Evaluate hydronic pumping systems.**
Primary and secondary pumping systems with variable-speed drives are worth consideration because of their effects on part-load energy use. Pressure losses in piping can be reduced by selecting pipe sizes with a lower pressure drop factor. The design should optimize total head loss with a minimum of flow-balancing controls. New systems that use hydronic system additives to reduce system friction losses and associated pumping energy are being developed.

❑ **Evaluate heat exchangers.**
Select heat exchangers with low approach temperatures and reduced pressure drops.

❑ **Consider other heating-system equipment and enhancements.**
It is advisable to use condensing boilers, match output temperatures to the load, use temperature reset strategies, and select equipment with good part-load ability. Specify multiple, staged operations wherever possible.

❑ **Evaluate heat-recovery options.**
Where simultaneous heating and cooling loads occur, evaluate the use of heat-recovery chillers. High ventilation loads benefit from air-to-air heat-recovery systems for both sensible (i.e., direct heating or cooling requirements) and latent loads.

Efficiency-Enhancement Options within HVAC Components

❑ **Consider additional improvements to energy efficiency.**

- High-efficiency motors are suggested for all applications because of their energy savings capabilities, longer life, and reduced maintenance costs. Motors should be of the proper size to avoid the inefficiencies of oversized equipment.
- Variable-speed drives have advanced significantly over recent years. They offer a proven means of substantially reducing the energy used by fans, chillers, and pumps under part-load conditions. Electronic drives are considered the best option; drive controller and motor selection are also important considerations.
- Mechanical drive efficiency can be improved to reduce losses in the power transmitted from a motor to the motor-driven equipment. Consider direct-drive equipment options and review actual loss factors on belt- or gear-driven equipment.
- Direct digital control (DDC) systems offer greater accuracy, flexibility, and operator interface than pneumatic systems. Use sensors that have the greatest accuracy to improve energy efficiency and performance.
- Advanced control strategies using DDC systems include system optimization, dynamic system control, integrated lighting and HVAC control, and variable-air-volume (VAV) box airflow tracking.

❑ **Undertake independent system testing, adjustment, and balancing to improve efficiencies and comfort.**

Building Commissioning

❑ **Use the commissioning process (see Chapter 15, "Building Commissioning") to ensure that HVAC operations meet expectations.**
Energy-saving features often have not met the design predictions in actual operation. The process of building "commissioning"—documenting that a completed building meets the original design intent and the owner's objectives—has evolved to reduce or eliminate this shortfall. Commissioning activities should begin at the inception of design and continue through completion of construction and occupancy. Commissioning should be tailored to each project. The process is governed by a commissioning plan that defines performance-test requirements, responsibilities, schedules, and documentation. The level of detail involved in commissioning depends on the project's complexity.

Balancing Energy and Indoor Air Quality

Energy efficiency and indoor air quality (IAQ) can be closely linked through integrated design strategies for ventilation systems. (See Chapter 13, "Indoor Air Quality," and Chapter 16, "Materials," for more information on reducing pollutant sources.) To balance energy efficiency and indoor air quality needs, consider the following:

❑ **Begin the design process with the goal of maximizing IAQ performance and energy efficiency.**
Project goals and performance guidelines for both areas are needed.

❑ **Include dedicated ventilation systems.**
With dedicated and controlled ventilation air fans and dampers and/or dedicated ventilation distribution, the quantity of air can be regulated, measured, and documented. This provides greater certainty that acceptable air ventilation is maintained. Ventilation air can be separately conditioned for improved energy efficiency.

❑ **Consider heat-recovery options.**
High ventilation loads benefit from air-to-air heat-recovery systems for both sensible and latent loads. Air that is exhausted from the building can be used to precondition air entering the building, thus reducing energy needs (however, care should be taken not to reintroduce exhaust air into the supply airstream). Run-around hydronic loops and heat pipes are two solutions that improve energy efficiency.

❑ **Reduce pollutants.**
Install separate exhaust systems in areas with high indoor air pollution sources such as kitchens, janitorial closets, photocopier areas, and office equipment rooms.

❑ **Institute ventilation demand strategies.**
Regulate quantities of ventilation air based on specific occupancy needs. For example, sensors that detect occupancy, carbon dioxide, and volatile organic compounds (VOCs) can be used to monitor occupant loads and provide greater fresh-air intake. Consider air cleaning with high-efficiency filtration.

❑ **Consider diffuser selection.**
Provide proper air distribution to deliver conditioned air to the occupants' work areas. The selection and location of diffusers can save energy and improve operation of the HVAC system control. Select diffusers with high induction ratios, low pressure drop, and good partial-flow performance. Locate diffusers for proper airflow, not on the basis of a simplistic pattern. Coordinate the layout with furniture and partitions.

❑ **Consider underfloor air distribution.**
Once the solution only for computer rooms, displacement ventilation is gaining acceptance for other building spaces, particularly in milder, low-humidity climates. Underfloor air systems can operate at higher supply-air temperatures with much lower fan energy requirements. IAQ is improved because of greater quantities of ventilation air and uniformity of distribution.

❑ **Perform a pre-occupancy flushout.**
The building controls can be programmed to initiate the flushing of a building with outside air prior to occupancy. This reduces indoor pollutants and pre-cools the space with night-time air. Running the HVAC system with a higher or continuous supply of fresh air is also beneficial during initial occupancy after construction.

❑ **Consider the use of evaporative cooling equipment.**
Primarily in dry climates, greater use of outdoor air can translate into improved effectiveness for direct or indirect evaporative cooling equipment, reducing mechanical refrigeration needs. However, proper maintenance is essential to prevent IAQ problems caused by microbial contamination. (See also Chapter 11, “Renewable Energy.”)

Renovation and Retrofit Issues

HVAC system renovations are initiated for a variety of reasons. It is important to consider all of the following issues during this process:

❑ **Consider chlorofluorocarbon (CFC) changeout.**
Retrofits offer an opportunity to replace or convert an existing refrigeration system to one that uses an environmentally benign refrigerant.

❑ **Replace outdated systems or components.**
Existing HVAC systems may be at the end of their expected life.

❑ **Address and correct past problems with ventilation and indoor air quality.**
(See Chapter 13, “Indoor Air Quality,” and Chapter 21, “Operations and Maintenance”).

❑ **Re-size components to current requirements.**
Existing system components may be oversized, especially after efficiency improvements are made to other systems (e.g., lighting reductions). The retrofit process allows system components to be matched to actual loads with a corresponding efficiency gain.

❑ **Improve occupant comfort.**
An assessment of occupant issues related to temperature control and ventilation levels can lead to renovations that improve comfort levels and productivity.

❑ **Eliminate code deficiencies.**
Upgrade components to comply with changes in building codes or comply voluntarily with current codes.

❑ **Install new building-control system.**
Control-system technology is far more advanced than it was several years ago. Modern systems can be used to manage multiple buildings, alarms, and zones. The purchase and installation costs of such systems may be justified based on energy savings and better indoor air quality.

Lighting

★ SIGNIFICANCE

Artificial lighting constitutes 20 to 30 percent of all energy use in a commercial building and approximately one-fifth of all electrical energy use in the United States.[1] Reductions in energy use can be achieved with natural daylighting, advanced lighting technology, and efficient lighting design.

Artificial light has been generally overused in most buildings. Current building codes mandate a maximum lighting power density of 1.5 to 2.5 watts per square foot. Nevertheless, a lighting power density of 0.65 to 1.2 watts per square foot can be achieved while still providing a fully functional, well-lit space. With additional improvements from control systems that reduce usage during periods of non-occupancy, the use of daylighting, and light-level maintenance and tuning control, energy savings of more than 50 percent are possible. Because reduced lighting generates less heat, HVAC cooling requirements are lowered as well.[2]

Daylighting, a standard design goal for all but the last 50 years, is often overlooked in today's design practice (see Chapter 9, "Daylighting"). Green building design guidelines should encourage the maximum use of natural light, supplemented by artificial systems as needed. Increased daylighting levels are now required by many building energy codes. The design team should be aware of basic options and methods for integrating effective daylighting with the control of artificial lighting performance. This demands close coordination and support among all members of the design team.

Building form, orientation, and envelope design play key roles in effective daylighting integration and should be considered by the design team in the pre-design phase. Computerized modeling and visualization tools can aid in quantitative and qualitative evaluation. Utilization of reflected light is another important factor in efficient and effective lighting. As much as 30 percent of light in most office environments comes from light reflected off walls, ceilings, tables, and other furniture. The use of bright colors and highly reflective surfaces on walls, ceilings, and furniture can play a major role in energy savings.

☞ SUGGESTED PRACTICES AND CHECKLIST

Lighting Design Guidelines

- ❑ **Include the entire design team in the design of building massing, orientation, and envelope to achieve greater daylighting contribution.**
  Understand and take advantage of the specific daylighting characteristics at the building site (see Chapter 9, "Daylighting").
- ❑ **Incorporate the most energy-efficient technology for lamps, fixtures, and control equipment.**
- ❑ **Consider all lighting functions (including the ambient system, task lights, emergency and 24-hour lighting, exterior lights, exit lights, and public-area lighting).**
- ❑ **Use sophisticated design analysis, including computer simulation, for system design.**
  Computer design tools such as the LUMEN MICRO, ADELINE, SUPERLITE, and RADIANCE programs are useful for avoiding the conventional practice of overlighting spaces. (See Chapter 9, "Daylighting" for more information on Design Tools.)
- ❑ **Consider using the guidelines of the Illuminating Engineering Society (IES).**
  Avoid the use of outdated, higher light-level standards. The IES guidelines provide specific target illumination levels for various visual tasks. Criteria should include illumination levels and luminance ratios since uniformity plays an important part in perceived lighting adequacy. Some variation of light is helpful for providing occupant comfort and more accurately reflects actual outside daylight conditions.
- ❑ **Design for specific visual tasks.**
  Typical lighting methodologies often do not tailor the lighting criteria and the resulting system to the visual task. With the visual display terminal (VDT) becoming standard in all building types, lower ambient lighting levels are gaining greater acceptance. Some professionals believe that overlighting VDT office environments causes visual fatigue because of the excessive contrast between the VDT and surrounding environment, resulting in lower productivity and long-term health problems.
- ❑ **Consider task-lighting systems that reduce general overhead light levels.**
  Provide supplemental task illumination only in required areas, with higher light levels only at the focal point of the visual task rather than throughout the entire space.

- ❑ **Match the quality of light to the visual task lighting requirement.**

  The quality is more important than the quantity of light delivered to the visual task. A high-quality lighting solution requires less light to yield the same visual performance. Light quality involves the following factors:
  - Luminance ratio limits;
  - Veiling reflections (reflection of light source in visual task);
  - Reflected glare;
  - Shadows;
  - Color; and
  - Intensity.

  For example, indirect lighting systems that reflect light off the ceiling can produce a low level of uniform, low-glare light that is sufficient for VDT lighting needs, with energy-saving results.

- ❑ **Improve lighting design and energy efficiency by performing several key activities in the early phases of architectural space planning.**
  - Coordinate the lighting plan (reflected ceiling plan) with furniture layout. Areas such as walkways or service spaces can "borrow" light from adjacent work areas.
  - Coordinate daylighting to be available in spaces such as walkways, lounges, and areas intended for recreation and other public uses where the variation of color, intensity, and direction of light are desirable. In other spaces such as offices and conference rooms where lighting quality is important for performance of visual tasks, daylighting needs to be controlled properly for brightness and direction of light.
  - Where possible, group occupants with similar work schedules together. This allows lighting in other areas to be turned off during unoccupied periods.

- ❑ **Improve room-cavity optics.**

  The use of smooth, high-reflectance surfaces can greatly improve the efficiency of natural and artificial lighting. For example, use:
  - Light- or neutral-colored surfaces to improve reflected light;
  - Fine-fissured ceiling tiles with a smooth, reflective surface;
  - Light shelves for introduction and control of natural light; and
  - Low office partitions to avoid shadows and dark zones.

Lighting Fixtures and Lamps

- ❑ **Specify efficient lamps for the intended use.**

  Choices in lamps have greatly expanded during the recent revolution in lamp technology to include:
  - T8 fluorescent lamps;
  - Compact fluorescent lamps;
  - Lower-wattage, high-color-rendering HID lamps;
  - Compact reflector HID lamps (such as PAR30 and PAR38);
  - Halogen lamps with infrared reflectors; and
  - Sulfur bulbs.

- ❑ **Use electronic ballasts.**

  One of the biggest improvements in fluorescent lighting efficiency over the past few years has been the introduction of reliable electronic ballasts, which are 10 to 20 percent more efficient than the most efficient magnetic-coil-type ballast. Electronic ballasts energize lamp phosphors at a higher frequency which eliminates flicker and offers better light quality while using less energy. Selecting electronic ballasts with the appropriate capacity of light output (known as the "ballast factor") makes it possible to match light output from fixtures and lamps to the specific design requirement. Dimmable ballasts (stepped and continuously dimming) provide a significant increase in efficiency when used in conjunction with the control opportunities discussed below. The latest ballasts have substantially reduced induced harmonics, one of their previous drawbacks, and high power factors. The use of electronic ballasts with HID lamps has been found to limit the color shift often inherent in HIDs and standard magnetic ballasts.

❑ **Improve optical control.**

Construction and retrofit projects can take advantage of new improvements in optical control by providing more light for the visual task and reducing glare or spilled light while also enhancing energy efficiency. Reflectors within the fixture that direct and control light into the space are now computer-designed and optimized for better efficiency and control. Louver-finish options are also available for visual comfort and integration into a VDT-intensive area. Specifying fluorescent fixtures with heat extraction over the lamp cavity also improves fixture efficiency by allowing the lamp to operate at a cooler temperature and produce more light output.

Lighting Controls

❑ **Provide effective lighting control.**

Among the greatest benefits of energy-efficient lighting are those resulting from effective lighting control. The most basic function is time-of-day control to turn lights on and off. In addition:

- Use occupancy sensors to detect when occupants are present in a space and to turn off lights when the space is unoccupied. Studies have shown that this results in a potential energy savings of more than 60 percent, depending on type of occupancy. Recent project experience indicates that occupancy sensors are less costly to install than programmable-control or dual-level manual switching.[3]
- Incorporate daylighting control strategies. Every building should provide the means to control the electric lighting system in response to natural light from all envelope sources. Dimmable and stepped daylighting controls are two options that take advantage of the latest technology. Continuously dimmed control systems have the highest level of energy savings and user acceptance. They also offer additional energy-saving operational strategies but have greater initial cost than stepped daylighting controls (see Chapter 9, "Daylighting").
- Incorporate lumen-maintenance controls that use photocells to continuously dim ballasts to maintain desired illumination levels and adjust lamp output in response to variable outputs. Lumen output from light fixtures and lamps will be reduced over the course of their operating lives because of factors such as inherent lamp lumen depreciation and dirt accumulation on the fixture. Controlling light fixture energy, and thus light output, overcome these factors to achieve energy savings.
- Incorporate light-level tuning. Develop light-fixture layouts according to the layout of workstations or illumination criteria. This is preferable to the practice of designing fixture layouts for visual appeal, uniformity, and standardization of lamps. Dimmable ballasts allow lighting levels to be dimmed or "tuned" to the desired light levels, reducing energy use accordingly.

Additional Lighting Considerations

❑ **Use efficient exit signs.**

Modern exit signs use only one to six watts, compared to 40 watts for older signs. The energy savings can be sizable given the large quantity of exits and the need for continuous operation of exit signs.

❑ **Consider improved task-lighting products.**

Inefficient incandescent and under-counter strip fluorescent fixtures are outdated when compared to the products now available on the market, such as 15-watt compact fluorescent task lights. Issues such as luminance ratios (critical in VDT environments), veiling reflectance glare, and asymmetrical light distribution are important factors for task lighting. High-performance task lights, compact fluorescent sources, asymmetric reflectors, and electronic ballasts should be specified. These measures can reduce energy use by more than 50 percent. Some task lights are available with occupancy sensors

Renovation and Retrofit Issues

❑ **Convert existing light fixtures.**
Consider all design-related issues such as appropriate light level and quality, architectural and furniture layout, and room cavity optics, as well as replacement and proper disposal of older ballasts containing polychlorinated biphenyls (PCBs). If major renovations are planned (such as new roofs and replacement windows), also consider daylighting improvements.

Electrical Power Systems

★ SIGNIFICANCE

Office technology, including telecommunication devices, personal computers, networks, copiers, printers, and other equipment that has revolutionized the workplace in the last 10 years, together with appliances such as refrigerators and dishwashers, makes up the fastest-growing energy load within a building. The consumption of energy to run these devices can be comparable to that of a building's mechanical or lighting systems. The design and management team should advise building users of the energy impact of efficient office equipment and appliances. The latest equipment offers energy reductions of more than 75 percent.[4]

Local area networks (LANs) and peer-to-peer computing create significant energy loads within a building because they create a demand for 24-hour operation. In addition, it is estimated that office computers consume over 26 billion kilowatt-hours of electricity annually, costing over $2 billion; this may increase five-fold in the next decade. Decentralized information processing also demands increased HVAC support. LAN rooms, telephone closets, and even some general office areas need to maintain 24-hour "computer-room" cooling and humidity requirements year-round, further increasing energy demands and costs.[5]

The indirect environmental costs of energy consumption associated with office equipment include the release of significant amounts of carbon dioxide, sulfur dioxide, and nitrogen oxide into the atmosphere each year. Office automation and telecommunications systems have led to a dramatic increase in the volume of CFCs in the workplace to meet the demands of distributed, packaged air conditioners and halon fire-protection systems.

Office technology contributes to "electromagnetic pollution" in the workplace, an issue that is beginning to generate increased research and public concern. Radio-frequency emissions from electronic devices and their interconnecting cables can cause mutual interference. Radio frequencies associated with microwave and satellite dishes, cellular telephones, and two-way radios may be harmful to building occupants, but additional research is required before a consensus in the scientific community can be achieved.

The electrical-power distribution system should deliver power reliably and efficiently throughout a building. Losses result in wasted heat energy. Measures that reduce loss and match power distribution to the various electrical loads in the building should be considered. Electrical loads may also degrade power quality and introduce wasteful harmonics or change power factors.

Design Considerations

❑ **Specify energy-efficient office equipment.**
The U.S. Environmental Protection Agency (EPA) and the electronics industry are working to cut the power consumption of desktop computers by 50 percent by the year 2000 through the Energy Star program. The program encourages the use of special features to put personal computers, printers, and copy machines into a low-energy "sleep" mode when idle. In addition, energy-saving computer chips, originally developed for laptop computer applications, will be used in desktop machines. Look for the Energy Star label when making equipment purchases. The EPA also publishes a list of energy-efficient retrofit kits for older computer equipment.

❑ **Specify energy-efficient appliances.**
Many energy-efficient and environmentally sound appliance alternatives now exist. New refrigerators consume less than one-half the energy of older models. In addition, some are CFC-free. Dishwashers that use less than one-half of the water and energy consumed by older models are also available.

❑ **Consider higher system voltages.**
Less energy is lost in distribution systems with higher system voltages. This factor is often ignored in an effort to minimize initial construction costs. The long-term impact of lower voltages typically is not quantified.

❑ **Improve power factor.**
Power factor is the ratio of active power to apparent power. The electrical load may shift the phased relationship between electric current and voltage, thereby altering the power factor. These shifts are often caused by large motors. Poor power factor results in increased distribution and motor losses that require additional energy. Use motor selection, proper motor sizing, and corrective equipment (such as capacitor banks) appropriately.

❑ **Use K-rated transformers.**
K-rated transformers better accommodate electric power irregularities or harmonics. They can be used when tenant equipment (such as personal computers) introduces harmonics on the power system. These devices accept the harmonics without a reduction in system rating or efficiency.

❑ **Size conductors correctly.**
Selecting conductors of the proper size can reduce voltage drop and power losses and should be considered, particularly for more concentrated loads. Neutral leg current flow, associated with equipment that has switched power supplies, should be addressed in design.

Renovation and Retrofit Issues

❑ **Optimize energy use of current equipment and specify more efficient systems with future equipment procurement.**

❑ **Retrofit computers with shut-off devices.**
Some users believe that turning off equipment can *shorten* its lifetime; however, equipment manufacturers have stated otherwise. Low-cost devices that sense periods of inactivity can automatically turn off computer equipment after a set period of time. These individual computer devices can be set to turn off a computer's central processing unit (CPU) and monitor separately. These devices have been shown to be extremely cost-effective, with payback periods of around one year.

Plumbing Systems

★ SIGNIFICANCE

Water use in buildings has two environmental impacts: (1) the direct use of water, a limited resource; and (2) the expenditure of energy used in water pumping, purification, treatment, and heating. This section considers the energy-use aspects associated with water usage within a building, including pumping and hot-water heating (see also Chapter 11, "Renewable Energy"). Other chapters discuss additional water-use strategies, such as graywater systems and landscape irrigation (for example, see Chapter 6, "Water Issues").

The overall amount of energy used to pump, treat, and heat water can approach 10 percent of a utility company's output. The primary areas where improvement is possible are: (1) more efficient water generation and end-use devices, (2) reduced storage losses in hot-water equipment, (3) reduced piping and pumping losses, and (4) reduction in hot-water temperatures to provide the minimum acceptable temperature for intended use.

SUGGESTED PRACTICES AND CHECKLIST

Hot-Water Heating

❑ **Consider hot-water heating options.**
Analyze and specify efficient equipment options. Heat pumps, heat recovery processes, tankless water heaters, and combination space heating-water heating systems are options that can improve efficiency significantly.

❑ **Reduce hot-water system standby losses.**
Losses from distribution piping and hot-water storage tanks can be more than 30 percent of heating energy input. Tank insulation, anti-convection valves and heat traps, as well as smaller heaters with high recovery rates, can reduce these loss factors.

❑ **Evaluate system configuration.**
Consider the benefits of localized hot-water equipment versus centralized equipment by evaluating the types of loads served. Localized heating equipment options for small isolated loads may include electric heat-tracing devices which use a linear-resistance heating element wrapped around the piping.

❑ **Reduce hot-water service temperatures.**
Confirm the lowest hot-water temperature needed for the usage or equipment. Lowering the hot-water supply temperature reduces initial heating-energy and system losses. This approach should be limited to a minimum water temperature so as not to allow growth of harmful bacteria in piping.

❑ **Install hot-water system controls.**
Appropriate controls optimize energy use. Time-of-day equipment scheduling is a basic function; the use of certain applications may benefit from temperature optimization features.

❑ **Consider solar hot-water heating**
Consider solar systems based on building type, hot-water needs, and solar conditions at project site (see Chapter 11, "Renewable Energy").

Water-Pumping Systems

❑ **Use low-flow plumbing fixtures.**
Low-flow fixtures may seem to be a water conservation method, but they also save energy because they reduce pumping energy and water heating. Products are available for a wide range of applications and have become standard in many areas.

❑ **Use water-booster pumps.**

Use packaged pumping systems with staged pump operation to better serve part-load flow conditions, such as after hours. Systems can include a pressurized tank to further reduce pump cycling and improve efficiency.

❑ **Prepare an efficient plumbing system layout.**

Prepare an efficient design for the layout of pumping and piping distribution, including:

– Simple, short piping runs with minimum offsets and pressure control stations;
– Stacking of water services in multi-story buildings;
– Gravity flow of effluent from buildings without mechanical sump pumps; and
– Calculation of minimum pressure requirements for distribution and booster pumps if necessary.

Utility Company Rebates and Assistance

★ SIGNIFICANCE

Over the past decade, utility companies across the country have developed both technical and financial programs to help their customers understand and implement energy-efficiency measures. These programs have garnered substantial customer awareness and response. With deregulation however, the utility industry is now beginning a radical restructuring of customer-service access that is expected to change the nature of utility involvement in promoting energy efficiency.

The industry now considers energy-efficiency issues for buildings under the broader concept of demand-side management (DSM), which encompasses all methods available to customers to reduce, modify, or control the use of energy. Utilities first became interested in DSM issues because of their desire to control peak utility supply requirements or to shift energy service to time periods most beneficial to their generation or transmission systems. Interest in actually reducing customer energy use came only after public utility commissions (PUCs), which regulate investor-owned utilities, identified the need to initiate more aggressive programs. By giving the utilities an economic return on efficiency investments, the PUCs developed the financial mechanism to reward utilities for promoting efficiency gains. In turn, the utilities have marketed energy efficiency to customers and created programs that offer incentives to install efficient systems.

The future of DSM programs will be driven by the future of utility deregulation, although the direction of change is uncertain. Deregulation effects power generation and distribution as well as energy costs. "Retail wheeling," an element of deregulation, allows the customer to negotiate with competing utilities to obtain service and select the most economical alternative regardless of geographical location. The loss of customers by a local utility could result in higher rates for remaining customers.

☞ SUGGESTED PRACTICES AND CHECKLIST

❑ **Obtain input from utilities early in the design process.**

The design team should meet with the designated account representative to learn about current and future design and financial incentive programs, including rebates or loans.

❑ **Seek out utility resources and design assistance.**

Some utility companies have recognized that additional assistance in the form of educational or technical offerings can be valuable to both the building owner and design professional. Offerings may include:

– Early project review by a utility-sponsored design group to solicit ideas on daylighting contributions and reduced HVAC requirements and to involve the group in creation of computer-based energy models for the project;

– Energy learning centers with classroom and library facilities; and
– Technical seminars on specific issues provided for general information.

❑ **Institute rebate documentation and verification measures with utility.**
Verification of system performance at construction completion may be needed for more complex efficiency measures or custom rebate applications. Utilities are interested in seeing that design-efficiency objectives are realized in operation and are beginning to offer rebate incentives for building commissioning.

❑ **Assess the impact of deregulation.**
Track current energy use and estimate the potential exposure to energy cost increases. Project any plans for building expansion and related modifications and their anticipated energy usage; consider energy-efficiency options as an alternative to increased supply needs.

➜ RESOURCES

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Series of technical handbooks considered the most comprehensive HVAC reference available. These handbooks introduce design issues and provide extensive technical documentation for engineering purposes. ASHRAE is responsible for the development of practice standards for specific issues such as ventilation and energy. ASHRAE also publishes a monthly journal, which includes technical articles on a variety of topics, including energy efficiency.

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DESIGN TOOLS

PASSIVE SOLAR DESIGN

BLAST. Calculates building loads, analyzes solar feasibility, predicts life-cycle costs, and helps select the optimal HVAC system for a building. Developed by Civil Engineering Research Laboratories, U.S. Army. Contact: University of Illinois, (800) UI BLAST

ENERGY-10, Low-Rise Building Design (Design manual and software). Windows-environment program for small commercial buildings allowing early design evaluation of 16 energy-saving strategies including daylighting. Developed by National Renewable Energy Laboratory (NREL), Passive Solar Industries Council (PSIC), U.S. Department of Energy (DOE), and Lawrence Berkeley National Laboratory (LBNL). Contact: Blaine Collison at PSIC, (202) 628-7400.

SERI-RES (also known as *SUNCODE)*. Useful for residential and small commercial buildings to analyze passive solar design and thermal performance. Developed by NREL and Ecotope Group. Contact: Ron Judkoff at NREL, (303) 275-3000.

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

ENERGY-EFFICIENT DESIGN

BLAST. See Passive Solar Design. Contact: University of Illinois, (800) UI BLAST

DOE-2. Calculates energy use and life-cycle costs of design options. Includes building envelope, HVAC systems, and daylighting analysis package. DOE Version 2.1E available for MS-DOS and Windows (386 and 486) and UNIX workstations. Developed by LBNL. Contact: Fred Winkleman, (510) 486-4925.

ENERGY-10, *Low-Rise Building Design*. See Passive Solar Design. Contact: Blaine Collison at PSIC, (202) 628-7400.

TRNSYS. See Passive Solar Design. Contact: TRNSYS Coordinator , (608) 263-1589.

DAYLIGHTING DESIGN

ADELINE. Advanced integrated lighting design and analysis package, incorporating DXF input capability, SCRIBE MODELLER, PLINK, SUPERLIGHT, SUPERLINK, and RADIANCE, for detailed and advanced analysis of complex buildings. Available for MS-DOS 486 platforms. Developed by LBNL. Contact: Steve Selkowitz, (510) 486-5064.

RADIANCE. Lighting and daylighting modeling tool for performing accurate photorealistic lighting simulation. Available for UNIX workstations. Developed by LBNL. Contact: Charles Erlich, (510) 486-7916.

SUPERLITE 2.0. Daylighting analysis tool. Available for MS-DOS 386 and 486. Developed by LBNL. Contact: Rob Hitchcock, (510) 486-4154.

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CHAPTER 13

Indoor Air Quality

Author
Anthony Bernheim

★ SIGNIFICANCE

With potentially hundreds of different contaminants present in indoor air, identifying indoor air quality (IAQ) problems and developing solutions is extremely difficult.[1] The study of indoor air quality is a relatively recent endeavor. Although much is known about the health effects of poor design and ways to overcome them through good design, a tremendous amount of research is needed in this complicated field. Over the past few years, several entities have undertaken considerable efforts to further the research and science in this area, including government agencies such as the U.S. Environmental Protection Agency (EPA), National Institute of Standards and Technology (NIST), National Institute of Occupational Safety and Health (NIOSH), and Occupational Safety and Health Administration (OSHA), and professional societies such as the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) and American Society for Testing and Materials (ASTM). The results of such activities will lead to more definitive IAQ practices, standards, and performance targets.

In the absence of such information and industry consensus, this chapter attempts to provide guidance on general industry practices for improved IAQ. These suggested practices should be updated and refined by the professional as more information becomes readily available.

The quality of indoor air results from the interaction of many complex factors *(Figure 1)*, each contributing different effects.[2] The ways in which these factors contribute to IAQ may be summarized as follows:

- **Construction materials, furnishings, and equipment.**
  These items may emit odor, particles, and volatile organic compounds (VOCs), and adsorb and desorb VOCs. Individual VOCs from a specific material may combine with VOCs from other materials to form new chemicals. VOCs and particulates can cause health problems for occupants upon inhalation or exposure. In the presence of adequate heat and moisture, some materials provide nutrients that support the growth of molds and bacteria, which produce microbial volatile organic compounds (MVOCs).[3]

These organisms can affect occupants adversely if fungal spores containing mycotoxins and allergens or the MVOCs are inhaled. A great deal of research remains to be done to identify individual metabolic gases, their odors, the microbes that produce them, and the human response to molds and fungi.

- **Building envelope.**
  The envelope controls the infiltration of outside air and moisture, and may include operable or inoperable windows.
- **Ventilation systems.**
  Acoustical materials in heating, ventilating, and air-conditioning (HVAC) systems may contribute to indoor air pollution in the same way as construction materials, mentioned above. Ventilation systems also control the distribution, quantity, temperature, and humidity of air.
- **Maintenance.**
  Lack of maintenance allows dirt, dust, mold, odors, and particles to increase. The use of high-VOC cleaning agents pollutes air.
- **Occupants.**
  The number of occupants and the amount of equipment contribute to indoor air pollution. People and pets are major sources of microorganisms and airborne allergens in indoor environments.[4] Occupant activities also can pollute the air.

MAJOR FACTORS CONTRIBUTING TO INDOOR AIR QUALITY

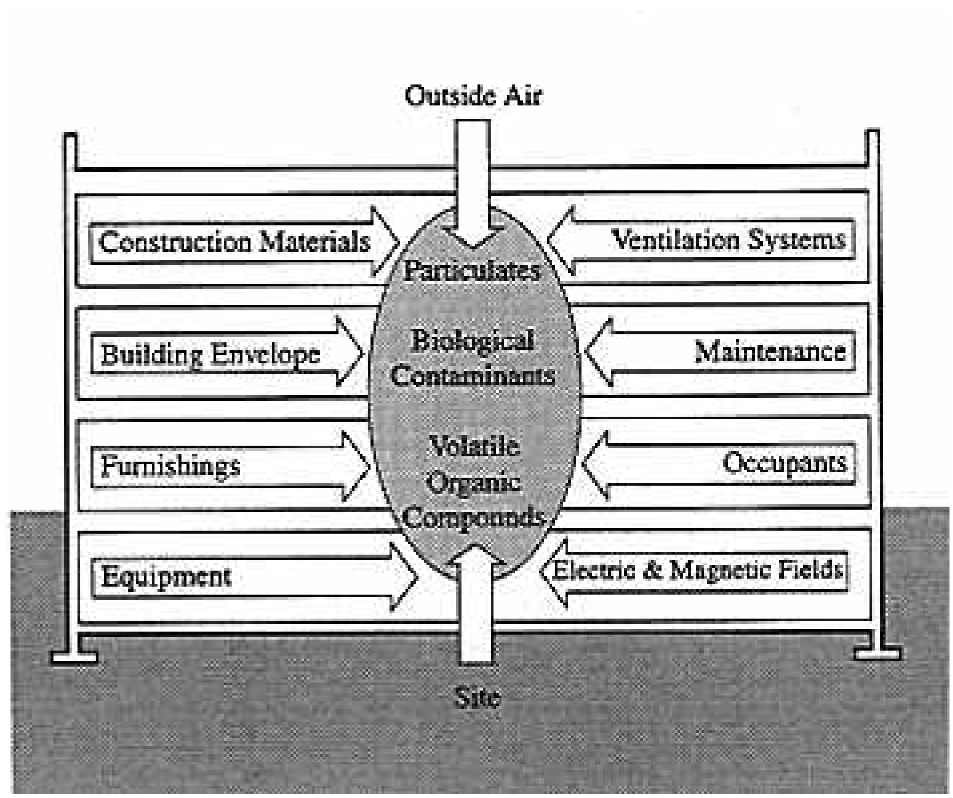


Figure 1

■ **Electric and magnetic fields (EMF).**
The possible health effects of electric and magnetic fields generated by power lines and electric appliances are not well understood at this time. There is considerable debate regarding possible health effects of these sources.[5] More research is required.

Poor indoor air quality can cause human illness, which in turn may result in increased liability and expense for building owners, operators, design professionals, and insurance companies. It can also lead to lost productivity of building occupants, resulting in economic losses to employers.[6] In the long term, these costs may exceed the additional initial cost, if any, of environmentally sound design in both new construction and renovation. Health problems that can result from poor indoor air quality may be short-term to long-term, and range from minor irritations to life-threatening illnesses. They are classified as follows:

■ **Sick-Building Syndrome (SBS)**
SBS describes a collection of symptoms experienced by building occupants that are generally short-term and may disappear after the individuals leave the building. The most common symptoms are sore throat, fatigue, lethargy, dizziness, lack of concentration, respiratory irritation, headaches, eye irritation, sinus congestion, dryness of the skin (face or hands), and other cold, influenza, and allergy type symptoms.[7]

■ **Building-Related Illnesses (BRI).**
BRIs are more serious than SBS conditions and are clinically verifiable diseases that can be attributed to a specific source or pollutant within a building. Examples include cancer and Legionnaires' disease.[8]

■ **Multiple Chemical Sensitivities (MCS).**
More research is needed to fully understand these complex illnesses. The initial symptoms of MCS are generally acquired during an identifiable exposure to specific VOCs. While these symptoms may be observed to affect more than one body organ system, they can recur and disappear in response to exposure to the stimuli (VOCs). Exposure to low levels of chemicals of diverse structural classes can produce symptoms. However, no standard test of the organ system function explaining the symptoms is currently available.[9]

☞ SUGGESTED PRACTICES AND CHECKLIST

General Approaches to IAQ

❑ **Employ an integrated approach.**
Even though current building codes are relatively silent on IAQ issues, a number of principles and practices have been developed to promote good IAQ designs that require a coordinated approach to building design. To achieve this goal, employ an organized and integrated approach that involves the building's owner, operator, design professionals, contractor, and tenants.

❑ **Practice "prudent avoidance."**
In cases where research is not definitive, which involves most cases at this time, a recommended alternative is to practice "prudent avoidance" of specific materials and systems that have been proven to contribute to IAQ problems. A "prudent avoidance" strategy means limiting the building occupants' exposure to these materials and systems when this can be accomplished at a reasonable cost and with reasonable effort.

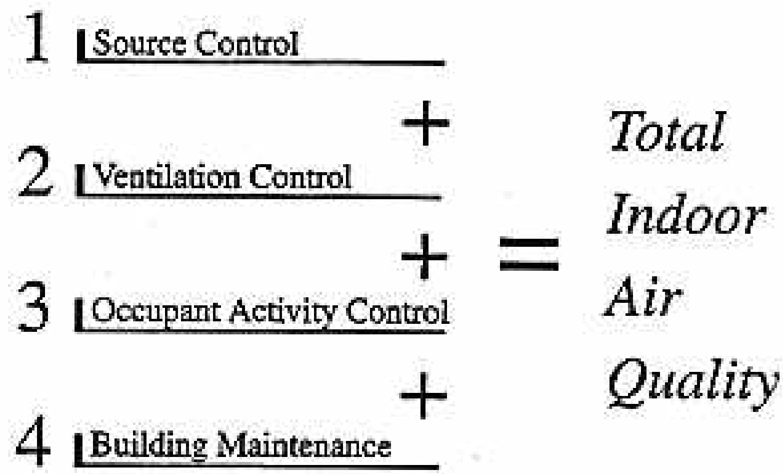
❑ **Evaluate the costs and benefits of all strategies.**
This analysis should include an understanding of initial and life-cycle costs weighed against the potential IAQ benefits such as reduced health risk, increased productivity gains, the associated economic benefits, and the long-term benefits to society, which at this time are somewhat difficult to determine and quantify.

Design Principles

Design for improved indoor air quality involves four interrelated principles *(Figure 2)* that should be implemented as a whole: source control, ventilation control, occupant activity control, and building maintenance.

Figure 2

FOUR PRINCIPLES OF INDOOR AIR QUALITY DESIGN



Source Control

There are many sources of potentially harmful air contaminants in buildings *(Figure 3)*. Contaminants may originate indoors, outdoors, from occupants, and from within the mechanical system of the building. VOCs and MVOCs may be emitted into the air from building materials, products, equipment, and furniture.[10] Pollutant sources can be controlled, reduced, or eliminated to produce a healthier indoor environment. Strategies for source control are listed below.

❑ **Set source-control priorities that are feasible within the project budget, project schedule, and available technology.**
Priority materials for source control are materials that will be prevalent in the building and are the most highly volatile (that is, they emit odors, releasing irritating and potentially toxic chemicals to the air, or may be susceptible to microbial growth). Identify and evaluate the priority materials, equipment, and furniture for use on the project.

❑ **Establish the building owner's and occupants' criteria and guidelines for improved IAQ.**

❑ **Request Material Safety Data Sheets (MSDSs) for priority materials from product manufacturers.**
OSHA regulations stipulate that product manufacturers must provide MSDSs with information on chemical identification, hazardous ingredients, physical/chemical characteristics, fire/explosion hazard data, reactivity data, health hazard data, spill and leak procedures, special protection information, and special precautions. However, MSDSs provide limited IAQ information, in part because the regulations do not require the identification of proprietary information or chemicals. Therefore, MSDSs should not be relied upon as the sole source of IAQ information, although they may provide the first level of information on potential IAQ concerns for some materials. In many cases, they may be the only source of information because "acceptable" third-party emissions testing information is not readily available.

SOURCES OF POTENTIALLY HARMFUL CONTAMINANTS AND DISCOMFORT IN BUILDINGS

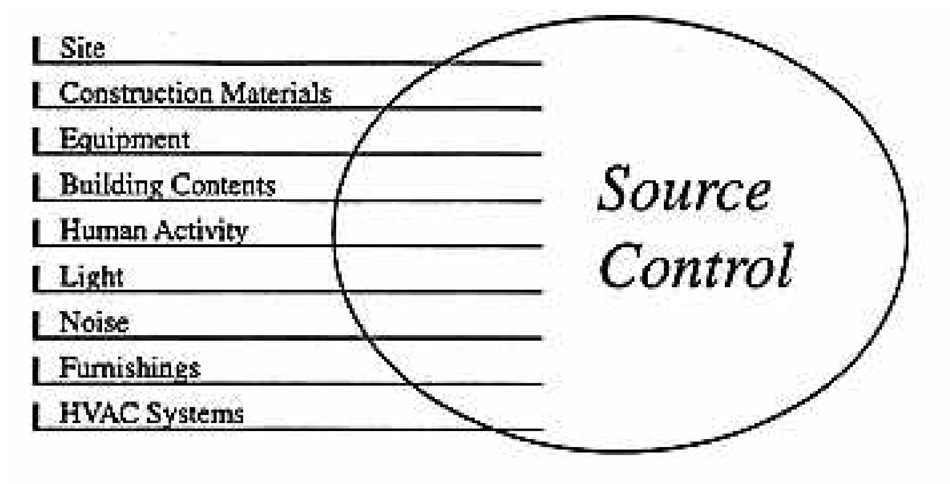


Figure 3

When chemicals or hazardous materials are identified in MSDSs, refer to the *Hazardous Chemicals Desk Reference* and existing regulations and guidance for information about their health effects and toxicity.[11] (For additional information regarding the interpretation of MSDSs, see Chapter 16, "Materials.")

❑ **Perform the following steps to evaluate the materials, products, and furniture in terms of their VOC contribution to indoor air:**

– Establish acceptable limits for total volatile organic compounds (TVOCs) and individual VOCs for the project. These limits should be based on regulatory requirements, guidelines, known health effects, and the professional advice of an IAQ specialist.

  At the time of publication of this manual, there are no laws or codes setting acceptable levels of overall TVOC concentrations for general indoor environments or TVOC and VOC emissions from materials, products, and furniture. Some of the uncertainty associated with emissions from materials is caused by lack of standardized testing procedures and inconsistency of data reported in the literature. ASTM has developed a general guidance standard for emission testing, however it is not specific for materials. Further research and development is needed to advance the state of the art to the point where reliable emissions data based on consensus standards are available.

– Request emissions test data from the manufacturer for each priority material, product, and furniture item. The data should be based on predetermined and agreed upon chamber test methods, from the manufacturer. Reports from chamber tests should include the following information:

  a. Clear definition of the materials and their origin, age, and history.
  b. Clear specification of the test methods, conditions, and parameters.
  c. Emission rates for TVOCs and individual VOCs as a function of time.
  d. Identification of hazardous VOCs and chemicals that are listed in any of the following internationally recognized regulatory and guidance chemical lists:
     1. California Environmental Protection Agency, Air Resources Board (ARB), list of Toxic Air Contaminants (California Air Toxics);[12]
     2. California Health and Welfare Agency, Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65), which lists chemicals known to cause cancer and reproductive toxicity;[13]

3. International Agency on Research of Cancer (IARC), which classifies chemicals that are carcinogenic to humans;[14]
4. National Toxicology Program, which lists chemicals known to be carcinogenic,[15] and
5. *Chemical Cross Index, Chemical List of Lists*, which shows listed hazardous chemicals regulated by various state and federal agencies and is published by the California Environmental Protection Agency.[16]

❑ **Evaluate the emissions test data.**

Prepare a simple graph of TVOC and individual VOC data as shown in *Figure 4*. For each IAQ priority material, multiply the emission factor by the area of the product found in the building to determine the total emission rate and plot micrograms of emissions per hour (µg/hr). In general, review these graphs to understand the emissions from a material, product, or furniture item over time. If an increase in the emission rate is indicated, additional investigation may be warranted.

SAMPLE GRAPH OF EMISSION RATE OVER TIME FOR A MATERIAL VOC

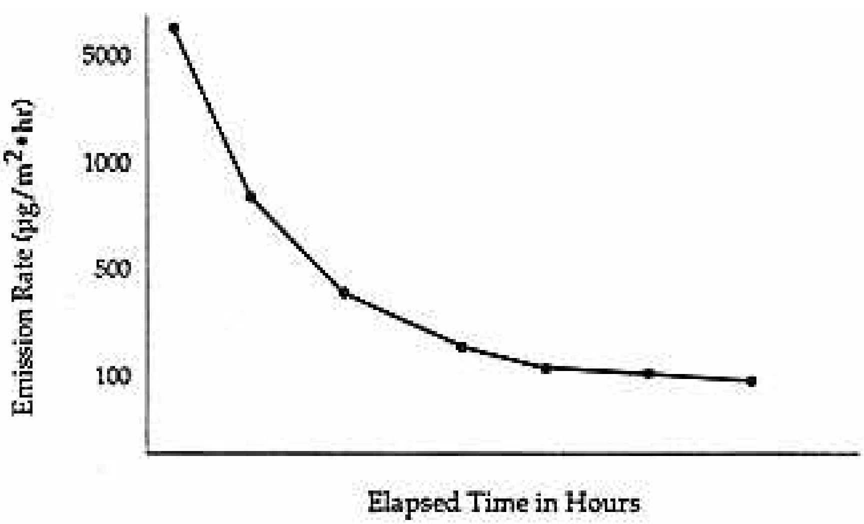


Figure 4

It is necessary to interpret these emission rates in terms of expected room concentrations of the contaminant of interest. This is not necessarily a simple conversion and needs to be done accurately and carefully. Factors such as room air exchanges (ventilation rates), concentration of contaminants in the exchange air, and the time dependence of the emission rates are essential in this determination. To the degree possible, these projected concentrations should then be compared with target concentrations for acceptable IAQ.

– Determine the emission factor and rate of the product VOCs to use as a potential indication of health concerns that may be associated with the use of the product.
– Where hazardous VOCs and chemicals are identified by the manufacturer, check the regulatory and guidance lists for the level of hazard (e.g.: "probably not carcinogenic," "possibly carcinogenic," "probably carcinogenic," and "known carcinogen").
– Prepare a chart to tabulate the hazard information for each material, product, or furniture item as indicated in *Figure 5*. It should be noted that the mere presence of such chemicals is not adequate evidence that they might or might not cause a hazardous exposure condition in a building. In any given situation, it is not always certain whether building occupants are actually exposed to emitted VOCs and, if there is exposure, whether this presents a risk to human health.

SAMPLE CHART FOR PRODUCT HAZARDOUS VOC/CHEMICAL IDENTIFICATION

Material, Product, Furniture

	Regulatory and Guidance List				
VOC/Chemical	Cal Air Toxics	CA. Prop. 65	IARC	NTP	Other Lists
Formaldehyde	*	*	*	*	
Toluene	*		*		
Styrene (Monomer)	*	*			

* indicates level of hazards, interpolated from the lists

Figure 5

Furthermore, the IAQ community is currently engaged in discussions about standards and quality control for chamber testing. Until these standards are developed, agreed upon, and implemented, review test result data with care and with the understanding that the data from different laboratories and from different equipment may not produce equivalent results.

– Determine the odor characteristics of the priority material, product, or furniture item. While odors may indicate a health-related IAQ problem, not all odors present a health risk. Nevertheless, be cautious initially about specifying products that emit strong odors, as they may indicate a potential and perceptual IAQ problem.

❑ **Based on the above information, determine if the priority material item is:**

– Acceptable—that is, it meets the project criteria for odor and contaminant concentration, as discussed above; the TVOC and individual VOC concentrations are not hazardous, based on regulatory and guidance lists; and the material will not significantly contribute to MVOC emissions.
– Acceptable in a specific location or condition only.
– Acceptable with modifications by the material manufacturer.
– Acceptable only when temporary construction ventilation is provided during installation.
– Unacceptable—that is, none of the above criteria can be satisfied or, because of insufficient information, "prudent avoidance" is appropriate.

❑ **Take steps to control the MVOC contribution to the indoor air from materials, products, and furniture.**

Since moisture and condensation allow molds and bacteria to start growing on the surface of indoor materials, finishes, products, ventilation ducts, and insulation materials, the primary methods to control microbial growth are controlling the interior temperature and humidity and removing the source of potential contamination. Source control to limit MVOC may be the primary method since the research has shown that increased ventilation may only produce limited results.[17] Source control can be achieved by the use of simple design and specification techniques:[18]

– Specify materials that are resistant to microbial growth especially in areas where moisture can support the growth of fungi.
– Encapsulate materials such as insulation that might support microbial growth.
– Require in project specifications that if any material susceptible to microbial growth becomes wet during the construction phase, that material should be carefully removed from the construction site to prevent further contamination of the indoor air.

- Clean air shafts, occupied areas of new construction, and all finish materials with high-efficiency particulate air (HEPA) vacuum equipment prior to occupancy to remove dust and debris.
- Carefully design the exterior wall envelope to control moisture by locating the moisture barrier appropriately. In warm, humid climates, the vapor retarder should be installed in the external portion of the envelope; in cold climates, the vapor barrier should be on the side of the building facing the occupied space.

❑ **Consider a building flush-out.**

In certain circumstances where high-emitting materials are used, where there are legitimate reasons to remove high emissions from other sources, or where temporary construction ventilation is insufficient, consider a building "flush-out" to reduce possible contamination.[19] This involves running the mechanical system with tempered 100 percent outside air for an extended period of time after construction completion and prior to occupancy. Care should be taken, however, with regard to humidity and microbial growth. A building flush-out should be carefully considered and weighed against the additional costs and delays involved. A "bake-out," which is the introduction of extraordinary heating to the space prior to occupancy, may damage building materials and cause other problems, and therefore is not recommended. Also, research shows that VOC levels after a bake-out may be higher than before the bake-out.[20]

❑ **In remodeling projects, test for and remove known hazardous materials such as asbestos,[21] lead, polychlorinated biphenyls (PCBs), and fungal contamination.**
- Ensure that any removal of hazardous materials is performed by specially licensed contractors under approved and carefully controlled conditions.
- Remove microbially contaminated materials using specially trained contractors who use negatively pressurized, isolated work zones. Extreme care should be taken to remove all microbial growth from the building. In some limited cases, treatment may be considered in lieu of removal, however, it has been shown that treated dead fungi may still present a health hazard and cause allergic reactions.[22]

Ventilation Control

Ventilation control involves many systems that need to be designed and modified as necessary to provide energy efficiency and adequate ventilation for building occupants *(Figure 6)*. Proper control prevents parts of the ventilation system from becoming sources of biological contamination.[23] The best strategy for improved IAQ is to implement source-control strategies and then combine them with ventilation control. Ventilation control alone may not always solve IAQ problems, as it cannot necessarily remove an IAQ problem source.[24] Strategies for ventilation control are as follows:

❑ **Review the building occupants' use needs and programmatic requirements and the energy conservation code requirements to determine whether fixed or operable windows will be provided.**

Where operable windows are selected, most energy-conservation codes require additional controls for the HVAC system.

❑ **Evaluate the HVAC system and develop the design criteria in accordance with applicable codes and ASHRAE standards to:**
- Provide adequate ventilation for the building population;
- Eliminate sources of, and growth locations for, microbial contamination; and
- Facilitate maintainability and cleanability of the HVAC system.

❑ **Consider use of the following interrelated HVAC strategies:**
- Locate outdoor-air intakes away from sources of contamination such as cooling towers,[25] plumbing vents, loading docks, parking areas, relief-air louvers, and dedicated exhausts from contaminated spaces such as toilets and copy rooms.
- Protect outdoor-air intakes from bird pollution with screens and bird guards.
- Locate airflow monitoring devices on the outdoor-air and return-air side of the air-han-

VENTILATION CONTROL FACTORS AFFECTING IAQ

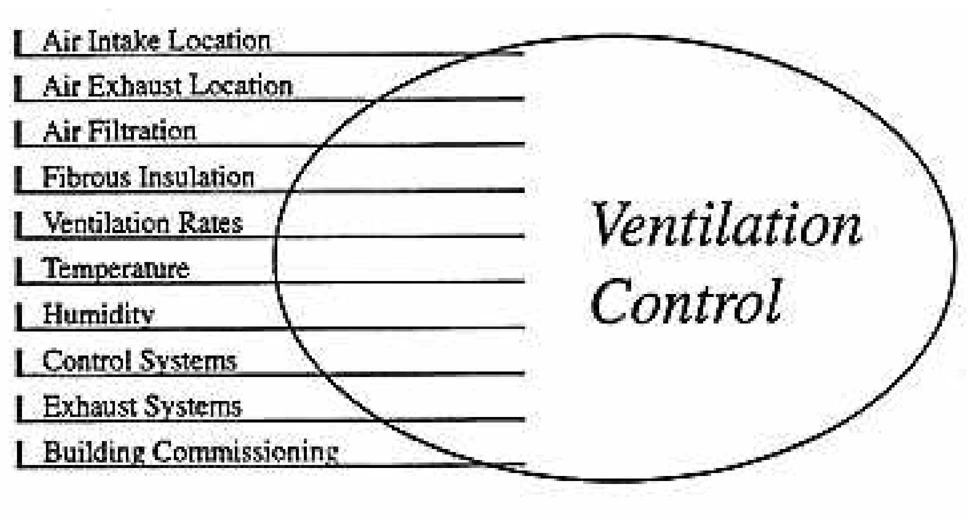


Figure 6

dling system. These devices monitor and regulate the amount of outdoor and recirculated air needed to provide minimum ventilation rates and adequate air quality.

– Install a high-efficiency air filtration system to remove particles of airborne dust from the outside air prior to distribution through the building's HVAC system. The filtration system should consist of two filters. The second or final filter should be 85 or 95 percent efficient or should be a HEPA filter.
– Either encapsulate fibrous acoustical insulation that is located inside the air-handling units, ducts, and variable-air-volume (VAV) boxes, or remove any exposed insulation. These fibers tends to trap dirt that provides a rich nutrient base for microbes.
– Design the HVAC system to provide adequate ventilation and appropriate temperature and humidity for human comfort in accordance with building codes and ASHRAE standards and guidelines.[26] Within certain limits only, increased ventilation may reduce the prevalence of MVOCs in indoor air.[27]
– Carefully design the HVAC system controls to allow the building operator to respond quickly to comfort problems and ventilation deficiencies by providing a building-control system with local controls (override switches and timers) where possible.
– Consider the use of an outdoor-air-economizer system. An air-economizer system enables the building operator to use the energy management system to vary the quantity of outside air brought into the building above minimum ventilation levels. This outside air can be used to maintain the required inside air temperature without use of the refrigeration cycle or recirculated air. With the refrigeration equipment turned off, energy is saved. The higher rate of outside air also improves ventilation conditions. Care should be taken with regard to humidity buildup.
– Install dedicated local-air exhaust systems vented to the outside, separate from the general exhaust system, in spaces that house specific contaminant sources, such as kitchens, janitorial closets, bathrooms, and copy rooms. Similarly, consider the viability of separate HVAC systems in buildings that support multiple uses.
– Consider the use of positive building pressurization in warm, humid climates to limit the infiltration of moist, hot outside air into the building interior. This will

reduce the exposure of the interior materials and finishes to moisture, inhibiting growth of molds and fungi on their surfaces.[28]

- Design the HVAC system installations with adequate access for inspections and regular housekeeping, maintenance, and cleaning.
- Design the air-distribution system for maximum ventilation effectiveness by ensuring the proper location and performance of the air-supply and return diffusers, so that sufficient air is delivered to occupants.[29]
- Arrange for independent professional testing, adjustment, and balancing of the HVAC system to assure proper operation for occupant comfort.
- Implement a building-commissioning program to ensure good IAQ and energy efficiency as described in the ASHRAE guidelines.[30] (See Chapter 15, "Building Commissioning," for a detailed description of the three-step process.)
- Implement an operations and maintenance plan for the HVAC equipment. (See the section on "Building Maintenance" below and Chapter 21, "Building Operations and Maintenance.")

(See also Chapter 12, "HVAC, Electrical, and Plumbing Systems," for additional information.)

Occupant Activity Control

Some indoor air quality problems can occur when the interior thermal load (heat) generated by the occupants, their activities, and their equipment exceeds the HVAC system's capacity to control the heating and cooling to ventilate the space. For example, if the HVAC system in a room is designed to provide adequate ventilation for three occupants and three personal computers, and there are actually six occupants and six computers in the room, the HVAC system may not be able to provide sufficient ventilation to cool the room and dissipate all environmental pollutants. Occupant activities may also generate odor and may cause VOCs to be released into the air. People and pets also produce microorganisms and allergens in the indoor air. Possible strategies for occupant activity control are listed below:

❑ **Implement a building commissioning program similar to the three-step commissioning process (see Chapter 15, "Building Commissioning").**
Design the HVAC system capacity to provide sufficient outside air for the projected building population and the anticipated heat-producing equipment. Prepare the HVAC system design documentation and design criteria accordingly. These documents, provided to the building operators, specify the maximum building population and permissible equipment designated by the design parameters of the HVAC systems.

❑ **Consider the use of carbon dioxide (CO_2) and VOC sensors in the occupied spaces.**
These monitors should be linked to the building or energy-management-system computer, which can be used to regulate the quantity of outside air needed to ventilate the building based on actual occupant-load conditions.

❑ **Implement a no-smoking rule from the commencement of construction through the life of the building.**
Note that some cities have local ordinances that regulate smoking in occupied buildings. (See also Chapter 15, "Building Commissioning," for more information.)

Building Maintenance

Air quality in poorly maintained buildings can deteriorate quickly. Materials, products, furniture, and HVAC systems need regular maintenance, cleaning, and inspections to ensure that they function as designed and to prevent indoor contaminants from developing in these locations. Other potential problems result from the use of pesticides, microbial growth caused by moisture within the building, and the emission of sewer gas where floor drains are concealed. Strategies for building maintenance are discussed below.

❑ **Select easy-to-maintain building materials and systems.**
For example, stone floors with metal-grate entry mats are easier to clean than carpets at building entrances.

- ❑ **Implement an integrated pest management program using only pre-authorized and non-hazardous chemicals that do not violate the integrity of building IAQ.** Use chemicals only when there is a problem, not for scheduled preventive maintenance (see Chapter 7, "Site Materials and Equipment").
- ❑ **Select low-emitting, environmentally friendly cleaning agents for use in regular maintenance (see Chapter 22, "Housekeeping and Custodial Practices").**
- ❑ **Prepare project specifications with appropriate warranties and, where appropriate, with extended maintenance contracts (see Chapter 17, "Specifications").**
- ❑ **Institute a tenant policy for IAQ practices, including a no-smoking rule.**
- ❑ **Adopt specific procedures for building operators to notify tenants when hazardous chemicals are used.**
- ❑ **Prepare an IAQ plan to be administered by the building IAQ manager. The plan should include the following:**
  - The building commissioning design documentation with a description of the building and its systems, the function and occupancy of each individual room or space, the normal operating hours, and any known contaminants and hazards;
  - Schematic drawings of the building systems indicating equipment types, their locations, and their maintenance and inspection points;
  - Locations of system manuals and commissioning reports, as-built drawings, water-treatment logs, inspection reports, and training manuals;
  - Performance criteria and operating setpoints for each operating unit, including domestic water system and normal humidity levels;
  - Sequence of operations for equipment and systems along with seasonal startup and shutdown procedures;
  - Daily operating schedules of all systems;
  - Preventive-maintenance and inspection schedules for equipment;
  - Test-and-balance report and airflow rates listed by area;
  - Required outdoor-air rates and building pressurization requirements;
  - Building IAQ inspection checklists;
  - Equipment maintenance checklists;
  - Procedure for documenting and responding to occupant complaints; and
  - IAQ documentation.
- ❑ **Prepare a maintenance plan with a schedule and budget for the HVAC systems, building materials, and furniture. The maintenance plan should include the following:**
  - HVAC Systems:
    - a. Maintain water treatment at cooling towers;
    - b. Change filters;
    - c. Lubricate dampers;
    - d. Eliminate standing water and excessive moisture;
    - e. Clean condensate pan; and
    - f. Clean coils and supply-air ducts.
  - Carpets:
    - a. Clean with vacuum cleaners equipped with HEPA filters.
    - b. Deep clean carpets periodically using water-extraction to remove particulates and contaminants that have accumulated at the base layer of the carpet.
  - Chairs:
    - a. Clean and vacuum regularly.
  - Office Systems:
    - a. Clean regularly.
  - Other Finish Materials:
    - a. Inspect regularly for microbial growth and remove material or finish if fungus is found.

  (See also Chapter 21, "Building Operations and Maintenance," and Chapter 22, "Housekeeping and Custodial Practices.")

- ❑ **Develop and provide the building operators with complete operations and maintenance manuals and a plan for appropriate system operation training.**
  (See Chapter 15, "Building Commissioning," for additional information.)
- ❑ **After the tenants have occupied a new or remodeled building, implement post-occupancy building commissioning and flush out the building as necessary to fine-tune the building systems under normal operating conditions.**
- ❑ **Develop a plan to provide post-occupancy building commissioning on a regular basis every few years.**
  (See Chapter 15, "Building Commissioning," for additional information.)

(See also Chapter 12, "HVAC, Electrical, and Plumbing Systems," and Chapter 21, "Building Operations and Maintenance," for additional information.)

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CHAPTER 14

Acoustics

★ SIGNIFICANCE

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Acoustics have a significant impact upon the overall indoor environmental quality of modern buildings and the amount of noise emission or pollution discharged to the outdoors. The levels of background noise, privacy, and separation between particular types of spaces have important implications for the work environment of building occupants. Commercial facilities would be well served by a careful review of acoustical considerations and their effects on occupant productivity.

In open office spaces, for instance, background noise that is too loud or has tonal qualities can distract occupants and reduce productivity. Other types of office spaces such as executive suites, conference rooms, and boardrooms have particular privacy requirements. Machine-rooms and other noise-producing facilities should be isolated from areas where privacy is required. There are numerous standards for acoustic quality in traditional building spaces and in specialty areas such as sound and production rooms, where acoustics is a high priority.

At the start of a project, the design team should work with the buildings' users to establish requirements for background noise levels, sound isolation, and speech privacy to ensure that sufficient levels are afforded to all spaces. Incorporating acoustic considerations into the design of a project at the planning phase can result in significant benefits and can avert costly, and possibly difficult, corrective measures later on. For example, by carefully locating internal spaces at the start of the project, the designer can reduce the need for high-sound-rated construction to mitigate noise problems. In certain noise-sensitive areas, and particularly in renovations, white noise and active noise systems may provide additional solutions.

Surface finishes are also important in the acoustic environment and can influence the character of the space as significantly as color or shape. Selecting the correct balance between hard, acoustically reflective materials and soft, absorptive ones facilitates the projection of speech to intended areas and prevents echoes or the excessive buildup of unwanted sound in other areas.

Outdoor sound emissions must also be considered. In manufacturing areas, the operation of equipment that exceeds ambient noise levels can affect adjacent residential areas. The criteria for noise emission to the external environment are based on existing environmental conditions. In rural areas, for instance, background noise levels during the quietest periods of the day or night may drop to 35 or 40 dB(A). (dB(A) is a measure that represents a single-figure decibel weighted to the A-scale, which simulates the response of the human ear to different sound frequencies.)[1] In urban areas, the level is unlikely to drop below 50 to 55 dB(A) at night and 60 to 65 dB(A) during the day. If the jurisdictional authority has not prescribed a limit on noise emissions, the designer should establish a level consistent with existing ambient noise levels at property lines or neighboring buildings.

Building designers should also be aware of applicable local and federal limits on noise levels in certain types of workplaces. For example, Occupational Safety and Health Administration (OSHA) guidelines restrict various sound levels to prevent long-term hearing damage among workers who occupy a given area for extended periods of time.

☞ **SUGGESTED PRACTICES AND CHECKLIST**

Planning Issues

❑ **Identify local zoning codes regarding noise and determine requirements for the project's adherence to such codes.**

❑ **Determine the impacts of proposed building systems on surrounding areas and ambient conditions.**
Minimize or reduce noise pollution generated by the building by assessing any noise-producing elements and their relationship to neighboring properties. Truck docks that operate 24 hours a day directly adjacent to residences will undoubtedly be cause for complaints. Central cooling towers and louvers from fan systems that direct noise toward nearby residences will require attenuation treatments.

❑ **Consider how the noise level from external sources around the building will affect occupants.**
Noise intrusion from adjacent activities and other external sources like airports can have a significant impact on building occupants and require special mitigation. For example, structures built near airports are typically required to have high-performance glazing systems. Wide-air-space glazing systems and laminated insulating units offer better performance than standard insulating glass.

Acoustic Criteria

❑ **Select the appropriate criteria for evaluating noise levels.**
Noise criteria (NC) are commonly used to rate interior noise levels of general office spaces. (NC numbers represent a series of curves of octave-band sound pressure levels.)[2] *Table 1* presents a list of typical NC values for various office spaces that can be a guide in establishing appropriate criteria for background noise.

❑ **Obtain the sound transmission class rating between spaces.**
The "barrier" performance of materials used in general building construction is expressed by a sound transmission class (STC) rating.[3] By obtaining STC ratings from wall and ceiling manufacturers for various construction materials, an acoustical engineer can project the overall STC rating of the combination of all elements separating two spaces. For example, if the wall between two offices is composed of multiple layers of gypsum board on metal studs and is erected up to the lay-in acoustical ceiling, the performance of that ceiling would dominate the barrier performance, or overall STC rating, between the two spaces.

RECOMMENDED DESIGN CRITERIA FOR BACKGROUND NOISE FROM HVAC, ELECTRICAL, PLUMBING, AND ELEVATOR EQUIPMENT	
Type of office space	**Noise criteria**
Studios	NC–20 to 25
Boardrooms, teleconferencing rooms	NC–25 to 30
Conference rooms	NC–30 to 35
Private offices, apartments	NC–35
Lobbies, toilets, corridors, computer terminal rooms, retail spaces	NC–40
Storage, locker rooms, laboratories without fume hoods	NC–45
Kitchens, laundry, computer rooms	NC–50
Garages, laboratories with fume hoods	NC–55+

Table 1

❑ **Calculate the speech privacy potential factor.**

Speech privacy potential (SPP) is a parameter that quantifies the privacy for a given room. *Table 2* identifies SPPs for natural human voice levels and applies a subjective definition to each rating. The table shows the various degrees of privacy and allows the end-user to select the appropriate criteria. The use of speaker phones and other voice amplification systems requires special consideration.

To calculate the SPP factor, arithmetically add the background noise level in a given space (its NC level) to the level of separation required between adjacent spaces (the STC rating). For example, if a private office had an NC-35 background noise level from HVAC systems and a total separation from its neighbor of STC-40, the SPP rating would be 75. Using *Table 2* to determine if this level is acceptable for the spaces being analyzed, adjustments can be made by either increasing the wall/ceiling performance (STC rating) with high performance structures or increasing the background noise level (NC rating). (See the section below on "White Noise.")

DEGREES OF SPEECH PRIVACY FOR CLOSED-PLAN OFFICES		
Speech Privacy Rating	**Speech Privacy Potential (SPP)**	**Description of Privacy**
Total privacy	85	Shouting is only barely audible.
Highly confidential	80	Normal voice levels are not audible. Raised voices are barely audible but not intelligible
Excellent	75	Normal voice levels are barely audible. Raised voices are audible but mostly unintelligible.
Good	70	Normal voices are audible but unintelligible most of the time. Raised voices are partially intelligible.
Fair	65	Normal voices are audible and intelligible some of the time. Raised voices are intelligible.
Poor	60	Normal voices are audible and intelligible most of the time.
None	Less than 60	No speech privacy.

Table 2

Architectural Issues

❑ **Locate noise-sensitive areas away from noise-producing elements.**

Careful "stacking" or placement of building elements can prevent costly mitigative changes later. The location of building spaces also has implications for the treatments required to provide adequate separation. Avoid locating sensitive spaces like executive office areas, studio-type environments, and meeting facilities immediately adjacent to noise-producing areas. Noise-producing elements include mechanical equipment rooms, fitness centers, production or manufacturing facilities, kitchen or food preparation areas, laboratories, gymnasiums, and music practice spaces. Data centers, storage rooms, mailrooms, and other less-sensitive spaces are more suitably placed adjacent to equipment rooms.

❑ **Evaluate slab construction between floors.**
Typical slab construction in modern buildings will usually provide adequate airborne noise separation. Thicker slabs are generally required if machinery rooms or other noise-producing spaces vertically adjoin other areas. Minimum slab constructions of six or eight inches are typically used in such cases. When evaluating the slab construction for a building:
– Determine if slab construction will serve as an adequate sound barrier.
– Evaluate the slab proposed for mechanical equipment rooms and machinery areas.
– Recommend an alternative slab where increased separation is necessary.

❑ **Consider the acoustic benefits of drywall construction.**
Generally, internal wall structures are constructed of gypsum board installed on both sides of metal studs. The level of acoustic performance varies depending upon the number of layers of drywall placed on each side of the metal stud and the thickness of insulation used in the cavity. The choice of full-height or non-full-height partition constructions also has a major bearing on the level of privacy afforded and the STC rating. Typically, monolithic drywall constructions provide a performance level of approximately STC-30 to 35 between adjacent offices when erected only to the ceiling line.[4] Full-height structures between offices can increase performance levels to between STC-40 and 50 or more, depending on whether single- or double-layer drywall is used. Double-layer construction is typically installed in conference rooms and executive spaces to afford maximum privacy and separation.

❑ **Select appropriate partitions to achieve the required speech privacy rating between spaces and separation from HVAC equipment areas.**
Determine which areas require increased separation, based on whether they are noise-sensitive or noise-producing. Consider the typical partitions proposed for use in each area. Recommend alternative partitions for noise-sensitive areas or noise-producing areas, as appropriate.

❑ **Use constructed or natural screens to reduce the impact of noise from external sources.**
Constructed barriers, such as the screen walls typically seen along highways, can offer significant shielding and acoustical attenuation. Natural earth berms can also serve this purpose, but other natural barriers such as vegetation and trees do not have significant acoustic screening effects.

Surface Finishes

❑ **Consider acoustical properties when selecting surface finishes.**
Determine how selected finishes will affect sound travel and reverberation within building spaces. Request acoustical information and standards from the product manufacturer. Surface finishes can be modified to meet acoustic demands.

❑ **Perform product reviews and analyses to assess safety and environmental factors.**
Consider the recycling potential and environmental friendliness of finishes. In addition, choose products that satisfy requirements for flame retardancy and smoke spread.

❑ **Confirm that acoustic material selections meet the project's environmental criteria.**
(See Chapter 2, "Selecting Environmentally and Economically Balanced Building Materials," and Chapter 16, "Materials.")

❑ **Test materials as specified in American Society for Testing and Materials (ASTM) acoustic standards.**
Before selecting acoustic materials, test them according to ASTM test standards to identify their actual performance and limitations and to assess their suitability for the intended purpose.

❑ **In highly sound-sensitive areas, perform a full analysis of room geometry, volume, and surface finishes to predict reverberation time.**
This type of analysis is necessary in boardrooms, auditoriums, and similar spaces to identify measures that attain the desired reverberation time. Where natural speech projection is of importance, such as in classrooms and lecture halls, strategic placement of suitably reflective surfaces enhances speech projection to the rear of the facility.

❑ **Use acoustical ceiling products and carpeted floors.**
Sounds generated by general office functions are typically controlled by acoustical ceiling products and carpeted floors. More critical spaces such as conference rooms and audio-visual facilities require acoustical wall treatment.

❑ **Determine when additional acoustical treatments are needed to increase sound absorption within a given spaces, and in those cases, consider using:**
- Acoustical ceiling tiles;
- Fabric-wrapped wall panels; and
- Spray-on acoustical treatments.

❑ **Select appropriate ceiling tiles based on ceiling sound transmission class rating.**
Ceiling materials are specified according to their level of "softness" to absorb sound in a given space and according to their barrier properties as denoted by their ceiling sound transmission class (CSTC) rating. The higher the CSTC value, the greater the material's ability to prevent sound transmission. Typical mineral-fiber ceilings are rated CSTC-35 to 39, while fiberglass systems are rated at the lower performance level of CSTC-20 to 25.

❑ **Avoid using acoustic materials that may adversely affect indoor air quality.**
Some sound insulation products can absorb dust and other substances that may later be emitted. These substances can become airborne and move through the HVAC system, potentially becoming a health hazard. The use of encapsulating products to address this problem may interfere with acoustic performance. (See Chapter 13, "Indoor Air Quality," for more information on materials and IAQ).

Mechanical Issues

❑ **Determine what mechanical equipment has been selected for the structure, for example:**
- Cooling tower;
- Chillers;
- Air-handling units;
- Exhaust fans;
- Heat pumps;
- Fan coil units; and
- Variable-air-volume boxes.

❑ **Consider what manufacturers report as the sound power and pressure levels for the selected models.**

❑ **Determine whether a mock-up test of specific project conditions is necessary to predict actual noise levels or to test new, previously untested equipment.**

❑ **Determine whether the equipment is suitable for the usage from an acoustic standpoint.**

❑ **Determine if noise levels of mechanical equipment meet the project's acoustical criteria.**

❑ **Recommend improvements to acoustic conditions related to the mechanical equipment, if necessary.such as the following:**
- Relocate the equipment to a less sensitive space;
- Install or increase lining within the ductwork;
- Include sound attenuators (silencers) within the system; or
- Re-select a given piece of equipment.

White Noise

❑ **Consider a white noise or sound-masking system to maintain a constant level of speech privacy.**

If office spaces are very quiet (less than NC-35 to 40 in prime speech frequencies), conversations are readily audible to adjacent occupants, especially in open-plan offices. This, in turn, reduces concentration and interferes with productivity. A white noise system ensures a constant background noise level to maintain speech privacy. In these systems an evenly distributed array of speakers concealed above the ceiling artificially raises the background noise level in the space. The sound is unobtrusive to occupants and is similar to that of an HVAC system. Central white sound systems for large offices incorporate amplifiers and equalizers that can adjust the spectrum shape of sound and intensity levels to best suit the objectives. Smaller systems use individual speaker cans with inboard amplification and equalization facilities. White noise systems are typically designed to provide an even background noise in the range of NC-38 to 42, depending upon whether a cellular or open-plan office arrangement is used.

Active Noise Control

❑ **Consider using newly developing active noise-control systems.**

Active noise-control systems are currently being developed for ducted HVAC systems, but to date their use is limited. Active noise cancellation (ANC), used in today's systems, employs a series of microphones to detect the noise occurring in the airstream of an HVAC duct. A speaker creates an identical noise sound field 180 degrees out of phase from the original sound waves processed in the controller. The result is a sound field reduced (not actually canceled) through the interaction of primary and actively controlled secondary sound sources. Currently, economic considerations limit the application of ANC to frequencies of 500 Hz and lower because passive noise methods (such as sound attenuators and acoustical duct lining) are effective and more cost-efficient at higher frequencies.

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CHAPTER 15

Building Commissioning

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★ SIGNIFICANCE

In recent years, most new buildings have been equipped with increasingly sophisticated heating, ventilating, and air-conditioning (HVAC) systems, energy conservation equipment, lighting systems, security systems, and mechanized sun control devices that rely on electronic control. However, in many buildings, some of these systems and design features have not performed as expected. This can result in energy-efficiency losses, occupant complaints about indoor air quality, high operating costs, and increased liability for building owners, operators, employers, and design professionals.

Building commissioning was developed in response to these concerns. Commissioning involves examining and approving (or withholding approval of) building systems to verify aspects of the building design, ensure that the building is constructed in accordance with the contract documents, and verify that the building and its systems function as intended. The process helps to integrate and organize the design, construction, operations, and maintenance of a building's systems.[1]

Commissioning is commonly performed when building systems are constructed or installed and, preferably, once again 12 months after occupants have been using the building and all systems have been operating for a while. However, a good commissioning process actually begins during the design phase with agreement on how the design criteria will be verified and documented during the post-construction and post-occupancy assessments. Recommissioning on an annual basis is also advantageous as a means of ensuring the proper functioning and upkeep of building systems throughout their useful lives. Given its importance and many potential benefits, commissioning is becoming part of good standard practice for the industry.

Benefits of Building Commissioning

- The building-commissioning process provides for testing and verification of building systems to ensure that they perform as designed and meet expectations for energy consumption and costs.
- The contractor commissioning activities and documentation ensure that systems are installed as designed, thereby reducing the occurrence of problems at the project's completion and over the life of the building.
- The building-commissioning process is used to discover deficiencies in the building and its systems before occupancy. It is more cost-effective to correct any deficiencies (both in design and construction) at that time.
- Construction-phase and post-occupancy building commissioning improve the building systems' performance under real, live conditions, reducing the potential for user complaints.
- The building-commissioning process helps ensure the proper functioning of buildings with good indoor air quality.[2] (See Chapter 13, "Indoor Air Quality," for additional information.)
- Using the HVAC system design documentation as a checklist ensures that the HVAC system capacity meets the projected peak and actual thermal loads for population and equipment.[3] This review reduces the need for potentially costly construction change orders, which in turn reduces construction costs and the architect's potential liability.
- The building-commissioning process provides the design team with a better understanding of the building's systems, resulting in improved design and better coordination of the construction documents.
- Recommissioning a building throughout its life on a regular, annual, or biannual, schedule ensures the proper functioning of systems on a continuing basis. By maintaining indoor air quality, building recommissioning may also reduce worker complaints and improve worker productivity.[4] This in turn may reduce the building owner's potential liability.
- Some utility companies are exploring the possibility of providing rebates or reduced utility rates to building owners whose buildings are commissioned or recommissioned, which may provide additional savings to cover the commissioning costs.
- Professional liability insurance companies are exploring the possibility of reducing annual premiums for architects and engineers who perform building commissioning on their projects.

A good building-commissioning process requires leadership, planning, thorough documentation, and systematic implementation. For the design and construction of green buildings, the advantages are tangible. Building commissioning reduces energy consumption and promotes good indoor air quality. It can be a cost-effective method to produce these results and should be seriously considered for large projects.[5]

☞ SUGGESTED PRACTICES AND CHECKLIST

Design and Construction Documents Phase

❑ **Select the building systems to be covered in the commissioning process.**
In large and sophisticated buildings, many systems are integrated. Expanding commissioning activities to cover multiple systems may be desirable. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published guidelines for commissioning HVAC systems.[6] *Figure 1* provides a list of additional systems that should be considered for commissioning.

EXAMPLES OF SYSTEMS THAT REQUIRE COMMISSIONING

1. Mechanical	Hot Water Heating System Pumps Electronic Steam Grid Humidifiers Cooling Tower Refrigeration Machines Air Handling Equipment - Fans - VAV and Constant Terminal Boxes Air Handling Services - Air Outlets - Fire Dampers - Balancing Dampers - Fire/Smoke Dampers Air Flow Measuring Stations Tanks Water Cooled Computer Room A/C Units Control Systems Fire Management Systems
2. Plumbing	Service Water Heaters Pumps Tanks Compressors
3. Electrical	Emergency Generator Systems Fire Management Systems
4. Controls	Air Handling Equipment - VAV and Constant Terminal Boxes Air Flow Measuring Stations Water Cooled Computer Room A/C Units Fire Management Systems Building Management System
5. Fire Management	Air Handling Equipment - Fans - VAV and Constant Terminal Boxes Air Handling Services - Fire/Smoke Dampers Fire Management Systems
6. Sprinkler	Standpipe and Sprinkler Systems
7. Elevators	
8. Audio-Visual Systems	

Figure 1

THREE–STEP COMMISSIONING PROCESS

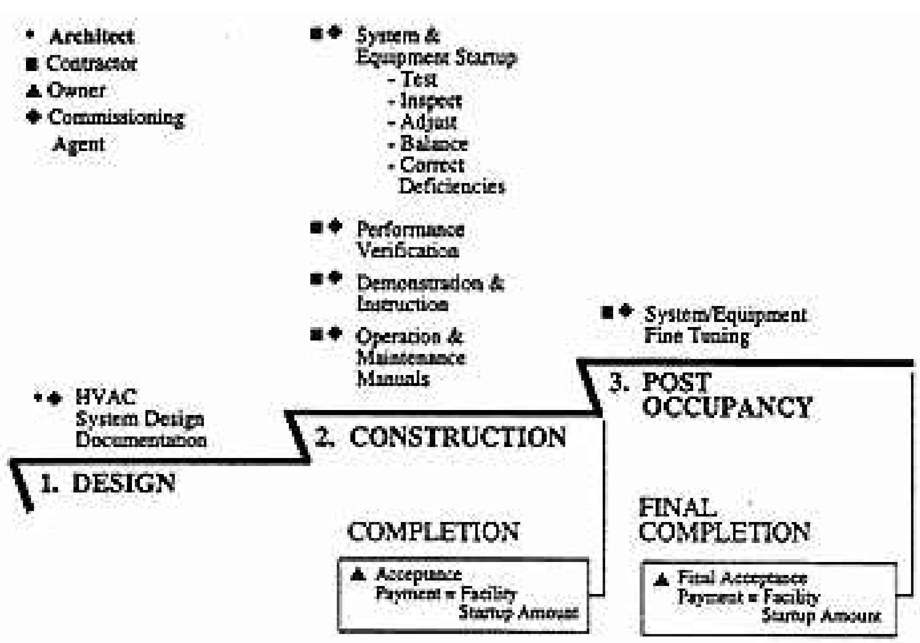


Figure 2

❑ **Develop a strategy to implement the building-commissioning process.**
The ASHRAE guidelines provide a good overall model. *Figure 2* illustrates a three-step commissioning process showing the suggested activities and responsibilities of team members during each step. Ensure that the commissioning strategy encompasses all of the necessary activities in each stage of the process.

❑ **Prepare the design documentation and design criteria for the HVAC system, including the following information:**
- The HVAC system building-commissioning design documentation form, similar to the example shown in *Figure 3;*
- The HVAC system design criteria; and
- The HVAC system description.

HVAC BUILDING–COMMISSIONING DESIGN DOCUMENTATION

Room		Maximum Occupants		Equipment		Ventilation in CFM	
Number	Name	Projected	Code	Computers	Photocopy Machines	Total Air Flow	Minimum Outside Air

Figure 3

❑ **Use these HVAC system design documents to:**
- Verify with the building owner or users the occupants' anticipated building program requirements and their planned activities and equipment;
- Verify the fire- and life-safety code requirements for the number of occupants; and
- Verify with the mechanical engineer the ventilation requirements for the occupants and their equipment so the HVAC system is designed with sufficient capacity to provide outside air for the projected building population and the anticipated heat-producing equipment.

❑ **Have the design team and building operators review the documents to confirm that the building is properly designed for its intended uses.**
The building population and equipment should not be increased beyond the design limits for the HVAC system.

❑ **Prepare design documentation and design criteria for the other building systems to be commissioned according to the format used for the HVAC system.**

❑ **Prepare specifications to describe the commissioning process.**
The commissioning process should be described in the Division 1 sections of Construction Specification Institute (CSI) documents (see "Specifications," Chapter 17, for additional information). The Division 1 sections should also refer the user to the appropriate technical sections for additional information about each system's commissioning details.

❑ **Specify facility startup amount in the commissioning section of Division 1 specifications.**
The facility startup amount is the total dollar amount that the project sponsor allocates to commissioning in the project specifications and is released to the contractor at

the successful completion of each phase of the commissioning (*Figure 2*). This facility startup amount needs to be determined prior to construction commencement and should be allocated to the general contractor for coordination and to specific subcontractors for their commissioning work.

❑ **Ensure that the commissioning process is addressed in contract documents and construction meetings.**
Contract documents should accurately reflect the process agreed upon for building commissioning. The architect should also be asked to describe the commissioning process at any pre-bid or pre-construction conferences and at pre-commissioning meetings.

❑ **Form a commissioning team and designate a commissioning authority.**
The ASHRAE guidelines define the commissioning authority as the qualified person, company, or agency that will plan and carry out the overall commissioning process.[7] There are many options as to who should be selected to serve this role, including the design professional, the contractor, the building owner, or a commissioning consultant/agent. It is often useful to form a commissioning team that works together to commission the building as illustrated in *Figure 4*. In this situation, the role of commissioning authority is divided among various members of the commissioning team, with specific members taking the lead in each phase of the project. Another approach is to consider hiring an independent commissioning agent to ensure that the commissioning is performed adequately.

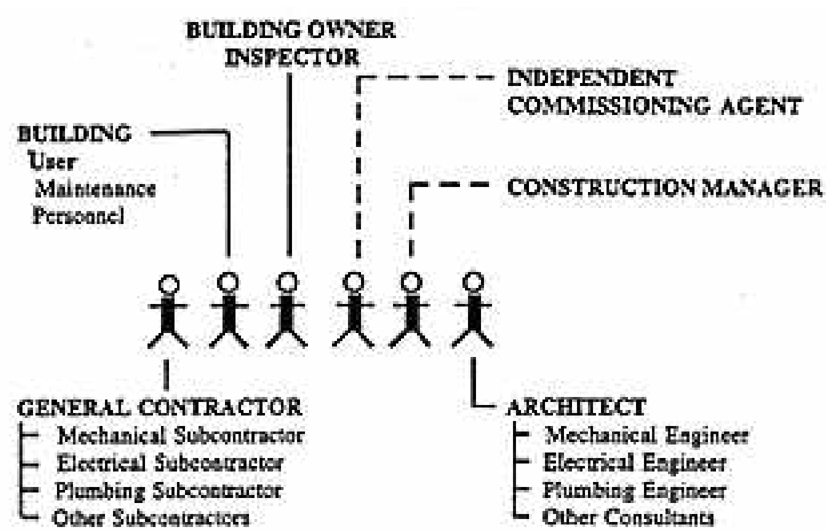
Construction Phase

❑ **Involve the design team in monitoring the construction commissioning process.**
During the construction phase, the contractor plays the major role in performing the building commissioning. However, the design team should also be involved in monitoring the building-commissioning process. Since this is a relatively new process, "partnering" or team building may be required to ensure success.[8] The benefit of partnering is that it establishes a forum for alternative dispute resolution so that building-equipment and system problems can be resolved quickly in "real time."

❑ **Conduct pre-commissioning workshops and commissioning progress meetings.**
Workshops and progress meetings are useful in ensuring that all building-commissioning issues are properly addressed. Attendees should include members of the commissioning team.

Figure 4

BUILDING–COMMISSIONING TEAM



❑ **Observe that construction is in accordance with the contract documents.**
The architect should monitor commissioning process, meetings, and workshops to ensure that this construction process is generally performed in accordance with contract documents. Ultimate responsibility for full-time observation rests with the owner's field representatives.

❑ **Perform systems and equipment startup.**
In this phase, the contractor should start the operation of building systems and equipment so they may be tested, inspected, adjusted, balanced, and corrected if necessary.

❑ **Demonstrate operations and conduct training.**
Training seminars and on-site "hands-on" training should be conducted for the building operators. The contractor should provide the systems and equipment operations and maintenance manuals.

❑ **Recommend acceptance of the work and payment of the facility startup amount.**
The architect and consulting engineers should review the work prior to acceptance.

❑ **Prepare the commissioning report.**
When the commissioning process is complete, the commissioning agent should issue a commissioning report to the owner, including the following information:

- Building description, including size, location, and use;
- Team members and responsibilities;
- The final project design documents and the commissioning plan and specification;
- A written and/or schematic description of each project system including architectural, mechanical, and electrical systems included in the project;
- A summary of system performances relative to the design intent;
- Completed pre-functional checklists;
- Completed functional checklists;
- All approval, non-compliance, and cost-tracking forms; and
- The manuals for each system, which should include the following information:
    a. System design intent;
    b. System description;
    c. As-built drawing;
    d. Specifications and approved submittals;
    e. Emergency shutdown and operational procedures;
    f. Test-and-balance and other testing reports;
    g. Startup and verification checklists and reports;
    h. Operations and maintenance manuals;
    i. Material safety data sheets (MSDSs), and chemical disposal requirements; and
    j. Training documents and programs.

Post Occupancy Phase

❑ **Conduct fine-tuning of building systems and equipment after one year.**
This phase of the commissioning activity should occur after the building is occupied and operating under normal and planned conditions for approximately 12 months. Fine-tuning is an extremely important part of the commissioning activity and provides the opportunity to solve any building problems identified through the owner's detailed surveys and environmental analysis. During the first 12 months, the building operators should record the conditions in the building and attempt to adjust the systems where needed. If they are unable to control the systems to sufficiently resolve malfunctions, the contractor should return to fine-tune the systems and equipment.

❑ **Recommission buildings throughout their life on a regular schedule, possibly every one to two years.**
Recommissioning is an opportunity to ensure that all systems and equipment are performing as intended and that the building occupants and activities conform to the HVAC system design documentation. (See Chapter 21, "Building Operations and Maintenance," for additional discussion.)

➜ RESOURCES

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7 ASHRAE, *Guideline 1-1989,* 2.

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SECTION C

Materials and Specifications

Life-Cycle Assessment and its Application to Green Building Principles

Author
Dr. James A. Tshudy

Improving the environmental performance of a building requires a systematic and comprehensive understanding of all the environmental impacts that occur throughout the building's life cycle. This approach—which may also be applied to products and activities—has come to be known as life-cycle assessment (LCA). When applied to a building, the life-cycle approach seeks to examine and analyze all environmental effects of that building, from the acquisition of all the materials, energies, and natural resources that ultimately go into the building to the point in time when the building has completed its useful life and is demolished. In addition, the life-cycle approach seeks to balance environmental concerns with traditional issues that have always affected decisions and choices in the building industry: function, performance, aesthetics, and cost. Equipped with the knowledge and understanding provided by the life-cycle approach, design professionals are able to make the decisions and choices that can lead to genuine improvement in a building's environmental performance.

Life-cycle assessment provides the most thorough assessment approach to understanding the environmental impacts of buildings and building materials. Although frequently cited and discussed, LCA is not thoroughly understood or utilized by many in the building industry. As a result, the application of some well-intended green building principles can be misguided. Often, materials or products are compared and decisions made on the basis of one or a few isolated environmental attributes without consideration of the full array of environmental impacts and implications present in the total life cycle. Such simplistic decisions can be risky and lead to a poor choice. For example, if "product A" is manufactured from a certain recycled material and "product B" incorporates no recycled material, the assumption usually is that A is a better choice than B. Or if A is made of natural materials and B is not, A is usually assumed to be the preferred environmental choice. Sound science and LCA may reject such a choice; making the proper decision requires a more thorough analysis.

Much has been written and a great deal of excellent work performed in the development of LCA principles and methodologies (see the “Resources” section below). It is not the intent here to review this work, but to briefly explore how these principles might be applied in the context of a building.

Green Building Principles

Viewed from a life-cycle approach, the fundamental principles and objectives of green building are to:

- Minimize natural resource consumption (materials and energy) throughout the total building life cycle;
- Minimize pollution and environmental releases throughout the total building life cycle;
- Protect the ecological (natural) environment;
- Create a healthy, comfortable, nonhazardous space;
- Incorporate quality, function, and performance consistent with the objective of the building; and
- Balance environmental performance with cost and economic performance.

Potential Benefits of a Green Building

A green building project must have clear and measurable benefits for the variety of stakeholders involved. Protecting the environment is certainly one of the primary benefits. More and more evidence demonstrates that other benefits are possible and that these can provide additional incentives for “building green,” such as:

- Reduced life-cycle costs, including:
  - First costs;
  - Operating costs (energy, maintenance, repair); and
  - Renovation, demolition, disposal costs.
- Reduced risk and liability (avoided costs).
- A better building offering, including:
  - Energy efficiency;
  - Improved lighting;
  - Improved comfort; and
  - Healthier indoor environment.
- Improved occupant productivity.
- Increased stakeholder understanding and awareness of environmental issues and considerations as a result of the experience.
- Potential identification of opportunities for new products, designs, and approaches.

The LCA Concept

The fundamental concepts of LCA are surprisingly simple. The application of the concepts to buildings and building materials is also reasonably straightforward. However, actually conducting a complete LCA for a “real building” can be another story. When dealing with the intricate relationships among many materials and components as well as their origins, uses, and fates, the practitioner is led to invoke numerous assumptions, approximations, and qualitative judgments. Factors that can make a complete LCA difficult and costly include the lack or inadequacy of data and information, questions about the quality of the data, problems of allocation, the incompleteness of the science of impact assessment, the difficulties in adequately conveying the thoroughness of the study, and many other concerns.

For those who subscribe to the belief that increased knowledge and understanding (though incomplete) lead to better decisions, the benefits of the LCA approach, whether carried out in great detail or in some streamlined way, can be significant. It can be argued that the information and data revealed by the LCA can provide new insight and understanding; and when viewed in the context of its limitations, the process can lead to better, more informed decision making. Moreover, there are approaches and support systems that can help make the process manageable.

A model suggesting how to apply the LCA concept to a building, with particular emphasis on building materials and products, is presented here. The model provides a systematic framework that illustrates how LCA can identify the complex relationships among all the materials and components that go into a building throughout the various stages of its life cycle. Understanding these relationships makes it possible to evaluate the environmental implications of various material, design, construction, and operation options possible for the building.

Definition of the Building Life-Cycle

The environmental assessment process begins with a definition of the total building life cycle, which entails the sequence of all events and activities in the life of the building from site selection through construction and operation to ultimate demolition *(Figure 1)*. The environmental impacts of the building and all components can be assessed in terms of the changes that occur in the environment as a result of this total sequence of activities. Included in this is an understanding of the environmental changes occurring as a result of materials or things being taken from and returned to the environment.

Environmental impact may be assessed in terms of the net changes that occur as a result of this interchange of materials. Generally, actual environmental changes are complex combinations of material movement and alterations, as well as chemical and other changes. These changes occur in a time-dependent context, so it is important to consider not only what changes take place, but where and at what rates they occur. This temporal context gives rise to such complex issues as the reversibility of environmental impacts and the renewability of resources.

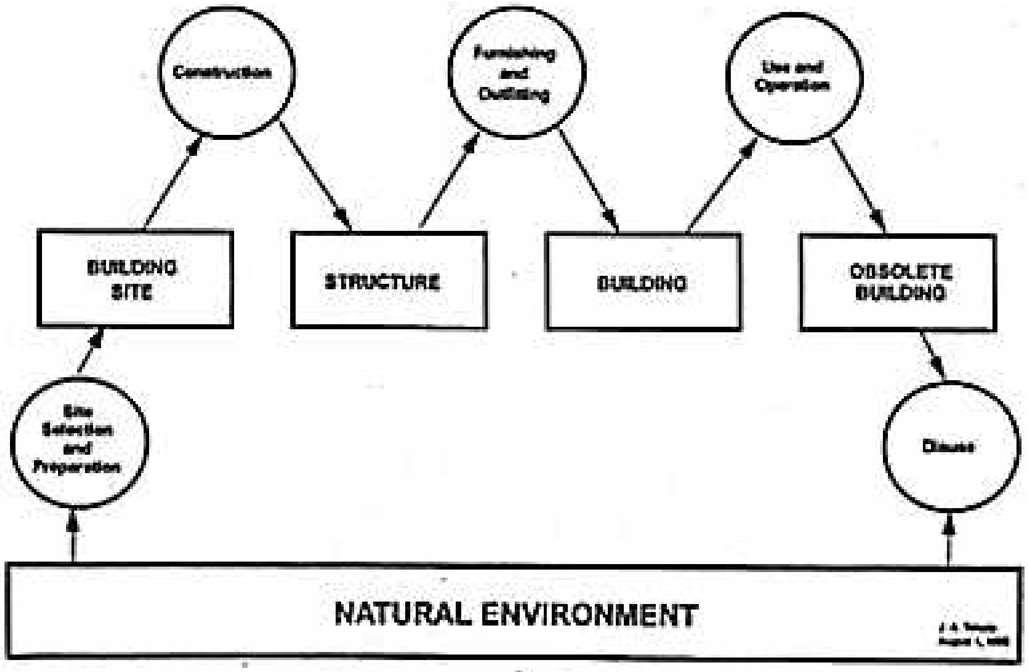
Inventory Phase

In principle, then, by developing an inventory, and examining the material and energy balances of each of the life-cycle processes, it is possible to identify the change and interchange of materials that affect the environment. This exercise is called the inventory phase of an LCA. It does not constitute an assessment of environmental impact, but instead an identification and measurement of things that can result in such impact. This inventory of environmental impacts is a significant first step, and with careful interpretation, can offer valuable insight.

During the inventory phase, it is helpful to use an expanded graphical framework that applies input-output analysis *(Figure 2)* to each of the activities or stages defined in the building life cycle. The framework suggests three categories of inputs and three categories of outputs. All input and output possibilities fall into one or another of these categories. *Figure 3* illustrates this input-output concept applied to the total building life cycle.

Each of these input-output categories generally comprises numerous specific processes and materials. The processes that provide materials to the building life-cycle need to be analyzed in the same way as the main building life-cycle processes. This leads to a graphical road map or cascade of processes that, although complex, permits a visual understanding of the complete building life cycle. *Figure 3* illustrates how building materials and products intervene in the life-cycle stages of a building. For purposes of illustration, this

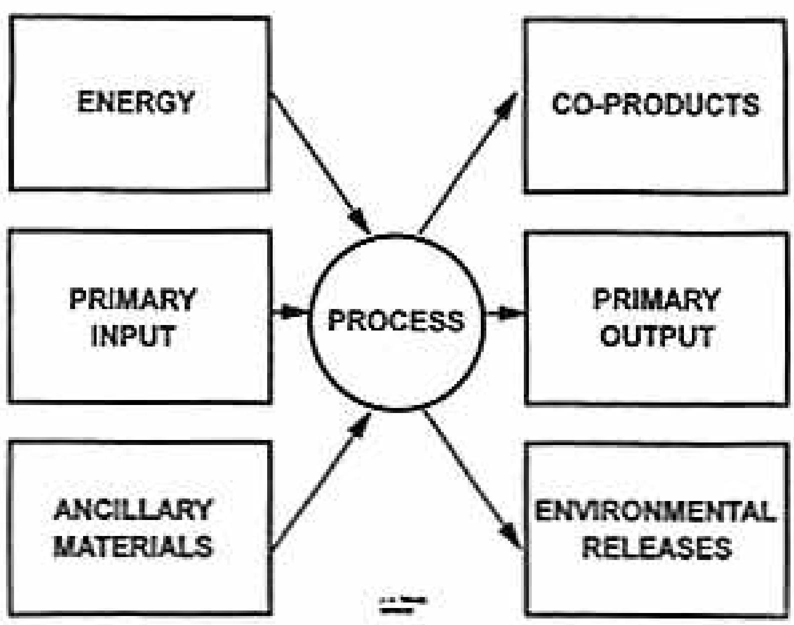
LIFE-CYCLE OF A BUILDING



Note: See Glossary in the Appendix for definition of terms.

Figure 1

FRAMEWORK FOR INPUT-OUTPUT ANALYSIS



Note: See Glossary in the Appendix for definition of terms.

Figure 2

TOTAL ENVIRONMENTAL ANALYSIS

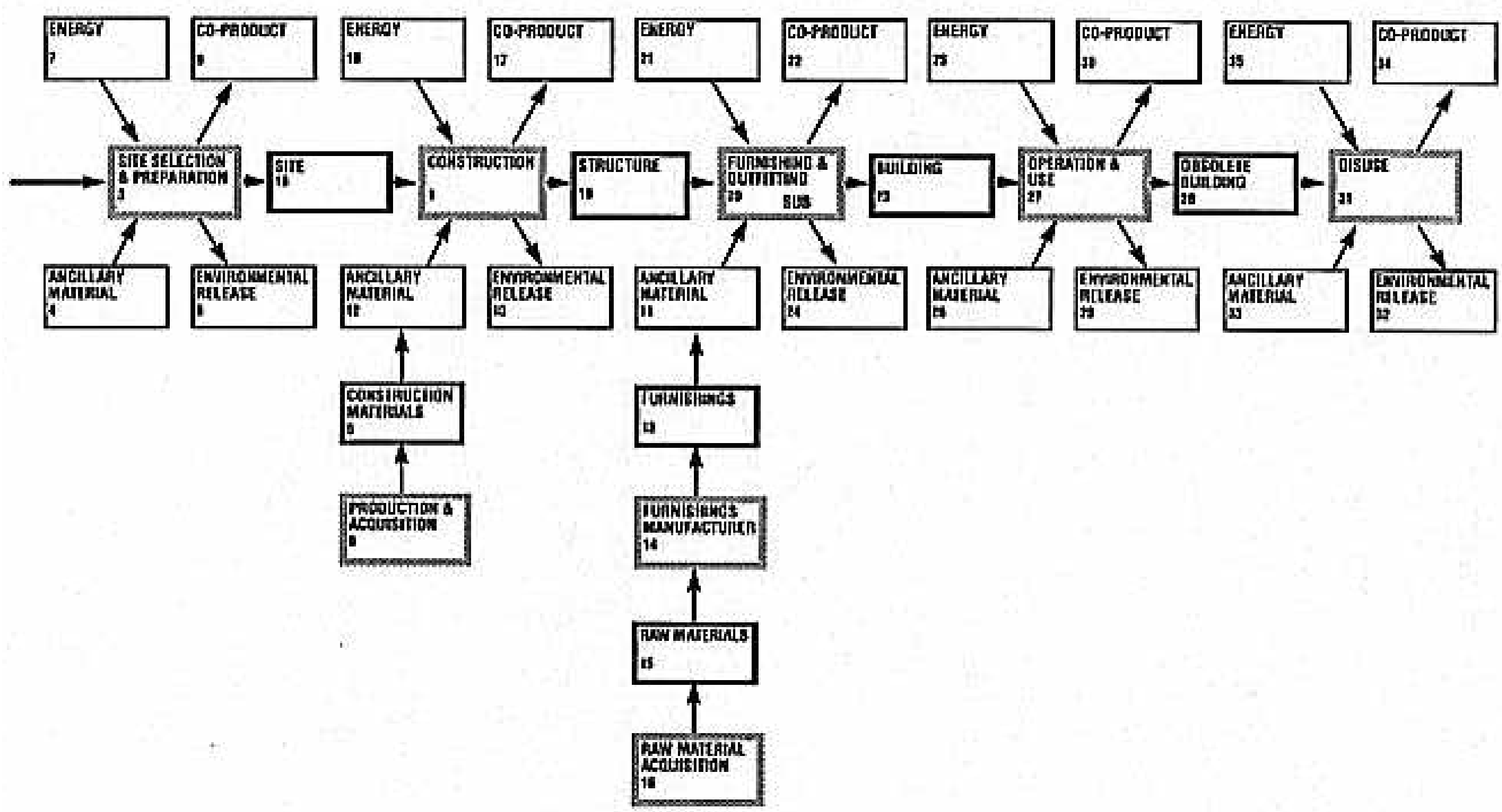


Figure 3

discussion focuses on the energy input throughout the life cycle, the material and product inputs from construction through the use and operation stages, and the environmental releases throughout the life cycle *(Figure 4)*. Coproducts are excluded here in the interest of simplification; they can be included in a similar manner.

The environmental impacts of the building materials and products entering the life cycle are examined in the same manner—and through the application of the same input-output concept—as the sequence of processes and activities that lead to or produce those materials. These processes begin with the acquisition of natural resources and continue through refining and manufacturing, including transportation, to the point when these materials and products are on the site, ready to be incorporated in the building. A single process representing the complete sequence of processes is represented here for simplification. *Figure 5* illustrates this process and the significant inputs and outputs. Expansion of this single process into its complete process sequence may be desirable depending on the scope of the LCA. Examination of each of the other main stages in the building life cycle can be performed in the same way and results in similar diagrams.

The next stage in the assessment is developing the life-cycle inventory, which involves collection of the data and information that characterizes the energy consumption, environmental releases (air, water, solids), and natural resources used in each of the main stages and associated processes in the building life cycle.

This inventory process can be carried out at varying levels of detail. The depth of the analysis, dictated by the purpose and objectives of the project, must be clearly defined at the beginning. It is likely, however, that a more thorough analysis will lead to greater confidence in the final result.

For purposes of illustration, a practical and somewhat subjective approach (rather than a highly detailed, in-depth analysis) is described here. Using the building life cycle shown in *Figure 4* and taking into consideration the intended purpose and use of the building, it is possible to identify various design options, material and product choices, and building operating decision, such as:

- Use of steel versus aluminum, wood, or masonry;
- Use of daylighting versus electrical solutions;
- Use of alternative glazing and window treatments;
- Design of heating, ventilating, and air-conditioning (HVAC) systems;
- Incorporation of electricity-saving devices, such as occupancy sensors and controls;
- Paint selection; and
- Flooring selection (e.g., marble versus ceramic, vinyl, or carpet).

Many material and product options are available. The options will be determined by the project itself and the many factors associated with it. It is often useful to begin with an initial building design and examine it in terms of the building life cycle. Then, compare this base case to an examination of other options and alternatives that are within the scope of the project.

The assessment must include examination of each of the building life-cycle stages: site selection and preparation, construction, furnishing and outfitting, use and operation, and demolition *(Figure 4)*. The assessment begins by determining the following for each life-cycle stage:

- The energy input necessary to carry out each stage;
- The environmental releases and pollutants resulting from each stage; and

BUILDING LIFE-CYCLE DIAGRAM FOR MATRIX I ASSESSMENT

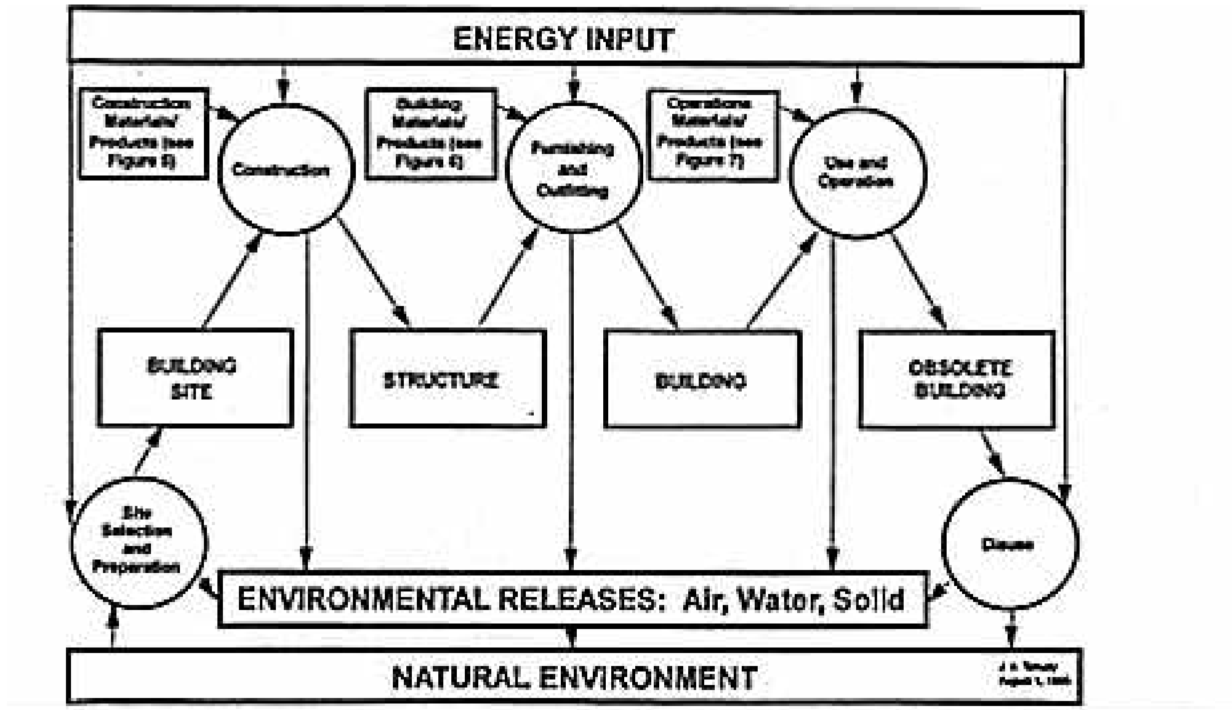


Figure 4

MATRIX I: ENVIRONMENTAL ASSESSMENT FOR BUILDING LIFE-CYCLE PROCESS

Life Cycle Processes	Enviro Releases				*Energy Use*	*Cost*
			Solid			
	Air	*Water*	*Landfill*	*Recycle/Reuse*		
Construction						
Furnishing and Outfitting						
Use & Operation						
Disuse						

Matrix 1

CONSTRUCTION STAGE OF BUILDING LIFE-CYCLE FOR MATRIX II

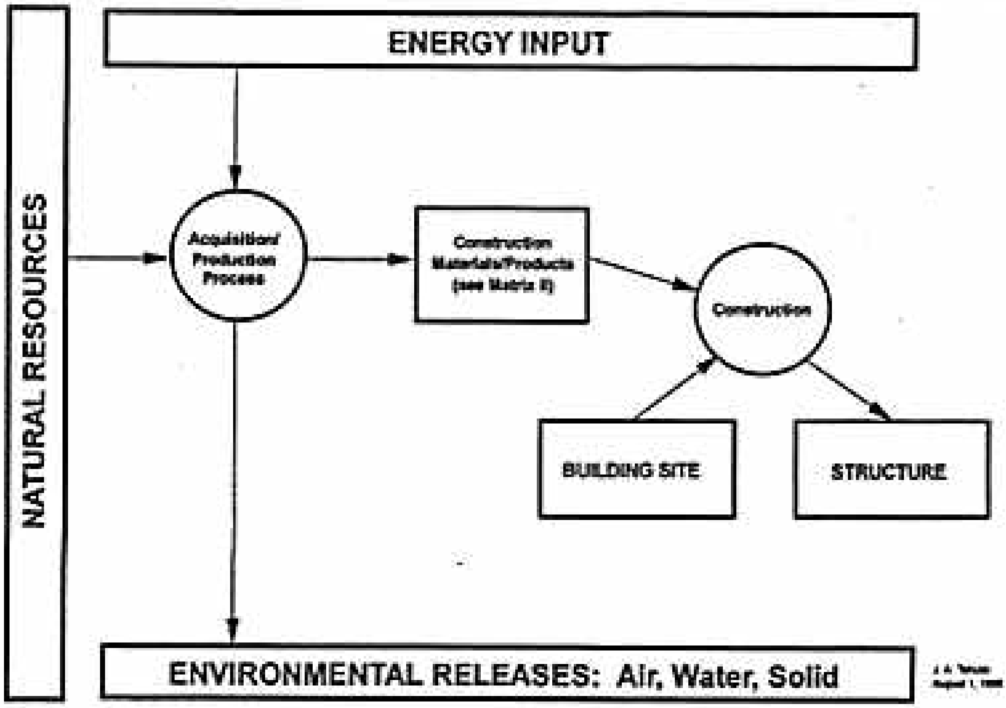


Figure 5

MATRIX II: ENVIRONMENTAL ASSESSMENT FOR MATERIAL/PRODUCT OPTIONS FOR BUILDING

CONSTRUCTION STAGE

Material/Product	Recycled Content	Natural Resource Depletion	Environ. Releases				Emb. Energy	Packaging	Cost	Product Lifetime	Manuf. Rating
			Air	Water	Solid: Landfill	Solid: [illegible]					

Matrix 2

- The inventory of input materials and products for each stage.

Once the material and product inputs (the third item above) to each life-cycle stage are identified, it is then necessary to analyze them in terms of the following factors (see *Figure 5* for an example):

- The energy input necessary to produce those materials and products;
- The total environmental releases and pollutants necessary to produce them; and
- All of the non-energy natural resources necessary to produce them.

As noted earlier, the data must take into account the entire process from the acquisition of natural resources to the point where the materials and products are on the site and ready to be used in the building life cycle.

These steps constitute a collection of inventory data only; a complete set of accurate data is difficult, if not impossible, to compile at this stage in the development and application of LCA to real-world problems. Consequently, it is important to record as much as possible about the quality of the data and the assumptions made in its acquisition. Quantitative data will likely not be available in many cases, making qualitative and subjective judgments necessary.

Recording, organizing, and managing the information may be done in several ways. Borrowing in part from the approach suggested by Graedel et al.,[1] one can develop a series of matrices for recording the above evaluations and managing the inventory information (see *Matrices I* and *II*). *Matrix I* deals with the environmental releases and energy usage associated with the primary processes of the building life cycle. *Matrix II* illustrates the types of environmental data and other relevant information that can be acquired for the materials and products that have been identified as inputs to the primary life-cycle processes. As indicated before, the information here is likely to range from quantitative measurements to subjective comments. Additional categories may be useful depending on the purpose and scope of the project. Non-environmental factors such as cost are also important in the ultimate decision-making process.

Comparing Options

Having examined the base case, one can now consider the various options in design or in materials and products. These options need to be examined for their effects throughout the entire life cycle. For example, a change in a specific design feature is likely to affect some of the material and product requirements in other stages (both upstream and downstream) of the life cycle. Similarly, different product options can affect other downstream processes in the life cycle. It is necessary to understand and examine the consequences of each option in the context of the complete building life cycle.

In principle, the various options can now be compared in terms of their environmental implications. Some would argue that the unknowns and uncertainties are too large to draw valid conclusions. Indeed, these are always issues to be considered. Those willing to deal with the uncertainties and risks and utilize some of the decision-support methods currently available can move forward.[2] By identifying the stakeholders and their sets of values, one should be able to make more informed judgments about the environmental benefits accruable to each of the various options. Evaluating the economic impacts and costs of implementing the various options should also be possible. A decision whether or not to adopt a building design option can now be made with considerably more information and insight.

(Section C contains two chapters on materials. Chapter 16, “Materials,” provides a discussion of general material categories from the perspectives of resource efficiency and occupant health issues. Chapter 17, “Specifications” offers examples of environmental language for specifications documents and information-gathering formats for assessing material choices.)

→ RESOURCES

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CHAPTER 16

Materials

Author

David Rousseau

Introduction

National and international standards organizations are currently developing life-cycle assessment standards for building products and materials. For example, life-cycle assessment standards being developed by the American Society for Testing and Materials' (ASTM's) Subcommittee E-50.06 will provide the basis for obtaining environmental information from product manufacturers in terms that are equivalent or comparative. These standards should make a comparative product life-cycle analysis easier and less costly for the design team. (See Chapter 25, "The Future of Green Building," for a listing of the various life-cycle standards under review and development.)

This chapter focuses on two elements of environmental life-cycle assessment for materials: 1) minimizing natural resource use, and 2) creating a healthy, comfortable, nonhazardous space for building occupants. (Other life-cycle criteria for materials selection mentioned in the Section C introduction are not included in this chapter.) Additional materials-selection criteria, such as code approvals, performance, aesthetics, cost, and availability, are already well established in traditional practice and are not emphasized here.

The information presented here is not meant to be conclusive or definitive. It is provided as an introduction and general guidance regarding resource efficiency and material-related health issues. The reader is encouraged to continue learning about these and other life-cycle assessment issues that impact building material options through references listed in "Resources" at the end of this chapter. (Also refer to Chapter 2, "Selecting Environmentally and Economically Balanced Building Materials," and Part IV, Section C introduction, "Life-Cycle Assessment and its Application to Green Building Principles".)

Resource Efficiency

★ SIGNIFICANCE

Renovation and construction projects, and maintenance programs are necessary to improve the nation's building stock. These efforts depend on reliable sources of quality building products. Limitations on the availability of some building material resources are beginning to occur. For some products, prices are rising faster than inflation as the availability of raw materials starts to decline. Products selected for construction not only consume resources and energy, but also produce air and water pollution and solid waste during their manufacture. Once installed, they may require maintenance or periodic replacement. When a building is demolished, the products and materials usually are disposed in landfills. Therefore, building materials that minimize the use of natural resources and are durable or reusable contribute to sustainable building practices.

The materials-selection practices discussed in this section relate to claddings (exterior walls), interior finishes, and furnishings (rather than structural materials) because they require maintenance every few years and replacement several times over the life of the building.

☞ SUGGESTED PRACTICES AND CHECKLIST

❑ **Consider the following criteria in materials selection:**

- *Resource quantity*. A fundamental strategy for resource-efficient building is to build less and use smaller quantities of materials in the construction process. The most cost-effective conservation strategy is to buy less product, or use the purchased product more efficiently. For example, gypsum wallboard installation typically results in a lot of scrap material because of sizing needs.
- *Reused materials*. Many durable products such as doors, cabinets, and other easily-removed millwork, and some architectural metals and glass, can be readily salvaged and reused. This practice has usually been limited to restoration work, but is becoming more common in building and renovation projects. Salvaging does require extra effort, but the quality and cost savings of some salvaged materials can be considerable. The additional labor cost may be entirely or partly offset by savings on new materials, transportation, and dumping fees.
- *Recycled content*. Although many building products are now available with a high content of recycled materials, there is confusion about the definition of the term. There are at least three types of recycled content materials:
  a. Postconsumer material, generated by commercial, industrial, and institutional facilities or households, and that can no longer be used for its intended purpose.
  b. Recovered industrial process waste that cannot be reused in the same process, such as slag from metal and mineral smelting.
  c. Internally recycled materials from a manufacturing process, such as scraps from trimming and returned or substandard product.
- *Renewability and use of sustainable management practices*. Renewable materials include wood, plant fibers, wool, and other resources that are potentially replaceable within a limited time period (such as a few decades or less) after harvesting. Information on wood harvested through sustainable management practices is becoming more readily available, including certification programs and standards.
- *Local content and reduced transportation*. Specifying products made with local materials and labor can contribute to low embodied energy consumption and life-cycle cost for building materials.
- *Regionally appropriate materials*. Some types of construction and materials are more appropriate in one region than another because of climatic differences. For example, it is well known that utilizing thermal mass in building design has important energy and comfort benefits in the Southwest United States, where daily temperature swings

can be extreme. However, in a hot, humid climate like that of the Southeast United States, lightweight construction and high ceilings may be beneficial.

- *Life-cycle cost and maintenance requirements.* Over the useful life of a commercial building, which may be 30 or more years, some materials will require maintenance and replacement more than once. When the full range of costs is considered, materials that are more costly upon initial purchase may be justified in terms of "avoided future costs." The higher initial cost may also be justified if the product compares favorably with others over their life cycle. (See Chapter 2, "Selecting Environmentally and Economically Balanced Building Materials," for a discussion on life-cycle cost.)
- *Resource recovery and recycling.* Once a material has completed its initial service in a building, it potentially has additional use as a resource and can later be recovered and recycled. The potential recyclability of metal, plastic, glass, wood, and masonry are discussed below.
  a. Metals are recyclable if they can be separated by type. Accordingly, steel and aluminum building elements have a high recycling value. Approximately 50 to 70 percent of the energy and pollution from steel production can be avoided by current recycling technology.[1] Up to 85 percent of the energy and pollution from aluminum manufacturing can be avoided by remelting.
  b. Most plastics are recyclable, but the current rates of recycling are not high because the wide variety of plastics in use makes them difficult to separate. Some plastics such as pure polyvinyl chloride (PVC) would be recycled from buildings more often if designed for easy removal. Additives, coatings, and colorants make recycling difficult.
  c. Glass products are recyclable if separated and uncontaminated; however, little recycling of glass building products now occurs. Recycled glass products are made with consumer container glass salvaged from the waste stream. Remelting glass offers only a marginal energy and pollution reduction.[2]
  d. Heavy timber is recyclable by salvaging and by resawing. Engineered structural wood products, wood panels, and millwork are candidates for salvage and reuse, particularly if they are fastened in such a way that they can be easily removed.
  e. Concrete, clay, and other masonry products and ceramics are examples of materials that are usually difficult to salvage and reuse. Some recycling of these products occurs by crushing them for use as granular fill in road and sidewalk base.

Health and Indoor Air Quality Issues

★ SIGNIFICANCE

Poor indoor air quality is caused by outdoor and indoor sources of gaseous and particulate air pollutants that exceed the capacity of the building's ventilation and filtration equipment to dilute or remove them to an acceptable level.[3] Although many pollutants originate outdoors or from occupant activities, equipment, and processes, other pollutants are generated from materials.[4] The various types of indoor air pollutants are:

- Volatile organic compounds (VOCs) emitted by interior materials and their components;
- VOCs emitted by cleaning and maintenance products periodically used with those materials (see Chapter 22, "Housekeeping and Custodial Practices");
- Fiber shed from textiles, insulation, and panel products;
- Soil, biological materials (e.g., fungi and bacteria), and gases released by biological activity; and
- Dust and other particulates from spraying, sanding, or finishing.

These material-based pollutants may affect the health and productivity of building occupants, maintainence personnel, and construction tradespeople. (See Chapter 13, "Indoor Air Quality" for further discussion on this topic.)

☞ SUGGESTED PRACTICES AND CHECKLIST

❑ **Review emission levels from building products at the following stages:**

- *Installation*. To prevent exposure among tradespeople and building occupants during construction or renovation. Information on potential hazards during the installation period is documented in manufacturers' Material Safety Data Sheets (MSDSs). These sheets are a requirement by law for any material that may have health risks; however, they typically do not disclose a full list of contents. Additional information is available from the Occupational Safety and Health Administration (OSHA).
- *Building occupancy*. To prevent exposure of building occupants to emissions from materials during building use. Information on risks of occupant exposures (typically those risks extending more than a few weeks after construction) is difficult to determine, because emissions data are difficult to obtain or unavailable from manufacturers. This information will become more available in the next few years as standards are developed for accurately measuring and interpreting such data.
- *Maintenance and removal*. To prevent exposure of building occupants and tradespeople during maintenance procedures and removal or demolition. Maintenance and removal risks are reasonably well known for many conventional materials.

❑ **Consider these additional materials issues and effects:**

- *Sink effect*. Rough and porous materials may contain microscopic planes and cavities that can adsorb airborne molecules. These molecules, which may be pollutants, can be released ("desorbed") from the material after several hours or days. This "sink" effect of materials can be quite significant when pollutant molecules are adsorbed. Hard, smooth, and nonporous surfaces typically have a low sink effect.
- *Moisture and temperature*. Moisture and heat in materials increase their deterioration and increase emissions of pollutants. Moisture also supports microbial growth.
- *Soiling and cleaning*. Improper cleaning practices may disturb soil and introduce exposure to chemicals in cleaning products. Soft floor coverings such as carpet are susceptible to this improper practice. Nonporous flooring with minimal seams and low-maintenance coatings are less prone to this occurrence.
- *Natural materials*. There is a common perception that "natural materials" are better environmental choices and less of a health risk than man-made "synthetic materials." Toxicity and emissions testing of products should help clarify which is the better choice with regard to health risk; however, predicting all potential health effects is not always possible.

Survey of Materials

★ SIGNIFICANCE

To adhere to sustainable principles, the material selection process needs to incorporate life-cycle assessment elements and the more conventional criteria such as cost, aesthetics, performance, availability, code, and manufacturer warranty. This section uses two life-cycle assessment criteria—minimizing natural resource use (resource efficiency options) and creating a healthy, comfortable, nonhazardous space for building occupants (health and pollution issues)—to discuss materials in eight of the 16 standard organizational format divisions used by the Construction Specifications Institute (CSI). CSI provides leadership for its membership and the building industry through its standard product organizational format and its work in development and advancement of specifications. Incorporating environmental elements into product review and specification has made the process even more challenging. Since the scope of "traditional practice" is currently being expanded to include these new elements, it will take time to achieve industry consensus with regard to environmentally sound material selections.

(Refer to the “Environmental Impact Questionnaire” in Chapter 17 “Specifications” as an example of an information-gathering mechanism for a life-cycle assessment of material options. This information can assist the design team in selecting environmentally sensitive products based on the priorities established by the building owner.)

☞ SUGGESTED PRACTICES AND CHECKLIST

The materials discussed below are generic—that is, they are product classes (organized by CSI divisions); several manufacturers may produce products in those classes. This is not a comprehensive listing of all materials for a given use nor an exhaustive list of materials. Resource guides and manufacturers’ product data can provide additional information. (See Chapter 17, “Specifications,” for more information on CSI.)

Division 3: Concrete

Making portland cement for concrete requires substantial energy, causing a significant amount of carbon dioxide emissions.[5] Because concrete is such a high-mass material and is used in buildings in large quantities, considering alternatives is important. If the selection is based on life-cycle assessment principles, other materials may be preferable.

❑ **Resource-efficient options**

- Use fly-ash concrete, available in many regions, as an alternative to conventional mixes. Fly ash is a waste material from coal-burning power plants. It can be used to replace up to about 30 percent of the portland cement in conventional mixes. It is also mixed with ground blast-furnace slag, a waste from metal smelting. Fly ash produces a superior concrete with excellent finishing characteristics; however, only some types of ash are appropriate for certain applications, and the proportions are restricted. Seek technical advice and refer to ASTM standards.
- Recycled aggregates and lightweight aggregates are available for some concrete applications. Recycled aggregate may contain crushed concrete, brick, and other masonry waste; or it may contain crushed glass. Lightweight concrete is made with expanded volcanic materials such as pumice and perlite in place of part of the usual stone aggregate. These materials place less load on structures (particularly when used on wood or lightweight steel floors) and provide some thermal insulation value.
- Anticorrosion agents such as epoxy coating extend the life of steel reinforcement, especially for applications such as parking slabs where salt is used in winter. These agents have been found to extend the life of slabs substantially, avoiding repair and replacement costs.
- Using low-waste formwork is a final step in resource conservation. Systems such as modular steel forms, slipforms, and preformed blocks can substantially reduce waste material from concrete forming.

❑ **Health and pollution issues**

- Air pollution emissions from concrete are low. Additionally, concrete is often confined to foundations and concealed structure where exposure to building air is minimal, although testing on radon emissions is ongoing. Other exceptions are some concrete additives and some form-release agents, particularly in interior applications.[6] Concrete additives such as water reducers or superplasticizers may produce odors and risk of skin and bronchial irritation. Form-release agents are sometimes made from diesel oil or other odorous petroleum oils that produce emissions. Wax- or mineral oil-based products are available substitutes.

Division 4: Masonry

Masonry products are made from concrete, clay, glass, and various types of standard and lightweight aggregates. Quarried stone is also used. Most masonry products are installed with mortar made from portland cement, sand, and lime.

❑ **Resource-efficient options**
- Consider lightweight concrete blocks and bricks made with expanded aggregates such as pumice to reduce weight and add insulating value.
- Other options are brick and block products with waste and recycled contents, such as sewage sludge and ash from incinerators and coal-burning plants. However, such ash should be tested for pollutants that could cause unacceptable health or environmental exposures. Hollow blocks are available with waste wood fiber and other recycled content. Native stone or lightweight cultured stone made from cement and recycled aggregates are appropriate for some uses.
- Glass block is available with recycled glass content.

❑ **Health and pollution issues**
- Overall, masonry products produce minimal air pollution.
- If sealers are needed to repel water, a low-volatility, water-dispersed product is safer than a solvent-based variety.

Division 5: Metals

Steel is the most common metal used in building products. It is highly recyclable, and its scrap has value. Aluminum, the second most common metal, is probably the most recyclable material in buildings. Stainless steel and brass products are alloyed metals that are recyclable if carefully separated by type. Copper is also a highly valued recyclable.

Metal plating is common in building products, especially in architectural metals, door hardware, and office systems and furniture. Chromium, cadmium, brass, and nickel plating is often carried out by electroplating plants, sometimes resulting in high levels of pollution. Emissions such as hexavalent chromium and cadmium and acid wastes are environmentally toxic. Plastic polymer coatings and "powder coatings" are alternatives; however, the use of plated metal versus plastic polymer coatings should only be evaluated by comparable life-cycle assessments, which can be done by using ASTM life-cycle assessment standards.

❑ **Resource-efficient options**
- Steel with verified recycled content of 30 percent or greater is available from sources in the United States.
- Aluminum from U.S. sources may have 20 percent or more of verified recycled content, which usually is derived from recycled consumer-product containers.
- Salvaged steel and aluminum beam and bar sections are also widely available from scrap dealers. These may be appropriate for some nonstructural uses.
- Architectural metalwork such as antique iron and brass, lighting fixtures, and door hardware are also readily available from building salvagers.

❑ **Health and pollution issues**
- Indoor air pollution is a minimal problem with metal products. The only exceptions are products that may require polishing, cleaning, or repainting in place. (See "Division 9, Finishes," below.)

Division 6: Wood and Plastic

Woods used in construction and interior finishing are primarily domestic species. Woods used in furniture, doors, and specialty millwork are often imported tropical varieties. Appropriate forest management is vital to more sustainable wood sources in many cases. Processed woods and wood substitutes are an alternative and are discussed further in "Division 12, Furnishings," below.

Most plastics are made from "nonrenewable" petroleum or natural gas feedstocks. Their production may involve use of toxic and potentially hazardous substances. Plastics are sometimes used in building systems as claddings and panels, but most often in interior finishes. These uses are discussed below in "Division 9, Finishes."

❑ **Resource-efficient options**

- Determine whether domestic wood is produced through sustainable forest management. Although this can be difficult, ASTM is developing a sustainably harvested wood standard that can be specified in building construction. An increasing number of producers have sustainable-based management programs and participate in third-party certification programs.
- Low-grade fiber, small-diameter trees, and fast-growing, less-utilized tree species can be used in engineered wood products and value-added products such as "I" joists, oriented strand board, laminated veneer lumber, finger-jointed lumber, open-web wood joists and trusses, stressed skin wood panels, and wood/steel joists. Salvaged timber and wood products are available from operators who disassemble old buildings and bridges and then clean, grade, and often resaw the timber.
- Structural sheathing made from pressed post-consumer newsprint is also available. This material not only uses a recycled material but also adds substantial insulating value and acoustic absorption to the wall or roof. In some circumstances, nonstructural insulating sheathing such as wood-fiber or glass-fiber boards can also be used with steel-strap and bracket-shear braces.

❑ **Health and pollution issues**

- Indoor-air-pollution emissions from glues used in the manufacturing process of some engineered wood products are substantial.
- Those made with exterior-type glues (phenolic resins) and urethane (polyurea) adhesives have some of the lowest emissions.[7]

Division 7: Thermal Insulation and Moisture Protection

Insulation

Thermal insulation can be an important factor in the energy performance of commercial buildings, depending on the climate, building form and orientation, occupancy, and use. Achieving high insulation values by designing larger cavities or using higher-performance materials may be cost-effective. Once the desired insulation value has been determined, a material can be selected that is resource efficient and that addresses health issues.

❑ **Resource-efficient options**

- Mineral-fiber insulation is made primarily from basalt rock or steel mill slag. It is available in loose-fill form, batts, and rigid boards, and can be used for most applications.
- Glass-fiber insulation is now available with 30 percent or more post-consumer recycled glass content from cullet.[8] It is available in loose-fill form, batts, and rigid boards.
- Cellulose thermal insulation and acoustic sprayed coatings contain at least 70 percent post-consumer paper waste. These are available only in loose-fill form. Walls can be insulated using the "blown-in batt" system, installed with a high-pressure blower and containment screen. If installed to density specifications, the insulation does not settle after application. Horizontal spaces are filled with a low-pressure blower. Some systems use a small amount of moisture to encourage stabilization. Sprayed cellulose systems are designed for acoustic and fire retardancy and may contain mineral fiber.
- Foamed polystyrene insulation is available with post-consumer recycled content from recycled fast-food containers and hot drink cups. "Expanded" types are made with a steam process and a non-chlorofluorocarbon (CFC) gas. "Extruded" types, which offer higher performance, were previously made with CFCs. However, they are now made with hydrochlorofluorocarbons (HCFCs), which have far less ozone-depleting potential. New extruded products containing no HCFCs will soon become available, although they contain chemicals that are now being evaluated based on their global warming potential.

– Urethane foams are high-performance insulating materials available as rigid boards or sprayed-in-place systems. These also were once made with CFCs and are now made with HCFCs.
– Vermiculite and perlite are naturally occurring minerals that can be used in insulating plaster mixes and in loose-fill applications such as filling cores of masonry walls.
– A spray-in-place foamed silicate insulation made from sodium silicate and magnesium oxychloride is available for use where fire retardancy and material safety are critical. Used for cavity-fill applications and some surface uses, it is very moist when applied and can take several days to dry.
– Reflective film-radiant insulation can be used effectively to reduce the radiant component of energy transfer, such as excess heat gain from the sun. This material can be particularly useful for reducing cooling loads in commercial buildings in sunny climates. It is made from aluminum foil and metallized plastics and usually installed in a roof cavity with an adjacent air space.

❑ **Health and pollution issues**
– Carefully handle and thoroughly clean up after using some thermal insulations, which may have health risks. It is recommended that they be applied in such a way that they can be completely contained or isolated and cannot enter the building air-handling system. Mineral fibers and glass fibers are now recognized by the United States government as possible carcinogens, and care should be taken by workers handling them. Cellulose fiber is relatively safe, but it contains borates and sulfates as fire retardants and stabilizers that are irritating and may require additional safety measures. The same is true for sprayable cellulose insulation containing mineral fiber. Vermiculite and perlite dust are potentially dangerous if inhaled, and should be handled with caution. These natural mineral products should be certified as asbestos free.
– Codes require a non-combustible covering over plastic insulations and may even prohibit them in some uses. All plastic insulation materials release some gases such as styrene and all are flammable, producing toxic gases when they burn. They are primarily useful for exterior applications. Cutting with a hot wire releases toxic gases and should be avoided on building sites.

Cladding and Roofing

Choices of materials used in cladding and roofing are important for building longevity. The materials used for these purposes should be durable, recyclable, and appropriate for the climate and application.

❑ **Resource-efficient options**
– Metal panels such as galvanized steel and enameled or anodized aluminum are appropriate for pitched roofs and cladding. They have the merit of using very little material to cover the area, and they are durable and recyclable.
– Composite shingles, tiles, and panels made from a variety of fiber-reinforced cement products (some coated with plastics, enamels, or thin metals) are also available for pitched roofs and cladding. These are durable, and some contain recycled content. Although they are not recyclable, these are a good choice for durability and resource efficiency.
– Stucco is a resource-efficient and durable finish where it is protected from moisture and frost damage by effective detailing. Acrylic-modified stucco is less massive and can be installed on exterior insulation board, adding to thermal performance.
– Where shingles are chosen for roofing, higher-quality asphalt shingles and fiberglass shingles are a moderately durable option. Some may be available with recycled content.
– For flat roofs, torch-on roofing has important advantages. Also called “cold-process built-up roofing,” it is fairly durable and repairable; although recycling systems are not in place, this roofing is relatively easy to remove. Flat and shallow-pitched roofs can also be prepared with drainage mats and topsoil to grow grass, helping control rainwater runoff and adding insulation value to the building, while also providing habitat for birds and other wildlife.

❑ **Health and pollution issues**

– Roofing, because of its location, is usually not an important contributor to indoor air pollution.
– Hot mopped asphalt roofing releases extremely high levels of air pollutants during installation and may be restricted in some urban areas because of its contributions to smog. It is also a health risk to installers.

Sealants

Sealants are used in small quantities and are therefore not a cause for serious resource-efficiency concern. However, they present important health concerns because many are solvent-based and toxic.

❑ **Resource-efficient options**

– Regardless of material type, the sealant with the best service life can be the best choice because of the high labor cost of replacement and the potential for costly building damage with lower-quality products.

❑ **Health and pollution issues**

– Generally, sealants used outside the building are not much of an indoor air pollution concern.
– Acrylics, silicones, and siliconized acrylics are typically the safest sealants to handle for inside use and have the lowest solvent content. Those used indoors in any quantity, such as vapor-barrier caulking, should be carefully selected only after review of health evaluations in MSDSs. Quantities of solvent-based products, such as common acoustic caulking, butyls, and urethanes, should be avoided indoors.

Division 9: Finishes

Interior finishes are the most important materials category for reducing indoor air pollution. They are also significant from the perspective of resource conservation because they wear out and are replaced regularly over the life of the building.

Gypsum Products

Gypsum products are the most common interior panels used because of their ease of installation, fire retardance, and low cost. Installation typically results in a high level of scrap materials discarded to the landfill. Gypsum can be recycled, minimizing its contribution to limited landfill space. Restrictions on dumping gypsum and other construction debris have helped start a gypsum-recycling industry in various parts of the United States.

❑ **Resource-efficient options**

– Some gypsum-board manufacturers can verify at least 10 to 15 percent recycled material content. Gypsum is recyclable if not contaminated with paint or adhesives. The paper facing can be made from recycled paper.

❑ **Health and pollution issues**

– Gypsum products themselves are minor sources of indoor air pollutants, although the paper facing and adhesives can be sources. Gypsum surfaces are potential "sinks" to the extent that they absorb other pollutants.
– In the construction phase, the application of adhesives, sealers, paints, and caulkings are the main concerns.

Engineered or Composite Wood or Plastic Panels

These panels have recycled content, but the adhesives and sealers used in their manufacture and installation may be sources of indoor air pollution.

❑ **Resource-efficient options**

– Hardboards are durable and resource-efficient. They are made with wood fiber that is pressed and heated to form panels. No adhesive is usually needed because the natural lignin in wood binds the fibers. These boards are reusable if installed for later removal.

- Particleboard and medium-density fiberboard (MDF) panels are pressed from sawdust, small chips, and fibers and bound with glue. They can contain low-grade wood and sawmill waste. These are resource-efficient products but should be chosen for low pollution potential.
- Low-density fiberboards made from paper and wood fiber are also resource-efficient. Some are made from 100 percent recycled newsprint, and most processes use no glue. Low density fiberboards are used as acoustic panels, underlayment, and tackboards, among other things. They also can be recycled.
- Veneered wood panels, such as oriented strand board with hardwood facing, are resource-efficient choices for interior finishing work. They are used for cabinets and millwork and can offer wood-grain surfaces while minimizing the use of wood. If installed for easy removal, these have good reuse potential.
- Recycled plastic panels made from consumer-product waste are available for interior uses such as toilet partitions and functional worktops. These have a good reuse potential.
- Some vegetable-oil-based plastics are available in flexible and rigid forms. They can be colored and filled with minerals, metal shavings, or other plastic waste and wood fiber, giving them a large range of texture and color possibilities. If installed for easy removal, these have good reuse potential.
- Fiber-reinforced cement boards made with recycled fiber are a resource-efficient choice. These very durable products can be used as substrates for tile and decorative finishes. In some installations they can have good reuse potential if designed for easy removal.

❑ **Health and pollution issues**

- Engineered wood products made with exterior glue (phenol formaldehyde) have low formaldehyde emissions. Products stabilized by ammonia treatment or other methods also have low emissions.[9]

High-Pressure Laminates

These surface materials are made by laminating paper and colorants together with melamine (phenolic) resin. They are a relatively resource-efficient use of plastics because a very small quantity of materials suffices to produce a durable surface.

❑ **Resource-efficient options**

- No manufacturers of high-pressure laminates known at this time offer substantial recycled content in their products, although some have made important process improvements, such as waste-to-energy and heat-recovery systems that exceed industry norms. Their products may have a small resource-efficiency advantage over others.

❑ **Health and pollution issues**

- Because the dust from cutting these laminates and emissions from glues used for installation can be quite significant, work ideally should be performed off the premises, if possible, and the adhesives chosen for safe handling characteristics. If work is to be performed on site, care should be taken in minimizing the dust and glue emissions. (See discussion of "Adhesives," below.)

Ceramics and Terrazzo

Ceramics and terrazzo are not only among the most durable finishes, they also have extremely low emissions. They do not adsorb odors, are easily cleaned, and resist abrasion and wear. Although they are costly to buy and install, their life-cycle cost is among the lowest of all finishes for some applications because of their long life and the minimal maintenance they require. The main air-pollution factors in the field are the setting method, the grout, and any sealers required to protect unglazed surfaces. Energy use in manufacturing should also be considered as part of a life-cycle assessment perspective.

❑ **Resource-efficient options**

- Using local or regionally manufactured ceramics reduces their high transportation cost.

– Some tile is available with recycled content (up to 70 percent), using materials such as scrap glass and feldspar waste from mining. These have important resource-efficiency merit. Some manufacturers also have added innovative conservation measures to their operations.
– Terrazzo made with cement and crushed stone is also resource-efficient.

❑ **Health and pollution issues**

– Cement mortars, usually modified with acrylic additives, are among the safest setting materials to handle. They also have good performance in most applications.
– Where adhesives and caulkings are used, such as for cove bases and flexible joints, a low-solvent-content product such as an acrylic can be chosen. Plastic adhesives contain some solvents and contribute to indoor air pollution.
– Cement- and cellulose-based grouts are very safe and have low emissions. Only epoxy-modified grout (used for some wet and high-wear applications) contains hazardous components.
– Glazed tile and high-fired tile usually do not require sealers.
– If a porous tile is chosen, the safest sealers are the low-volatility, acrylic or water-dispersed silicone types. Sealers containing hazardous solvents contribute to indoor air pollution.

Wood Flooring

Many resource-efficient types of wood flooring are available, including salvaged, laminated, and veneered products. The most important air quality issues are the installation method and the finish.

❑ **Resource-efficient options**

– Salvaged solid-wood flooring is widely available. This is high-quality material available for a modest cost; however, the installation is more expensive than for new material because it requires extra labor for fitting and refinishing. Salvaged flooring also requires sanding and refinishing on-site.
– New wood flooring materials include a wide range of veneered and laminated products that have a plywood or MDF core with a hardwood surface. These are usually prefinished at the factory with a very durable, low-maintenance finish. These are a resource-efficient choice, but are less repairable than solid wood.
– Domestic hardwoods such as oak, maple, birch, and ash, and imported species such as Australian eucalyptus and Scandinavian beech, are most likely to come from sustainable sources. Sustainably-managed sources of tropical hardwoods are also available.[10]
– A steel-track system using wedges to hold flooring in place, or a "floating system" using edge gluing where necessary, makes wood floors easy to remove. A nail-down system is also salvageable, but with some loss of material. A glue-down system is probably the least salvageable, but is required for parquet flooring.

❑ **Health and pollution issues**

– Factory prefinished products offer air-quality benefits because no sanding or finishing is performed on-site.
– If sanding is performed on the premises, the area must be carefully isolated; this should include sealing off the doors and HVAC system and using temporary fans.
– Final cleanup with a high-performance high-efficiency particulate air (HEPA) filter vacuum is recommended.
– For finishing on-site, consider the water-dispersed urethanes (actually urethane-acrylic blends) with low-volatility contents because they are among the lowest-emission finishes. Those with "crosslinker" additives are very durable. Hardening oils, solvent varnishes, and acid-cured varnishes give off prolonged emissions of pollutants.[11]
– If edge gluing is required, white carpenter's or woodworker's glue is a low-toxicity product. If glue-down methods are required, use a low-volatility flooring adhesive.

Resilient Floorings

Vinyl, rubber, linoleum, and cork floors have merit for their easy maintenance, and some types are very durable. Some materials are manufactured with renewable contents, and others have recycled content. In terms of air quality, there are important distinctions among material types, installation methods, and maintenance products.

❑ **Resource-efficient options**

- True linoleum is made with many renewable materials (linseed oil, cork, wood dust, and jute), as are cork products. Linoleum is highly durable.
- Recycled rubber tile and sheet goods made with waste tires are also available. These can provide good, resource-efficient choices for heavy-traffic and utility areas.

❑ **Health and pollution issues**

- Resilient flooring products produce some air-pollutant emissions; as do the setting and maintenance products used with them. Some manufacturers provide emissions data to aid in the selection process. In some applications, interlocked rubber tiles can be laid without adhesive.
- Maintenance products for resilient flooring can also be high pollution sources. Flooring with sealed "low-maintenance" surfaces reduces both maintenance costs and the use of cleaners and waxes.

Carpets and Underpads

Given their high level of use and frequency of replacement over the life of a building, carpeting and underpads are important products to consider for resource-efficiency and pollution potential. Several products with recycled content, lower pollution potential, and lower maintenance requirements are now available.

❑ **Resource-efficient options**

- Polyester and nylon-blended carpets are available with recycled content from polyethylene terephthalate (PET) soft-drink containers. The properties of these materials are similar to those of other polyesters. Care should be taken in reviewing these products for high performance and durability.
- Commercial, high-density, low-pile wool carpet is also available. Wool-face fiber is a renewable material with inherent fire resistance and adequate durability for some commercial uses.
- Carpet tile and releasable roll carpet systems can possibly be switched from low-wear areas to high, to extend the life of the floor. They are also easily removed and replaced during renovation. Carpet tile by design requires the lowest quantity of materials over the building's life, as replacement can occur in smaller installments. The lowest-maintenance carpets are typically the low-pile, dense-loop, and needlepunch types, all of which capture little soil and show less wear.
- One type of nylon fiber, Nylon 6, offers a high level of recyclability. Recycling is an industry priority today because carpeting is sent in large quantities to landfills and does not easily decompose. The major obstacles are the recyclability of the face fiber, the added colorants, and separation of the different materials in the product. Carpets made from fewer materials require less separation for recycling.
- Carpet pad is usually made from sponge plastics and rubber as well as woven and non-woven textile fibers. Rubber pad made from recycled tire rubber, a resource-efficient choice, is dense and durable with a long life expectancy. Fibrous pad made from recycled synthetic and natural fiber from textile mill waste is also available in commercial grades.

❑ **Health and pollution issues**

- The manner in which carpet is constructed affects the emissions it produces. A majority of carpet is made by tufting the face fiber into a polypropylene mat, and gluing it in place with a synthetic latex resin. The synthetic latex is a source of air pollution, including 4 phenylcyclohexene (4PC), an irritant cited in several cases of Sick Building Syndrome.[12]

– One method of low-emission carpet construction is to eliminate the latex bond through "fusion bonding." Carpet made in this manner has a sponge plastic backing into which the face fiber has been heat-welded. It has a low indoor pollution potential. Needlepunched carpets are also made without latex. Among latex-bonded carpets, including wool products, emissions vary widely. Some carpet manufacturers have made considerable effort to provide low-emission products and provide test results, including VOC and other emissions at different time periods.[13]
– Airing out new carpet has often been recommended as a pollution-reduction measure, but the evidence of its effectiveness is still being studied. While this can help reduce some short-term volatile emissions and reduce odors adsorbed during manufacturing and storage, other carpet contents can produce emissions for many months.

Finished Concrete Flooring

Finished concrete flooring is an integral system of slab and finish produced by adding colorants and sealers to the topping concrete either before or after it cures. The concrete is usually stamped with tile patterns and grid lines to control cracking and to enhance its appearance. It is a durable and low-maintenance finish.

❑ **Resource-efficient options**
– Finished concrete may be appropriate for areas that would otherwise be surfaced with tile or terrazzo. Systems with integral color added to the entire topping layer are more resistant to damage and less likely to require recoloring than systems dyed after the concrete is laid. Proper sealing and waxing can lead to longer life.

❑ **Health and pollution issues**
– Finished concrete is low in emissions.
– The choice of sealers is the main concern. Water-dispersed acrylic sealers and waxes meeting low-volatility standards are among the safest.

Paints

Paint is an important indoor air pollution and toxic waste consideration. Volatile emissions from paint tend to be short term—that is, they decrease to a small fraction of the wet emission rate within a few days or weeks. Some of the most toxic emissions from paints and coatings are from evaporating solvents and a wide variety of volatiles released by oxidation. These volatiles are produced by both solvent- and water-based paints. As much as 12 percent of water-based paints may be solvents, although currently paints for interior applications are available containing very little toxic solvents. Water-borne acrylics are clearly preferable to alkyds (solvent-based oil paints) for handling safety, and they are highly durable and produce no hazardous waste from cleanup.

❑ **Resource-efficient options**
– Several U.S. companies are now providing recycled paints made by mixing leftover manufacturing product with returned customer products. These recycled paints are generally good-quality acrylic latex paints, suitable for moderate-duty interior use, although the color range is quite limited.
– For exterior use, solvent-based products are required in some applications. These paints can be recycled either through municipal programs or through paint suppliers.

❑ **Health and pollution issues**
– The first priority is to avoid paints containing lead, mercury, hexavalent chromium, and cadmium. Although regulations have nearly eliminated many of these toxic components from consumer paint lines, industrial and commercial paints may still contain them. Check MSDSs for these toxic contents as they must be disclosed.
– Selecting paints with the least volatile emissions, provided they still meet the other project criteria, is important. Many such paints are water-dispersed acrylic and latex products. Some of the emerging third-party certification groups provide environmental standards for paints.

Ceiling Tile

Ceiling tile is the most common ceiling treatment in commercial and public buildings. Because of the large area it covers, its potential for disturbance during renovation, and its contact with HVAC systems, it is important to evaluate ceiling tile in terms of resource efficiency and indoor air quality.

❑ **Resource-efficient options**

- Ceiling tile is usually made from mineral fiber with added clay or gypsum fillers for fire retardancy and a minimal amount of wood fiber, and it is then painted. Most ceiling tile contains significant amounts of recycled material. Reusable and paintable tile should last many years if handled carefully.

❑ **Health and pollution issues**

- Tile collects dust and adsorbs odors. Ceiling tile with mineral-fiber content may also begin to shed hazardous fiber if disturbed or as it ages. Both problems can be a concern where the ceiling is used for a plenum carrying recirculated air back to HVAC plants. If this type of system is used, the tile should be checked for damage, and the plenum space cleaned with a high-performance vacuum as advised by an IAQ professional.
- In either new or renovation projects, install ducts in HVAC ceiling plenums if possible to secure the plenums from contamination by debris in the suspended ceiling.
- Older products classified within CSI Division 9 may contain hazardous materials such as asbestos and lead paint. A discussion of these issues and suggested practices to address them is outside the scope of this manual. Professional advice and listings of qualified consultants can be obtained from regional Environmental Protection Agency offices, or local departments of public health.

Division 10: Specialties

❑ **Resource-efficient options.**

Several panel systems available for office partitions and non-structural interior uses allow changes to floor plans without major demolition and waste. Although they usually cost more than lightweight steel framing and gypsum panels built on-site, they are reusable and allow rapid changes to be made with minimal disruption. They also have many components that can be recycled when the panels are no longer useful. Usually referred to as "demountable systems," they typically have steel or aluminum tracks at the top and bottom to hold gypsum panels that lock into place. Door modules, glass, different surface finishes, and several other options are available. The manufacturers claim typically less than 10 percent material waste with relocation. Used systems can be purchased and matching components traded between departments or buildings or stored for future use. These products can have important resource-efficiency merits.

Division 12: Furnishings

Furnishings are an important resource-efficiency and indoor-air-quality consideration for organizations. A major cost and maintenance component for interiors, they are essential to workplace satisfaction and comfort.

❑ **Resource-efficient options**

- The most resource-efficient option is to repair any good-quality furniture currently owned by the organization. Good-quality used office furniture can also be purchased from local office-furniture suppliers.
- Some furniture manufacturers and several resale operators offer reconditioned furniture as a purchase or lease option. These are usually classic and durable lines that have been bought back or returned by lessees and have had surfaces and hardware replaced.
- Steel, glass, and solid-wood furniture has significant resource-efficiency merits and recycling potential. It also has minimal indoor pollution potential.

- Tropical hardwoods are common in office furniture, both as solid components and veneers. Rare woods such as rosewood, teak, and ebony are becoming scarce, and extracting them can contribute to forest degradation. To find well-managed sources of tropical hardwoods, refer to the guides listed in the "Resources" section below. Some conscientious furniture manufacturers offer substitute woods that are more environmentally and economically sustainable.
- Manufactured hardwoods are another option. These are typically northern hardwoods that have been dyed and machined to create beautiful and unique wood finishes.
- Upholstery foams used in chairs are generally high-density urethane products. These were once manufactured with ozone-depleting CFCs, but are now made with less-depleting HCFCs. HCFCs are also due to be phased out from upholstery-foam manufacture in 1996.

❑ **Health and pollution issues**

- The main air-pollution potential associated with furniture is from glue-bonded wood products, soft plastics, fabric treatments, and finishes. Some furniture manufacturers provide emissions data for their products.
- Fabric coverings, foam fillings, and fabric-coated acoustic panels are dust collectors and adsorb odors; clean them regularly to minimize these problems (see Chapter 22, "Housekeeping and Custodial Practices").
- Metal-coating systems and wood finishes are important environmental issues associated with furniture. "Powder-coated" metal finishes are a substitute for painting and plating. The process involves applying dry powder polymers to metal and fusing them with heat. Powder-coated finishes are harder than many paints and can actually rival plating for durability. For woods, factory-applied and -cured coatings such as urethanes have minimal emissions, and the factory can capture the resulting dust and recycle solvent.

➜ RESOURCES

American Institute of Architects Committee on the Environment. *Environmental Resource Guide*. Washington, D.C.: American Institute of Architects, 1992. A large and thorough reference work on design and conservation. The guide includes substantial background information on generic materials but no specific materials listings and is supplemented periodically.

American Recycling Market. *The Official Recycled Products Guide*. Ogdensburg, N.Y.: American Recycling Market. A substantial listing of industrial and construction products with recycled content that is updated periodically.

Center for Resourceful Building Technology. *The Guide to Resource Efficient Building Elements*. Missoula, Mont.: Center for Resourceful Building Technology. The original listing of resource-efficient construction products and those with recycled content. The guide is updated and revised periodically.

Harris, B. J. *The Harris Directory 1993–1995*. Seattle, Wash.: Stafford-Harris, 1993. A comprehensive database of construction materials with recycled content for Macintosh computers. It is updated yearly.

Iris Communications. *The REDI (Resources for Environmental Design Index) Guide*. Eugene, Ore.: Iris Communications, 1994. A database (for Windows or Macintosh) of construction materials with recycled content, resource-efficient products, and sustainably managed wood sources.

Leclair, K., and D. Rousseau. *Environmental by Design, Professional Edition*. Vancouver: Leclair/Rousseau, 1994. A guide to specific products for interiors, including thermal insulations. Product reviews are graphic and easy to understand. The book contains readable background information and is updated twice annually.

Tree Talk. *Woods of the World Database*. Burlington, Vt.: Tree Talk, 1995. A sophisticated and comprehensive guide to woods available on CD ROM with graphics or in simplified format on diskettes.

NOTES

1 Natural Resources Canada and Forintek Canada Corp., *Building Materials in the Context of Sustainable Development*, Summary Report and Research Guidelines (Ottawa: Forintek Canada Corp., 1994).

2 Using waste consumer glass in building products is an example of a controversial recycling measure. Opponents argue that glass containers should be reusable and that any waste should be recycled into consumer glass. Proponents argue that a lot of low-quality crushed glass (cullet) is contaminated and unsuitable for containers. The energy benefit from recycling glass is small because remelting it takes about 80 percent of the energy used to make new glass, and the raw materials are plentiful. In the current waste-glass market, making tile and insulation from low-grade cullet probably makes more sense than using it for drainage fill or as aggregate.

3 D. T. Grimsrud and K. Y. Teichman, “The Scientific Basis for Standard 62-1989,” *ASHRAE Journal* (Oct. 1989): 514.

4 E. Tucker, “Emission of Organic Substances from Indoor Surface Materials,” *Environment International* 17 (1991): 357–63; H. Levin,“Building Materials and Indoor Air Quality,” *Occupational Medicine, State of the Art Reviews* 4, no.4 (Oct.–Dec. 1989): 667–94.

5 Natural Resources Canada and Forintek, *Building Materials*.

6 M. R. Rixom, *Chemical Admixtures for Concrete* (New York: E&F.N. Spon., 1986).

7 T. Godish, *Indoor Air Pollution Control* (Chelsea, Mich.: Lewis Publishers, 1989); and C. B. Meyer and K. Hermanns, “Formaldehyde Release from Wood Products: An Overview,” *Symposium Series* 316 (Washington, D.C.: American Chemical Society, 1986).

8 Using waste consumer glass in building products is an example of a controversial recycling measure. (See note 2 above.)

9 Godish, *Indoor Air Pollution Control*; and Meyer and Hermanns, “Formaldehyde Release.”

10 Tree Talk, *A Forest of Choices* (Burlington, Vt.: Tree Talk). (800) 858-6230, (802) 863-6789.

11 Godish, *Indoor Air Pollution Control.*

12 J. Davidson et al., “Carpet Installation During Building Renovation and its Impact on Indoor VOC Concentrations,” in *Proceedings, Healthy Buildings* (Washington, D.C.: Sept. 1991); and Anne Wagner, “Floor Coverings & IAQ,” *Indoor Air Quality Update* (Arlington, Mass.: Cutter Information Corp., 1991).

13 M. Black et al., “The State of Washington's Experimental Approach to Controlling Indoor Air Quality in New Construction,” in *Proceedings, Healthy Buildings* (Washington, D.C.: Sept. 1991); and the *Washington State Procurement Standard for Furniture Systems*.

CHAPTER 17

Specifications

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★ SIGNIFICANCE

The purpose of the construction documents—the drawings and specifications—is to convey the building design concept to the contractor. The more accurately the concept is conveyed, the more likely it is the concept will be realized.

In order to facilitate communication of the building design concept, industry members have standardized the format of construction documents. The drawings describe the location, size, and quantity of materials. The specifications are the written documents that accompany the drawings and describe the quality of construction. For example, if the drawings indicate a plaster wall, the specifications will describe the plaster mix, lath and paper backing, and finishing techniques.

In the early 1960s, the Construction Specifications Institute (CSI) produced a standard organizational format for specifications, which is now used by manufacturers, architects, engineers, interior designers, contractors, and building officials across the United States. Under the CSI format, information is organized in a standard outline form. Types of work are broadly grouped within 16 CSI *Divisions*, which are divided into *Sections*. The Sections are identified by five-digit numbers. The first two digits are for the Division (01–16) and the last three indicate more and more precise units of work (i.e., broadscope, mediumscope, and narrowscope). Each Section contains three *Parts: General, Products,* and *Execution*. There is also a standardized system of *Articles* and *Paragraphs* within each Part. The 16 Divisions are as follows:

Division 1 — General Requirements
Division 2 — Site Work (soon to be renamed Site Construction)[1]
Division 3 — Concrete
Division 4 — Masonry
Division 5 — Metals
Division 6 — Wood and Plastics
Division 7 — Thermal and Moisture Protection

Division 8 — Doors and Windows
Division 9 — Finishes
Division 10 — Specialties
Division 11 — Equipment
Division 12 — Furnishings
Division 13 — Special Construction
Division 14 — Conveying System
Division 15 — Mechanical
Division 16 — Electrical

When the building design concept addresses green issues, the specifications should clearly indicate the green requirements. Often green requirements do not conform to standard practices and are unfamiliar to contractors. While compliance with these requirements is often simple and inexpensive, noncompliance can be difficult and expensive—if not impossible—to correct. For example, if the contractor overlooks temporary ventilation requirements detailed in standard Section 01500 clauses, the building's indoor air quality (IAQ) may be significantly impacted, during and after construction. It would be difficult to undo the "damage" and to assess the compensation due the owner for the oversight.

☞ SUGGESTED PRACTICES AND CHECKLIST

Although green concepts can be addressed with existing CSI Sections and Articles, it may be more useful and provide more clarity to create new, separate, readily available Sections and Articles to address green requirements. The following includes a few suggested enhancements to the existing CSI format:

❑ **Division 1, which addresses broad administrative and procedural issues, should clearly indicate the broad green considerations for design and construction, identify the owner's commitment, and require the contractor's participation.**
Some environmental controls are already common in Division 1 Sections. For example, Section 01100, Special Project Procedures (soon to be renamed Section 01350, Special Procedures),[2] is sometimes used to address project-specific concerns such as the existence of hazardous materials in a renovation project or noise restrictions for construction near a hospital. Section 01500, Construction Facilities and Temporary Controls (soon to be renamed Section 01500, Temporary Facilities and Controls),[3] commonly includes requirements for tree and plant protection, cleaning of the site during construction, dust control, and erosion control. Theoretically, existing environmental controls in Division 1 could be expanded to address the environmental goals of the project. However, to facilitate communication, it may be useful to locate environmental requirements in a single Division 1 section, Section 01150, Environmental Procedures (soon to be renamed Section 01360, Environmental Procedures).[4] Refer to the sample specification in *Exhibit 1*.

❑ **For CSI Divisions 2 through 16, communication of green requirements can be improved by identifying them in separate Articles under each of the three main Parts.**
Refer to the Environmental Specifications Format in *Exhibit 2*.

❑ **Consider the CSI format when investigating product options and record the information gathered accordingly.**
Refer to the sample Environmental Impact Questionnaire in *Exhibit 3* and the sample Indoor Air Quality Emission Questionnaire in *Exhibit 4*. These research tools organize product data to coordinate with the major Article and Paragraph format in the Environmental Specifications Format.

❑ **Develop new product Sections as necessary.**
Many green products do not correspond to an existing CSI Section. CSI is beginning to address this growing need. In the meantime, it will be necessary for individual projects to create broadscope and mediumscope sections appropriate for the new categories of

products such as alternative agricultural products, plastic lumber, and constructed wetlands. It may also be necessary to create new narrowscope sections to more efficiently organize the proliferation of similar, competing products such as fiber insulation (cellulose, fiberglass, mineral wool, cotton), rock insulation (perlite, basalt), and foam insulation (polystyrene, polyisocyanurate, polyurethane, glass, and cementitious).

EXHIBITS

Following are four comprehensive exhibits that provide detailed examples for design and construction professionals regarding environmental specifications and procedures, and environmental impact and indoor air quality questionnaires for use with manufacturers. These exhibits are provided as examples of the environmentally oriented specification forms and questionnaires developed and used by BSW International, a major international architectural/engineering firm. They provide an excellent example to help organizations gain an understanding of the issues and develop similar documents to satisfy their own unique requirements. The exhibits are as follows:

- *Exhibit 1* — Section 01150, Environmental Procedures (Sample Specification, BSW International)
- *Exhibit 2* — Environmental Specifications Format (Sample Format, BSW International)
- *Exhibit 3* — Environmental Impact Questionnaire (EIQ) (Sample Form, BSW International)
- *Exhibit 4* — Indoor Air Quality Questionnaire (Sample Form, BSW International)

NOTES

1 New title anticipated for 1995 Edition of the CSI Master Format, projected for early 1996 publication.

2 New number and title anticipated for 1995 Edition of the CSI Master Format, projected for early 1996 publication.

3 New title anticipated for 1995 Edition of the CSI Master Format, projected for early 1996 publication.

4 New number anticipated for 1995 Edition of the CSI Master Format, projected for early 1996 publication.

EXHIBIT I: ENVIRONMENTAL PROCEDURES

BSW International One West Third Street, Tulsa, OK 74103-3506 (918) 582-8771/(918) 587-3084

The following document is furnished by BSW INTERNATIONAL and is intended to be used only as a guide. It should not be used as a final solution for any purpose. Language is presented for example only and no warranty or guaranty is made as to completeness or accuracy of information contained herein.

SECTION 01150
ENVIRONMENTAL PROCEDURES

SPECIFIER NOTE: THIS SECTION INCLUDES REQUIREMENTS FOR WASTE MANAGEMENT AND THE PROTECTION OF NATURAL RESOURCES. THIS SECTION EMPHASIZES A TEAM APPROACH, INCLUDING OWNER, DESIGN PROFESSIONAL, AND CONTRACTOR, TO ADDRESS ENVIRONMENTAL ISSUES. THIS SECTION DOES NOT ADDRESS REQUIREMENTS FOR ENVIRONMENTAL IMPACT STATEMENTS OR ENVIRONMENTAL IMPACT REPORTS. REFERENCES TO ORGANIZATIONS, PROGRAMS AND MANUFACTURERS IN THIS SECTION DO NOT REPRESENT A GUARANTY, WARRANTY, OR ENDORSEMENT THEREOF. COORDINATE WITH REQUIREMENTS OF OTHER SECTIONS; VERIFY THAT PRODUCTS AND INSTALLATION METHODS SPECIFIED IN OTHER SECTIONS ARE ENVIRONMENTALLY APPROPRIATE. EDIT TO SUIT LOCATION AND PROJECT.

PART 1 GENERAL

1.1 SUMMARY

A. Section includes: Procedures for achieving the most environmentally conscious Work feasible within the limits of the Construction Schedule, Contract Sum, and available materials, equipment, and products.
   1. Participate in promoting efforts of Owner and Architect to create an energy-efficient and environmentally-sensitive structure.
   2. Use recycled-content, toxic-free, and environmentally-sensitive materials, equipment, and products.
   3. Use environmentally-sensitive procedures.
      a. Protect the environment, both on-site and off-site, during demolition and construction operations.
      b. Prevent environmental pollution and damage.
      c. Effect optimum control of solid wastes.

SPECIFIER NOTE: COORDINATE REQUIREMENTS FOR WASTE COLLECTION AND DISPOSAL AND FOR ENVIRONMENTAL PROTECTION SPECIFIED UNDER THIS SECTION WITH WORK SPECIFIED UNDER RELATED SECTIONS. EDIT BELOW TO SUIT PROJECT.

B. Related Sections:
   1. Section 01025 - Measurement and Payment: Applications for payment.
   2. Section 01200 - Project Meetings: Preconstruction conference.
   3. Section 01500 - Construction Facilities And Temporary Controls: Temporary ventilation, environmental protection, waste collection, and disposal operations.
   4. Section 01600 - Material and Equipment: Substitutions.
   5. Section 01700 - Contract Closeout: Cleaning and final submittals.
   6. Section 02070 - Selective Demolition: Salvage and waste disposal operations.
   7. Section 02100 - Site Preparation: Tree and plant protection.

1.2 DEFINITIONS

SPECIFIER NOTE: VERIFY VENTILATION REQUIREMENTS FOR INDOOR AIR QUALITY. "ADEQUATE" REQUIREMENTS FOR ONE MATERIAL MAY NOT BE "ADEQUATE" FOR ANOTHER; FOR EXAMPLE, CARPET CAN CONTAIN OVER 100 CHEMICALS, INCLUDING POSSIBLE CARCINOGENS, AND MAY REQUIRE MORE COMPLEX VENTILATION TO ACCELERATE OFFGASSING PRIOR TO INSTALLATION. MATERIALS/PRODUCTS THAT GENERALLY REQUIRE TEMPORARY VENTILATION FOR OFFGASSING INCLUDE: ADHESIVES, WOOD PRESERVATIVES, COMPOSITE WOOD PRODUCTS, PLASTICS, WATERPROOFING, INSULATION, FIREPROOFING, SEALANTS/CAULKING, ACOUSTICAL CEILINGS, RESILIENT FLOORING, CARPET, PAINTING, SEALERS/COATINGS, WALL COVERINGS, MANUFACTURED CASEWORK, AND FURNITURE.
FOR MORE INFORMATION AND INFORMATION ON CURRENT FEDERAL ACTIVITIES FOR IAQ, CONTACT EPA INDOOR AIR QUALITY INFORMATION CLEARING HOUSE (800) 438-4318/(202) 484-1307; NATIONAL PESTICIDES TELECOMMUNICATION NETWORK (800) 858-7378; NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (800) 35-NIOSH; AND THE DEPARTMENT OF ENERGY (DOE) OFFICE OF CONSERVATION AND RENEWABLE ENERGY (800) DOE-3732.

A. Adequate ventilation: Ventilation, including air circulation and air changes, required to cure materials, dissipate humidity, and prevent accumulation of dust fumes, vapors, or gases.

B. Construction and demolition waste: Includes solid wastes, such as building materials, packaging, rubbish, debris, and rubble resulting from construction, remodeling, repair, and demolition operations.
   1. Rubbish: Includes both combustible and noncombustible wastes, such as paper, boxes, glass, crockery, metal and lumber scrap, metal cans, and bones.
   2. Debris: Includes both combustible and noncombustible wastes, such as leaves and tree trimmings that result from construction or maintenance and repair work.

C. Chemical waste: Includes petroleum products, bituminous materials, salts, acids, alkalis, herbicides, pesticides, organic chemicals, and inorganic wastes.

D. Environmental pollution and damage: The presence of chemical, physical, or biological elements or agents which adversely affect human health or welfare; unfavorably alter ecological balances, or degrade the utility of the environment for aesthetic, cultural, or historical purposes.

E. Hazardous materials: Includes pesticides, biocides, and carcinogens as listed by recognized authorities, such as the Environmental Protection Agency (EPA) and the International Agency for Research on Cancer (IARC).

F. Interior final finishes: Materials and products that will be exposed at interior, occupied spaces; including flooring, wallcovering, finish carpentry, and ceilings.

SPECIFIER NOTE: VERIFY CLASSIFICATION OF LANDFILL(S) AS APPROPRIATE TO LOCATION OF PROJECT. FOR EXAMPLE, IN CALIFORNIA, UNDER THE CALIFORNIA CODE OF REGULATIONS - TITLE 23, SPECIFY CLASS III LANDFILL. FOR INFORMATION ON SOLID WASTE LANDFILLS AND DISPOSAL REGULATIONS, CONTACT APPLICABLE SOLID WASTE AGENCY. THE RCRA (RESOURCE CONSERVATION RECOVERY ACT) HOTLINE MAINTAINS CURRENT LISTS OF STATE SOLID AND HAZARDOUS WASTE MANAGEMENT OFFICIALS. CONTACT RCRA AT (800) 424-9346. EDIT BELOW TO SUIT PROJECT.

EXHIBIT I: ENVIRONMENTAL PROCEDURES (CONT.)

G. Municipal Solid Waste Landfill: A permitted facility that accepts solid, non-hazardous waste such as household, commercial, and industrial waste, including construction and demolition waste.

H. Packaged dry products: Materials and products that are installed in dry form and are delivered to the site in manufacturer's packaging; including carpets, resilient flooring, ceiling tiles, and insulation.

I. Sediment: Soil and other debris that has been eroded and transported by storm or well production runoff water.

J. Sanitary wastes:
1. Garbage: Refuse and scraps resulting from preparation, cooking, distribution, or consumption of food.
2. Sewage: Domestic sanitary sewage.

K. Wet products: Materials and products installed in wet form, including paints, sealants, adhesives, and special coatings.

SPECIFIER NOTE: COORDINATE BELOW WITH SECTION 01600, MATERIALS AND EQUIPMENT, FOR SUBSTITUTION REQUIREMENTS. INDICATE UNIQUE PROCEDURES APPLICABLE FOR PROPOSAL OF ENVIRONMENTAL SUBSTITUTIONS.

1.3 Substitutions

A. Notify Owner when Contractor is aware of materials, equipment, or products that meet the aesthetic and programmatic intent of Contract Documents, but which are more environmentally-sensitive than materials, equipment, or products specified or indicated in the Contract Documents.

B. Requirements of Section 01600, Materials and Equipment apply except as follows:
1. Prior to submitting detailed information required under Section 01600, submit the following for initial review by Owner and Architect:
a. Product data including manufacturer's name, address, and phone number.
b. Description of the differences of the proposed substitution from specified product. Include description of environmental advantages of proposed substitution over specified product.
2. Submit additional information as directed by Architect.

SPECIFIER NOTE: COORDINATE BELOW WITH SECTION 01200, PROJECT MEETINGS, FOR PRECONSTRUCTION MEETING REQUIREMENTS.

1.4 PRECONSTRUCTION MEETING

A. After award of Contract and prior to the commencement of the Work, schedule and conduct meeting with Owner and Architect to discuss the proposed Solid Waste Management and Environmental Protection Plan and to develop mutual understanding relative to details of environmental protection, recycling, and rebate programs.

1.5 SUBMITTALS

A. Solid Waste Management and Environmental Protection Plan: Not more than 20 days after the Preconstruction meeting, prepare and submit a Solid Waste Management and Environmental Protection Plan including, but not limited to, the following:
1. List of federal, state, and local laws, regulations, and permits concerning environmental protection, environmental pollution and damage, hazardous materials, construction and demolition waste, chemical waste, sanitary waste, sediment, water, air, and noise pollution that are applicable to the Contractor's proposed operations.

2. List species of fish and wildlife that require specific attention along with measures for their protection.

SPECIFIER NOTE: CONTRACTOR IS REQUIRED TO PRESERVE THE NATURAL RESOURCES ON THE SITE AND TO RESTORE RESOURCES DAMAGED DURING CONSTRUCTION OPERATIONS; REFER TO ENVIRONMENTAL CONTROLS AS SPECIFIED HEREIN. THEREFORE, IT IS NECESSARY TO ESTABLISH EXISTING CONDITION OF NATURAL RESOURCES ON THE SITE. IF OWNER HAS NOT ADEQUATELY DOCUMENTED EXISTING CONDITIONS, CONTRACTOR MAY BE REQUIRED TO DO SO. EDIT BELOW AS APPROPRIATE.

3. Procedures to be implemented to provide the required environmental protection and to comply with the applicable laws and regulations.
a. Document existing conditions.

4. Permit or license and the location of the municipal solid waste landfills and other disposal area(s).

SPECIFIER NOTE: EDIT BELOW TO SUIT PROJECT.

5. Procedures for Recycling/Re-Use Program.

SPECIFIER NOTE: DELETE BELOW IF PROJECT DOES NOT QUALIFY FOR REBATE PROGRAMS.

6. Procedures for Rebate Program(s).
7. Revise and resubmit Solid Waste Management and Environmental Protection Plan as required by Owner.
a. Approval of the Contractor's Solid Waste Management and Environmental Protection Plan, will not relieve the Contractor of responsibility for adequate and continuing control of pollutants and other environmental protection measures.

SPECIFIER NOTE: COORDINATE BELOW WITH SECTION 01025, MEASUREMENT AND PAYMENT, FOR APPLICATION FOR PAYMENT REQUIREMENTS.

B. With each application for progress payment, submit a summary of solid waste generated by the construction and demolition operations. Submit on form in Appendix A of this Section. Include manifests, weight tickets, receipts, and invoices specifically identifying the Project and waste material for:
1. Municipal Solid Waste Landfills.
2. Recycling Centers.
3. Non-Profit Organizations.

C. With each application for progress payment, submit records of noise level. Indicate procedures for measurement and any problems and the alternatives implemented for mitigating actions.

SPECIFIER NOTE: DELETE BELOW IF PROJECT DOES NOT QUALIFY FOR REBATE PROGRAMS. IF REBATE PROGRAMS ARE APPLICABLE, COORDINATE WITH SECTION 01700, CONTRACT CLOSEOUT FOR CLOSEOUT SUBMITTAL REQUIREMENTS.

D. Prepare 3-ring binder with rebate information and product documentation as required or Owner to qualify for Rebate Programs. Submit binder with final closeout submittals.

PART 2 PRODUCTS - not used

PART 3 EXECUTION

3.1 RECYCLING AND REUSE

SPECIFIER NOTE: IDENTIFY TYPES OF MATERIALS TO BE RECYCLED OR REUSED. VERIFY AVAILABILITY OF LOCAL FACILITIES CAPABLE OF PROCESSING THE MATERIALS AND NOTE ANY SPECIAL LIMITATIONS IMPOSED BY LOCAL FACILITIES ON THE CONDITION OF MATERIALS ACCEPTED.
CONSIDER HIGHEST AND BEST USE OF EACH MATERIAL (REUSE IS MORE EFFICIENT THAN RECYCLING); FOR EXAMPLE, MANY BUSINESSES COLLECT ITEMS SUCH AS USED PAINT, BRICK, OR METAL FABRICATIONS FOR REUSE. ALSO, SOME MANUFACTURERS ACCEPT USED PACKAGING FROM THEIR PRODUCTS FOR REUSE. CONSIDER RECYCLING OR REUSING MATERIAL ON SITE; FOR EXAMPLE, CRUSHED GYPSUM MAY BE USED AS SOIL AMENDMENT IN SOME AREAS. COORDINATE WITH SPECIFIC PROJECT MATERIALS AND REQUIREMENTS. THE FOLLOWING IS AN EXAMPLE.

A. Collection: Implement a recycling/reuse program that includes separate collection of waste materials of the following types:
1. Asphalt.
2. Concrete.
3. Porcelain plumbing fixtures.
4. Metal.
   a. Ferrous.
   b. Non-ferrous.
5. Wood, nails and staples allowed.
6. Debris.
7. Glass, colored glass allowed.
8. Red clay brick.
9. Paper.
   a. Bond.
   b. Newsprint.
   c. Cardboard and paper packaging materials.
10. Plastic.

SPECIFIER NOTE: MANY TYPES OF PLASTICS MAY BE MIXED TOGETHER TO MAKE PLASTIC LUMBER. HOWEVER, SOME FACILITIES OPERATE PREDOMINANTLY FOR THE CONSUMER SECTOR AND REQUIRE SEPARATION OF PLASTIC BY "CONSUMER" TYPES. MILK JUGS ARE GENERALLY FABRICATED FROM HDPE; PLASTIC WRAP AND PLASTIC BAGS ARE GENERALLY FABRICATED FROM LDPE; PLASTIC SODA BOTTLES ARE GENERALLY FABRICATED FROM PET.

   a. High density polyethylene (HDPE).
   b. Low density polyethylene (LDPE).
   c. Polyethylene terephthalate (PET).
   d. Polystyrene.
   e. Other.
11. Gypsum.
12. Paint and paint cans.
13. Others as appropriate.

SPECIFIER NOTE: IDENTIFY LOCAL RECYCLING CENTERS AND WASTE HAULERS. SOURCES FOR THIS INFORMATION INCLUDE STATE SOLID WASTE OFFICES AND ENVIRONMENTAL PROTECTION AGENCY (EPA) REGIONAL OFFICES - WASTE MANAGEMENT DIVISION. LIST CENTERS THAT ACCEPT MATERIAL IDENTIFIED ABOVE FOR RECYCLING/REUSE. THE FOLLOWING IS AN EXAMPLE.

B. Recycling/Reuse Centers: The following is a partial list for Contractor's information only. For more information, contact the Integrated Solid Waste Management Office, City Hall.

SPECIFIER NOTE: FOR INFORMATION ON RECYCLING/REUSE OF ASPHALT, CONTACT THE ASPHALT RECYCLING AND RECLAIMING ASSOCIATION (410) 267-0023.

1. Asphalt:
2. Concrete:
3. Porcelain plumbing fixtures:
4. Metal:

SPECIFIER NOTE: OPTIONS FOR COMPANIES THAT ACCEPT WOOD WASTE INCLUDE WOOD RECYCLING INC. (800) 982-8732.

5. Wood, clean and mixed (nails and staples allowed):
6. Debris:
7. Glass:
8. Red clay brick:
9. Paper:

SPECIFIER NOTE: FOR INFORMATION ON RECYCLING/REUSE OF PLASTIC, CONTACT THE VINYL ENVIRONMENTAL RESOURCE CENTER OF THE VINYL INSTITUTE AT (800) 969-8469; THE ASSOCIATION OF FOAM PACKAGING RECYCLERS (202) 822-8424; AND, THE AMERICAN PLASTICS COUNCIL AT (800) 2-HELP-90.

10. Plastic:
11. Gypsum:

SPECIFIER NOTE: OPTIONS FOR COMPANIES THAT ACCEPT USED PAINT AND USED PAINT CANS FOR REUSE INCLUDE THE GREEN PAINT COMPANY (800) 527-8866 AND MAJOR PAINT CO. (310) 542-7701. GREEN PAINT HAS PROGRAMS TO ACCEPT USED PAINT FROM CONTRACTORS. MAJOR PAINT HAS PROGRAMS TO ACCEPT USED PAINT FROM PUBLIC AND PRIVATE AGENCIES (NOT CONTRACTORS). FOR MORE INFORMATION ON FACILITIES THAT ACCEPT USED STEEL CANS, CONTACT THE STEEL CAN RECYCLING INSTITUTE (SCRI) AT (800) YES-1-CAN/(800) 937-1226.

12. Paint and paint cans:

C. Handling:
1. Clean materials which are contaminated prior to placing in collection containers. Deliver materials free of dirt, adhesives, solvents, petroleum contamination, and other substances deleterious to recycling process.
2. Arrange for collection by or delivery to the appropriate recycling or reuse facility.

SPECIFIER NOTE: IDENTIFY LOCAL AND REGIONAL RE-USE PROGRAMS. ALSO, IDENTIFY NON-PROFIT ORGANIZATIONS SUCH AS SCHOOLS, LOCAL HOUSING AGENCIES, AND PUBLIC ARTS PROGRAMS, THAT ACCEPT USED MATERIALS. IDENTIFY SPONSOR AGENCY AND CONTACT FOR EACH PROGRAM. THE FOLLOWING ARE EXAMPLES.

D. Participate in Re-Use Programs:

SPECIFIER NOTE: FOR INFORMATION ON THE NATIONAL MATERIALS EXCHANGE NETWORK CONTACT THE PACIFIC MATERIALS EXCHANGE (509) 466-1532; MODEM ACCESS THROUGH (509) 466-1019/(800) 858-6625.

1. California Materials Exchange (CAL-MAX) Program sponsored by the California Integrated Waste Management Board.
   a. CAL-MAX is a free service provided by the California Integrated Waste Management Board, division of the California Environmental Protection Agency, designed to help businesses find markets for materials that traditionally would be discarded. The premise of the CAL-MAX Program is that material discarded by one business may be a resource for another business.
   b. To obtain a current Materials Listings Catalog, call CAL-MAX/California Integrated Waste Management Board. Contact ______________.
2. Materials For The Arts (MFA) sponsored by the Department of Cultural Affairs.
   a. MFA is a materials exchange that accepts waste and excess materials from private donors and distributes them to various non-profit art organizations throughout the City. Contact ______________.

SPECIFIER NOTE: FOR INFORMATION ON LOCAL ACTIVITIES OF HABITAT FOR HUMANITY, CONTACT THE NATIONAL HOTLINE (800) HABITAT.

3. Habitat for Humanity, a non-profit housing organization that rehabilitates and builds housing for low income families.
   a. Sites requiring donated materials vary. Contact ______________.

SPECIFIER NOTE: IDENTIFY RECIPIENT OF MONEYS RECOVERED FROM RE-USE AND REBATE PROGRAMS. IF MONEYS WILL NOT ACCRUE TO CONTRACTOR, EDIT BELOW.

E. Rebates, tax credits, and other savings obtained for recycled or re-used materials accrue to Contractor.

3.2 REBATE PROGRAMS

A. Execute final implementation of Rebate Programs. Obtain information packets from each sponsoring agency prior to starting Work. Document installation of products eligible for rebates under the following programs:

SPECIFIER NOTE: IDENTIFY PROGRAMS FROM UTILITIES AND GOVERNMENTAL AGENCIES UNDER WHICH PROJECT QUALIFIES FOR A REBATE. IDENTIFY CONTACT FOR EACH PROGRAM. THE FOLLOWING ARE EXAMPLES.

1. Energy Efficiency Incentive Program for Small and Medium Size Commercial and Industrial Customers: Sponsored by the Department of Water and Power (DWP). Contact ______________.
2. Commercial New Construction - Design Advantage: Sponsored by the Department of Water and Power (DWP). Contact ______________.
3. Commercial Energy Efficiency Program: Sponsored by ______________. Contact ______________.

SPECIFIER NOTE: COORDINATE ENVIRONMENTAL CONTROLS WITH SECTIONS 01500, CONSTRUCTION FACILITIES AND TEMPORARY CONTROLS; 01700, CONTRACT CLOSEOUT; 02070, SELECTIVE DEMOLITION; AND 02100; SITE PREPARATION FOR REQUIREMENTS FOR ENVIRONMENTAL PROTECTION, CLEANING, AND WASTE DISPOSAL. EDIT BELOW TO SUIT PROJECT.

3.3 ENVIRONMENTAL CONTROLS

A. Protection of natural resources: Preserve the natural resources within the Project boundaries and outside the limits of permanent Work performed under this Contract in their existing condition or restore to an equivalent or improved condition as approved by Owner, upon completion of the Work.
1. Confine demolition and construction activities to work area limits indicated on the Drawings.
   a. Temporary construction: As specified in Section 01500, Construction Facilities And Temporary Controls.
   b. Salvage operations: As specified in Section 02070, Selective Demolition.
   c. Disposal operations:
      1) Promptly and legally transport and dispose of removed and demolished items and waste materials that are not identified to be recycled or reused.
      2) Do not burn, bury, or otherwise dispose of rubbish and waste materials on project site.
2. Water resources: Comply with applicable regulations concerning the direct or indirect discharge of pollutants to the underground and natural waters.
   a. Oily substances: Prevent oily or other hazardous substances from entering the ground, drainage areas, or local bodies of water.
      1) Store and service construction equipment at areas designated for collection of oil wastes.
   b. Mosquito abatement: Prevent ponding of stagnant water conducive to mosquito breeding habitat.

SPECIFIER NOTE: COORDINATE BELOW WITH WORK SPECIFIED IN DIVISION 2, SITEWORK.

3. Land resources: Prior to construction, identify land resources to be preserved within the Work area. Do not remove, cut, deface, injure, or destroy land resources including trees, shrubs, vines, grasses, top soil, and land forms without permission from Owner.
   a. Earthwork: As specified in Section 02200, Earthwork and as follows:
      1) Erodible soils: Plan and conduct earthwork to minimize the duration of exposure of unprotected soils, except where the constructed feature obscures borrow areas, quarries, and waste material areas. Clear areas in reasonably sized increments only as needed to use the areas developed. Form earthwork to final grade as shown. Immediately protect side slopes and back slopes upon completion of rough grading.
      2) Erosion and sedimentation control devices: Construct or install temporary and permanent erosion and sedimentation control features as required.
   b. Tree and plant protection: As specified in Section 02100, Site Preparation.
4. Air Resources: Prevent creation of dust, air pollution, and odors.
   a. Use water sprinkling, temporary enclosures, and other appropriate methods to limit dust and dirt rising and scattering in air to lowest practical level.
      1) Do not use water when it may create hazardous or other adverse conditions such as flooding and pollution.
   b. Store volatile liquids, including fuels and solvents, in closed containers.
   c. Properly maintain equipment to reduce gaseous pollutant emissions.

SPECIFIER NOTE: COORDINATE BELOW WITH SECTIONS 01500, CONSTRUCTION FACILITIES AND TEMPORARY CONTROLS. EDIT BELOW TO SUIT PROJECT.

d. Temporary Ventilation: As specified in Section 01500, Construction Facilities And Temporary Controls, and as follows:

SPECIFIER NOTE: MOST OF THE EMISSIONS FROM WET PRODUCTS WILL OCCUR DURING THE FIRST FEW HOURS OR DAYS AFTER INSTALLATION; HOWEVER, MANY MATERIALS/PRODUCTS CONTINUE TO EMIT FOR WEEKS, MONTHS, AND YEARS. EMISSION RATES GENERALLY DECREASE OVER TIME.

1) Provide adequate ventilation during and after installation of interior wet products and interior final finishes.

SPECIFIER NOTE: PACKAGED DRY PRODUCTS FREQUENTLY PRODUCE A BURST OF EMISSIONS WHEN THEY ARE INITIALLY REMOVED FROM PACKAGING. THE INITIAL BURST IS SIGNIFICANTLY HIGHER THAN THE EMISSIONS A WEEK OR A MONTH LATER; FOR EXAMPLE, CARPET BACKED BY STYRENE BUTADIENE RUBBER LATEX (SBR) TENDS TO EMIT SIGNIFICANTLY HIGHER QUANTITIES OF 4-PHENYLCYCLOHEXENE (4-PC) DURING THE FIRST DAY THAN AT THE END OF A WEEK, BUT WILL CONTINUE TO EMIT AT LOW LEVELS FOR SEVERAL MONTHS. FOR MORE INFORMATION ON CARPET VENTILATION, CONTACT THE CONSUMER PRODUCT SAFETY COMMISSION AT (800) 638-2772, PRESS 1, PAUSE, PRESS 000, PAUSE, PRESS 129.

2) Provide adequate ventilation of packaged dry products prior to installation. Remove from packaging and ventilate in a secure, dry, well-ventilated space free from strong contaminant sources and residues. Provide a temperature range of 60 degrees F minimum to 90 degree F maximum continuously during the ventilation period. Do not ventilate within limits of Work unless otherwise approved by Architect.

SPECIFIER NOTE: COORDINATE BELOW WITH OWNER'S OCCUPANCY REQUIREMENTS AND WITH INDOOR AIR QUALITY IMPLICATIONS OF MATERIALS SPECIFIED FOR PROJECT. IN GENERAL, THE HIGHER THE VENTILATION RATE AND THE LONGER THE VENTILATION PERIOD AFTER INSTALLATION, THE LOWER THE RESIDUES WHEN THE SPACE IS OCCUPIED. HOWEVER, HIGH PERCENTAGES OF OUTSIDE AIR MAY NOT BE APPROPRIATE IN HUMID CLIMATES OR INDUSTRIAL AREAS.

WHERE OWNER REQUIRES AIR QUALITY MONITORING, CONFORM TO STANDARD TESTS AND PROCEDURES. THE EPA HAS PUBLISHED METHODS FOR AIR QUALITY MONITORING COVERING THE NAAQS CRITERIA POLLUTANTS AND A COMPENDIUM OF INDOOR AIR QUALITY SAMPLING AND ANALYTICAL METHODS. ADDITIONAL METHODS INCLUDE THE STANDARDS THAT HAVE BEEN ADOPTED BY ASTM OR NIOSH, ACCORDING TO THEIR AVAILABILITY AND APPLICABILITY.

WHERE CHAMBER TESTING IS REQUIRED, SPECIFY TESTING UNDER ASTM D5116 GUIDE FOR SMALL SCALE ENVIRONMENTAL CHAMBER DETERMINATION OF ORGANIC EMISSIONS FROM INDOOR MATERIALS/PRODUCTS.

3) Pre-occupancy ventilation: After final completion and prior to initial occupancy, provide adequate ventilation for minimum 5 days. Pre-occupancy ventilation procedures:

a) Use supply air fans and ducts only.
b) Temporarily seal exhaust ducts;
c) Temporarily disable exhaust fans;
d) Provide exhaust through operable windows or temporary openings.
e) Provide temporary exhaust fans as required to pull exhaust air from deep interior locations. Stair towers may be used for exhausting air from the building during the temporary ventilation.
f) After pre-occupancy ventilation and prior to final testing and balancing of HVAC system, replace air filters and make HVAC system fully operational.

5. Fish and Wildlife Resources: Manage and control construction activities to minimize interference with, disturbance of, and damage to fish and wildlife.
6. Noise Control: Perform demolition and construction operations to minimize noise. Perform noise producing work in less sensitive hours of the day or week as directed by Owner.
   a. Repetitive, high level impact noise will be permitted only between the hours of 8:00 a.m. and 6:00 p.m. Do not exceed the following dB limitations:

Sound Level in dB	Time Duration of Impact Noise
70	More than 12 minutes in any hour
80	More than 3 minutes in any hour

   b. Provide equipment, sound-deadening devices, and take noise abatement measures that are necessary for compliance.
   c. Maximum permissible construction equipment noise levels at 50 feet (dB):

EARTHMOVING	dB	MATERIALS HANDLING	dB
FRONT LOADERS	75	CONCRETE MIXERS	75
BACKHOES	75	CONCRETE PUMPS	75
DOZERS	75	CRANES	75
TRACTORS	75	DERRICKS IMPACT	75
SCRAPERS	80	PILE DRIVERS	95
GRADERS	75	JACK HAMMERS	75
TRUCKS	75	ROCK DRILLS	80
PAVERS, STATIONARY	80	PNEUMATIC TOOLS	80
PUMPS	75	SAWS	75
GENERATORS	75	VIBRATORS	75
COMPRESSORS	75		

   d. At least once every five successive working days while work is being performed above 55 dB noise level, measure sound level for noise exposure due to the construction.

END OF SECTION 01150

SPECIFIER NOTE: EDIT BELOW TO SUIT PROJECT.

Appendix A

SUMMARY OF SOLID WASTE DISPOSAL AND DIVERSION

Project Name: ____________ Project Number: ____________

Contractor Name: ____________ License Number: ____________

Address: ____________

Type of Material	Disposed in Municipal Solid Waste Landfill	Diverted from Landfill by Recycling/Reuse	Other
Asphalt			
Concrete			
Porcelain			
Ferrous metal			
Non-ferrous metal			
Wood			
Debris			
Glass			
Red clay brick			
Bond paper			
Newsprint			
Cardboard			
Plastic			
Gypsum			
Paint and paint cans			
Other:			

Signature: ____________ Date: ____________

Title: ____________

EXHIBIT 2: ENVIRONMENTAL SPECIFICATIONS FORMAT

BSW International One West Third Street, Tulsa, OK 74103-3505 (918) 582-8771 (918) 587-3594

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ENVIRONMENTAL SPECIFICATIONS FORMAT

SECTION 00000
TITLE

SPECIFIER NOTE: THIS DOCUMENT IS INTENDED TO BE A FORMAT GUIDE. LANGUAGE IS PRESENTED FOR EXAMPLE ONLY AND NO WARRANTY IS MADE AS TO COMPLETENESS OR ACCURACY OF INFORMATION CONTAINED HEREIN. VARIOUS TOPICS ARE INCLUDED TO PROVIDE A RANGE OF EXAMPLES. THESE TOPICS ARE *ITALICIZED* AND ONLY PERTAIN TO THEIR RESPECTIVE SPECIFICATIONS SECTIONS. TEXT AND SPECIFIER NOTES ADDRESS ENVIRONMENTAL ISSUES; OTHER SPECIFICATIONS ISSUES ARE NOT ADDRESSED.

PART 1 GENERAL

1.01 SUMMARY

A. Section includes:
1.
x. Environmental requirements for work of this section.

1.02 REFERENCES

SPECIFIER NOTE: STANDARDS ARE BEING DEVELOPED RAPIDLY BY MANY SEGMENTS OF THE BUILDING INDUSTRY TO SUPPORT MARKET DEMANDS FOR PRODUCTS AND SERVICES THAT ADDRESS ENVIRONMENTAL ISSUES. VERIFY CURRENT STANDARDS APPROPRIATE TO [TITLE OF SECTION]. THE FOLLOWING ARE EXAMPLES.

A. *American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE):*
1. *ASHRAE/IES 90.1: Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings.*

B. *American Society for Testing and Materials (ASTM):*
1. *ASTM C618: Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete.*
2. *ASTM D5116: Guide for Small Scale Environmental Chamber Determination of Organic Emissions from Indoor Materials/Products*

C. *Green Seal:*
1. *GS5: Environmental Standard for Compact Fluorescent Lamps.*
2. *GS6: Environmental Standard for Water Efficient Fixtures.*

D. *Rainforest Alliance:*
1. *Smart Woods Program.*

E. *Scientific Certification Systems (SCS):*
1. *Forest Conservation Program.*

1.03 SUBMITTALS

SPECIFIER NOTE: VERIFY GREEN SUBMITTAL REQUIREMENTS. FOR PROPRIETARY SPECIFICATIONS, SUBMITTAL OF MANUFACTURER'S PRODUCT DATA MAY NOT BE REQUIRED. VERIFY THAT REVIEWER HAS THE EXPERTISE REQUIRED TO ASSESS THE SUBMITTALS.

A. Submit manufacturer's product data, including:
1. *Emission data: Conduct materials testing according to the general guidelines of ASTM D5116.*
2. *Material Safety Data Sheets.*
3. *Recycled content data: Indicate percentage of pre-consumer and post-consumer recycled contents.*
4. *Energy performance data.*
5. *Corporate environmental statement of manufacturer.*
6. *Maintenance data.*

B. Submit certification evidencing compliance with requirements for:
1. *Sustainably harvested wood.*
2. *Low flow water fixtures.*

1.0X ENVIRONMENTAL REQUIREMENTS

SPECIFIER NOTE: SPECIFY GREEN QUALITY CONTROL REQUIREMENTS UNDER THIS PARAGRAPH. LOCATE PARAGRAPH 1.0X AT END OF PART 1. COORDINATE FORMAT WITH FORMAT OF ENVIRONMENTAL IMPACT QUESTIONNAIRE. COORDINATE REQUIREMENTS WITH MATERIALS SPECIFICATIONS UNDER PART 2; WHERE PRESCRIPTIVE SPECIFICATIONS ARE USED AND SUBSTITUTIONS ARE NOT ALLOWED, QUALITY CONTROL REQUIREMENTS UNDER THIS PARAGRAPH MAY BE REDUNDANT.

A. Resource Management:
1. Renewable Resources:
   a. *Wood: Provide products from sustainably harvested wood/sustainably managed forest as certified under the Rainforest Alliance Smart Woods Program or the SCS Forest Conservation Program.*
   b. *Water: Provide equipment that minimizes water usage.*
      1) *Water closets, lavatory faucets, and faucet aerators: Certified under GS 6.*
2. Managed Resources:
3. Recycled Content: *Provide [TITLE OF SECTION] manufactured from recycled materials.*
   a. *Pre-Consumer recycled content: Minimum __ percent of complete product.*
   b. *Post-Consumer recycled content: Minimum __ percent of complete product.*
   c. *Concrete: Type F or Type C fly ash in accordance with ASTM C618 may be used as a substitute for a maximum of 20% of portland cement.*
4. Reuse/Recyclability/Disposal: *Provide [TITLE OF SECTION] for which secondary markets or leasing programs exist.*

SPECIFIER NOTE: LEASING OPTIONS WITH A MANUFACTURER WHO COMMITS TO RECLAIM, REUSE AND RECYCLE PRODUCTS FURNISHED UNDER [TITLE OF SECTION] MAY BE NEGOTIABLE AS A SEPARATE CONTRACT BETWEEN OWNER AND MANUFACTURER. COORDINATE SEPARATE CONTRACT INFORMATION WITH SUMMARY OF WORK.

   a. *Carpet: Furnished and installed by manufacturer under separate contract. Coordinate installation with carpet manufacturer.*

EXHIBIT 2: ENVIRONMENTAL SPECIFICATIONS FORMAT (CONT.)

SPECIFIER NOTE: MANY ENVIRONMENTAL ISSUES, ESPECIALLY THOSE RELATED TO HAZARDOUS MATERIALS, ARE BEING ADDRESSED THROUGH LEGISLATION/REGULATION AS WELL AS THROUGH INDUSTRY STANDARDS. VERIFY APPLICABILITY OF LOCAL, STATE AND FEDERAL REGULATIONS TO PRODUCTS FURNISHED UNDER [TITLE OF SECTION].

B. Toxicity/Hazardous Materials:
   1. Toxic/Hazardous By-Products:
   2. Toxic/Hazardous Contents: Products containing carcinogens listed by any of the following will not be permitted.
      a. EPA-CAG list of carcinogens.
      b. Clean Air Act - Sections 109, 111, and 112.
      c. The National Toxicology Program's - latest published "Annual Report on Carcinogens".
      d. IARC - Human Carcinogens (Groups 1, 2A, and 2B).
   3. Outgassing/Reactivity:
      a. *Formaldehyde: Products containing urea-formaldehyde will not be permitted.*
      b. *Chlorofluorocarbons (CFC): Products and equipment requiring or using CFC during the manufacturing process will not be permitted. Products and equipment requiring or using CFC during normal operation will not be permitted.*
      c. *Volatile Organic Compounds (VOC):*
         1) *Paints, Coatings, Sealers: Comply with South Coast Air Quality Management District (SCAQMD) rules and regulations.*

C. Performance:
   1. Maintenance:
      a. Products that require toxic or hazardous materials for maintenance will not be permitted.
      b. Durability:
   2. Energy Efficiency: *Provide equipment that is energy efficient as demonstrated by comparative industry standards.*
      a. *Lamps and Ballasts:*
      b. *Compact Fluorescent Lamps: Certified under GS5.*
      c. *HVAC System: Minimum __ EER (energy efficiency rating) as referenced in ASHRAE 90.1.*
      d. *motors:*
      e. *appliances:*

D. Environmental Impact of Accessories:
   1. *Adhesives: Non-toxic, water based.*
   2. *Solvents:*
   3. *Concrete placement accessories:*
      a. *Formwork: Reuse forms to greatest extent possible without damaging structural integrity of concrete and without damaging aesthetics of exposed concrete.*
      b. *Mixing equipment: Return excess concrete to supplier; minimize water used to wash equipment.*
      c. *Moisture curing: Prevent water run-off.*

PART 2 PRODUCTS

SPECIFIER NOTE: INDICATE PERFORMANCE REQUIREMENTS OR IDENTIFY SPECIFIC MANUFACTURERS, MATERIALS, FINISHES AND FABRICATION REQUIREMENTS IN APPROPRIATE PART 2 PARAGRAPHS; BECAUSE NEW TECHNOLOGIES AND PRODUCTS MAY BE DIFFICULT TO LOCATE, CONSIDER IDENTIFYING CONTACT PERSON AND PHONE NUMBER FOR GREEN PRODUCTS.

PART 3 EXECUTION

3.0X ENVIRONMENTAL PROCEDURES

SPECIFIER NOTE: SPECIFY GREEN INSTALLATION REQUIREMENTS UNDER THIS PARAGRAPH. LOCATE PARAGRAPH 3.0X AT END OF PART 3.

A. Indoor Air Quality:
   1. Temporary ventilation: During and immediately after installation of products/materials that may negatively impact indoor air quality of completed Work, provide temporary ventilation as specified in Section 01150 - Environmental Procedures.
   2. Cleaning: Use non-toxic materials and procedures.

B. Construction Waste Management: As specified in Section 01150 - Environmental Procedures and as follows:
   1. Reuse of packaging by manufacturer:
   2. Reuse of scrap and waste materials by manufacturer:

END OF SECTION

EXHIBIT 3: ENVIRONMENTAL IMPACT QUESTIONNAIRE

BSW International One West Third Street, Tulsa, OK 74103-3505 (918) 582-8771/(918) 587-3584

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ENVIRONMENTAL IMPACT QUESTIONNAIRE (EIQ)

I. DIRECTIONS

A. Complete the following and submit for review to:

____

B. Relate information concerning only one product per questionnaire.

C. All questions may not apply to every product or manufacturer. It is not expected the manufacturer will have addressed all of the environmental concerns expressed in the EIQ.
1. Respond to every question even if response is "not available", "not applicable", or "no".
2. Attach additional sheets as required. Reference additional sheets to correspond with the question number.

II. IDENTIFICATION

A. Material/Product: ________________

Brand Name: ________________

Manufacturer: ________________

What is the primary use or application for this product? ________________

B. Contact for EIQ:

Name: ________ Title: ________

Address: ________ Zip Code: ________

Telephone: ________ FAX: ________ Date: ________

Environmental Impact Questionnaire Page 1 of 9

III. RESOURCE MANAGEMENT

A. Renewable Resources:
1. List renewable resources used as product raw materials. Provide percentage amounts in relation to complete (100 percent) product.

renewable resource	percentage

2. Does manufacturer obtain product raw materials or fabricate this product outside of the United States: ___Y ___N?
   a. If yes, are United States environmental standards or more strict standards followed in these countries: ___Y ___N?
   b. List countries involved.

____

B. Managed Resources:
1. Does extraction of product raw materials or fabrication of this product affect endangered specie(s): ___Y ___N?
   a. If yes, list species and describe effect, including mitigation methods for negative effects.

endangered species	effect

2. Products Containing Wood: Are wood materials obtained from certified sustainable forestry operations: ___Y ___N?
   a. If yes, provide name of certification organization for each wood species being used in this project.

species	certification organization

   b. If no, state where the product resources are produced and describe forestry operations.

product resources	forestry operations

Environmental Impact Questionnaire Page 2 of 9

EXHIBIT 3: ENVIRONMENTAL IMPACT QUESTIONNAIRE (CONT.)

C. Recycled Content:

1. List recycled materials used as product raw materials; distinguish pre-consumer and post-consumer materials. Provide percentage amounts in relation to complete (100 percent) product.

recycled material	*% pre-consumer*	*% post-consumer*

D. Embodied Energy:

1. Product Transport:

a. Where are raw materials acquired? Identify state and country.

raw material	*source (state and country)*

b. Describe means of transporting raw materials to the manufacturing plant.

raw material	*transportation*

c. Where is product manufactured/fabricated? Identify state and country.

d. Is the product warehoused locally, regionally, or nationally? ______

e. Describe means of transporting product to distribution facilities.

2. Production Energy: List energy sources used in production process; indicate which are renewable energy sources (e.g. wind, solar). Provide percentage amounts in relation to complete (100 percent) product.

energy sources	*renewable*	*percentage*
	__Y __N	
	__Y __N	
	__Y __N	

3. Provide an embodied energy study of the product from extraction of raw materials through production and assembly. Include an estimate for the total number of BTU's required per pound of finished products. Identify parameters for study.

4. Describe measures the manufacturer has taken to minimize energy usage in the production process.

E. Reuse/Recyclability/Disposal

1. Reuse:

a. Can product be reused directly (in same or similar use): ___Y ___N?

b. If yes, discuss possibility of direct reuse of the product after project demolition.

2. Recycling:

a. Can product be recycled: ___Y ___N?

b. If yes, list the parts of the product which can be post-consumer recycled into raw materials for the product and the parts which can be post-consumer recycled into other types of items. Provide percentage amounts in relation to complete (100 percent) product.

post-consumer - raw	*post-consumer - other*	*percentage*

c. If yes, describe the process of separation of the parts for post-consumer recycling from the product.

d. If yes, list current markets using recycled materials from the product.

e. If yes, estimate the practical number of times this item can be recycled.

3. Describe the manufacturer's policy and program to facilitate the recycling or reuse of its product by accepting product returns at the end of their "useful life".

EXHIBIT 3: ENVIRONMENTAL IMPACT QUESTIONNAIRE (CONT.)

IV. TOXICITY/HAZARDOUS MATERIALS

A. Toxic/Hazardous By-Products :

1. List the production wastes involved with the manufacture of this item. Distinguish the production wastes between toxic and non-toxic. Provide percentage amounts in relation to complete (100 percent) product.

toxic	non-toxic	percentage

2. Estimate the quantity of production waste produced per unit of finished product.

3. Is reclamation of production waste done on site. ___Y ___N? with outside services: ___Y ___N?
   a. If outside services are used, list companies involved.

4. Is waste water reclaimed by manufacturer. ___Y ___N?
   a. If yes, describe process of recycling/reuse of waste water.

5. Describe the manufacturer's active steps to minimize or eliminate production wastes; include process of liquid and solid waste material treatment or reclamation if performed at manufacturing site.

6. Describe the manufacturing procedures and chemicals involved that would be considered better than industry standard.

B. Toxic/Hazardous Contents (carcinogens and other hazards inherent in product/material):

1. Provide a complete chemical profile of the item; include all chemical components and provide percentage amounts in relation to complete (100 percent) product; identify biocides (mildewcides or in-can preservatives) and carcinogens listed by any of the following:
   a. United State Environmental Protection Agency (EPA) Carcinogen Assessment Group (CAG) list of carcinogens.
   b. Clean Air Act Sections 109, 111, and 112.
   c. The National Toxicology Program's latest published "Annual Report on Carcinogens".
   d. IARC Human Carcinogens (Groups 1, 2A, and 2B).
   e. California Proposition 65

chemical	carcinogen	percentage
	__Y __N	
	__Y __N	
	__Y __N	
	__Y __N	
	__Y __N	

C. Material Safety Data Sheet (MSDS):

1. Provide Material Safety Data Sheet (MSDS).
   a. Articles: Finished products which are manufactured off-site and shipped to the project for installation while conforming to Title 29 of the Code of Federal Regulations, OSHA Hazard Communication Regulation 29CRF 1910.1200, Section (b)6 and Section (c) are defined as articles. If by being defined as an article, a MSDS has not been developed for a particular product, then provide MSDS on raw materials, goods, and items used in the fabrication of that article.

D. Outgassing/Reactivity:

1. Chlorofluorocarbon (CFC):
   a. Are CFC's or HCFC's used in the manufacture and/or content of the item specified: ___Y ___N?
   b. If CFC's or HCFC's were previously used in the product and/or its manufacture, describe measures taken by manufacturer to eliminate their use.

2. Indoor Air Quality:
   a. Does the product outgas (emit) carcinogens or other hazardous substances into the air after installation, including final curing/drying: ___Y ___N?
   b. If yes, submit IAQ test report.

E. Electromagnetic Radiation:

1. Does the product emit electromagnetic radiation ___Y ___N?
2. If yes, at what rate per hour? ________________
3. If yes, describe methods for installation, use, and maintenance of product to minimize generation of and occupant exposure to electromagnetic radiation.

EXHIBIT 3: ENVIRONMENTAL IMPACT QUESTIONNAIRE (CONT.)

F. Compliance with Regulations (Environmental Statutory Compliance):
1. Does the manufacturer meet all federal, state, and local environmental laws, including laws governing air emissions, waste water treatment, and solid waste disposal/treatment: ____Y ____N?
2. Has the manufacturer met the above criteria for the previous five years: ____Y ____N?
3. List these applicable standards.

____

____

____

____

4. Does the product meet applicable industry standards, such as ASTM, Green Seal, manufacturing standards, LA or NY research report numbers, and UL approvals: ____Y ____N? List these standards.____________________

____

____

____

V. INSTALLATION

A. Environmental Procedures/Precautions:
1. Describe special procedures and precautions to be used while handling and installing the product:

____

____

____

____

2. Identify accessories, such as fasteners, sealers, and adhesives that are non-toxic (or less toxic than industry standard), energy efficient, or recycled or recyclable products?

____

____

____

____

B. Installation Energy:
1. Product Transport: List the means to transport the finished product to the construction site.

____

____

2. Installation: List energy means and describe energy requirements for installation of the product.

____

____

C. Construction Waste :
1. List the recommended method(s) for proper products disposal; stipulate preferred method and restrictions which might apply.

____

____

____

____

2. Comment on the environmental impact of the product as a waste material.

____

____

____

3. Packaging:
a. Describe packaging for the product.

____

____

____

b. Does manufacturer accept return of used packaging for reuse: ____Y ____N?
c. If yes, state limitations and procedures for packaging return.

____

____

____

VI. PERFORMANCE

A. Maintenance
1. Describe the recommended cleaning and maintenance procedures for the product using products which have minimal VOC emission.

____

____

____

2. Estimate the "useful life" expectancy for this product.

____

3. Are replacement parts available: ____Y ____N?
a. If yes, Can replacement parts be installed in the field: ____Y ____N?
4. Provide a copy of the life cycle analyse for this product.
5. Provide a copy of the manufacturer's warranty for this product.

B. Energy Efficiency (energy required to operate/maintain):
1. Estimate BTUs required to operate the product when new? ______________; after five years? ______________; after ten years? ______________

EXHIBIT 3: ENVIRONMENTAL IMPACT QUESTIONNAIRE (CONT.)

C. Compliance with Regulations (Environmental Statutory Compliance):

1. Does the product meet all federal, state, and local environmental laws, including laws governing energy efficiency and air emissions: ____Y ____N?
2. Has the product met the above criteria for the previous five years: ____Y ____N?
3. List these applicable standards.

____

VII. CORPORATE COMMITMENT

A. Corporate Environmental Policy:

1. Provide copy of manufacturer's stated environmental policies.

END OF ENVIRONMENTAL IMPACT QUESTIONNAIRE

EXHIBIT 4: INDOOR AIR QUALITY EMISSION TEST REPORT

BSW International One West Third Street, Tulsa, OK 74103-3505 (918) 582-8771/(918) 587-3504

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INDOOR AIR QUALITY EMISSION TEST REPORT

I. DIRECTIONS

A. Complete the following and submit for review to:

B. Relate information concerning only one product, material, or accessory item per test report.

C. It is not expected the manufacturer will have addressed all of the environmental concerns expressed in the Indoor Air Quality Emission Test Report.
1. Respond to every question even if response is "not available", "not applicable", or "no".
2. Attach additional sheets as required. Reference additional sheets to correspond with the question number.

II. IDENTIFICATION

A. Material/Product: ________
Brand Name: ________
Manufacturer: ________
What is the primary use or application for this product? ________

B. Testing Laboratory:
Name: ________
Phone number: ________
Address: ________
Contact person: ________

Indoor Air Quality Emission Test Report — Page 1 of 4

III. TEST PARAMETERS AND PROCEDURES

A. Test Objectives: Describe the purpose of the testing and the intended use of the results:

B. Facilities and Equipment:
1. Describe the facilities and equipment; indicate sensitivity of the analytical system.

C. Experimental Design:
1. Describe test conditions including temperature, humidity, air exchange rate, and test materials loading.
temperature: ________
humidity: ________
air exchange rate: ________
test materials loading: ________
general test conditions: ________

D. Sample Description:
1. Describe the sample(s) tested including the type of material(s) or product(s), brand name or other identification as appropriate, size or quantity tested, and sample selection process (e.g. random).
material/product: ________
brand name: ________
manufacturer: ________
size/quantity: ________
sample selection process: ________

2. For wet samples or samples applied to a substrate, describe the substrate and methods to attach the sample to the substrate and to seal the sample edges.
substrate: ________
attachment methods: ________
sealing methods: ________

Indoor Air Quality Emission Test Report — Page 2 of 4

EXHIBIT 4: INDOOR AIR QUALITY EMISSION TEST REPORT (CONT.)

E. Experimental Procedures: Describe the experimental procedures used during testing including details of the sampling and analysis techniques.

1. Identify date(s) of testing: ______
2. Identify duration of exposure: ______
3. Were standardized test procedures such as ASTM D5116, *Guide for Small Scale Environmental Chamber Determination of Organic Emissions from Indoor Materials/Products*, used: ____Y ____N?
   a. If yes, cite standards: ______
   b. If no, describe the experimental procedures used during testing and analysis: ______

IV. TEST RESULTS

A. Data Analysis: Describe the accuracy of the test results.

B. Discussion and Conclusions:
1. Discuss the relevance of the findings and provide conclusions. For example, describe the effect of temperature and/or air exchange rate on emission factors. Note any anomalies and describe data treatment to address such data.

2. List all substances identified in a sample of the air emitted from product; indicate amounts detected in parts per million (ppm); identify carcinogens that appear on any of the following lists:
   a. United State Environmental Protection Agency (EPA) Carcinogen Assessment Group (CAG) list of carcinogens.
   b. Clean Air Act Sections 109, 111, and 112.
   c. The National Toxicology Program's latest published "Annual Report on Carcinogens".
   d. IARC Human Carcinogens (Groups 1, 2A, and 2B)
   e. California Proposition 65.

substance	carcinogen	ppm
	__Y __N	
	__Y __N	
	__Y __N	
	__Y __N	
	__Y __N	
	__Y __N	
	__Y __N	

3. Provide instructions, requirements, or recommendations on minimizing the impact of emissions from the products on workers installing the items and on indoor air quality in the completed building. Include information on original installation of the item, maintenance, and eventual removal from the facility.

installation: ______

maintenance: ______

removal/disposal: ______

C. Other reports: If other reports and evaluations have been performed for the product, submit copies.

END OF INDOOR AIR QUALITY EMISSION TEST REPORT

SECTION D

Local Government

There are numerous examples of local government actions to integrate passive solar design, energy-efficient building systems, and environmentally sound materials into new building construction and renovations. These opportunities yield positive financial benefits to local governments through lower operating costs and can enhance community perception of the effective management of financial and environmental resources by public officials. Chapter 18 provides examples of local government initiatives in the area of building design.

CHAPTER 18

Local Government Information: Building Design

Passive Solar Design

Author
Michael Myers

IMPLEMENTATION ISSUES

Passive solar design is based on optimizing the "whole-building" concept by integrating site conditions, building materials, and mechanical equipment. Local governments around the country are building facilities that integrate these factors while meeting functional requirements, operating cost-effectively, and providing occupants an improved work environment.

When municipal project managers are informed about and understand the benefits of passive solar design principles, it enhances the design team's efforts to utilize these principles in local government construction projects. In addition, the cooperation of local government departments in addressing siting issues for optimum solar access or other potential policy or regulatory issues will help ensure success.

A local government's adoption of life-cycle cost analysis for construction projects will also help the design team convey the benefits of design and material innovations that may be necessary to gain long-term energy cost savings and potential gains in occupant satisfaction and productivity.

LOCAL ACTIONS

➤ Valmeyer, Illinois, and Pattonsburg, Missouri, two Midwestern towns that are rebuilding after major floods in August, 1993, have embraced passive solar design concepts for residential and municipal buildings. Through a state and federal educational effort, local residents in Valmeyer learned about the value of this approach. The state Department of Energy and Natural Resources provided design assistance to residents to implement super insulation and passive solar features with high-efficiency heating and cooling systems. As a result, 40 percent of Valmeyer's new homes are being built to stringent standards and are predicted to have annual heating bills of less than $200. Valmeyer's municipal/emergency services building is a model passive solar building, designated as an Exemplary Building by the U.S. Department of Energy (DOE). A downtown senior center and multifamily complex are both passive solar and super-insulated. In Pattonsburg, a passive solar land-use plan was developed. A village center there has also been designated as a DOE Exemplary Building project, and residents are learning about the energy-efficiency potential of passive solar structures as they select home designs.

➤ San Jose, California, has taken steps to encourage the use of solar systems in buildings by protecting solar access for new housing. At the direction of the City Council, the Environmental Services Department researched the costs and benefits of adopting solar access guidelines and found that such a move would result in significant energy savings and reduced carbon dioxide emissions. The City Council adopted solar access guidelines in December 1992. Since the guidelines are voluntary, the city provides workshops for architects, builders, developers, and city staff to encourage their use in building design and siting. With implementation of this measure, the city hopes to boost the local economy through increased local business activity and lower energy bills, bringing more profits and disposable income to the area.

➤ St. Mary's Parish School in Alexandria, Virginia, built a 9,000 square foot gymnasium/auditorium using several passive solar design features, including a 22-foot-high Trombe wall that stores the sun's heat. Daylight enters the structure through a pair of roof monitors—openings fitted with translucent insulating panels. Ventilation is provided by operable windows and four roof fans that circulate heat stored in the floor and walls. The facility uses only about one-third of the energy consumed by a typical school gymnasium.

➤ The roof monitor system at Abrams Elementary School in Bessemer, Alabama, cuts down on the school's lighting energy needs by admitting glare-free, diffuse light. Beneath each roof opening are water-filled pipes that also serve as baffles to intercept and diffuse the light as it enters each of 20 hexagonal classrooms. Overheating is minimized because heat remains at the top of the roof monitors. Fluorescent lights used for backup are equipped with light-level controls to reduce energy consumption. Other energy conservation features at the school include the use of thermal mass in the walls and floors to store heat and minimize temperature fluctuations, a well-insulated roof, and a minimum amount of vertical glazing to prevent unwanted heat gain or loss.

➤ The Portland, Oregon, Bureau of Environmental Services' new Water Pollution Control Laboratory is designed to integrate passive solar features—including site orientation, daylighting, energy efficiency, and building overhangs for shading—into a high-quality building environment. The complex contains diverse use areas, including an office complex, a laboratory complex and a field-operations complex, that require distinct applications. For example, heat exchangers are being evaluated for use in the laboratory areas due to the large volume of ventilation required.

➤ Jordan Commons is a Habitat for Humanity project being built in Metro-Dade County, Florida, to provide for the development of affordable homes, community buildings, and parks. The designers have worked with county officials to develop a site plan, obtain proper zoning and identify highly energy-efficient plans, using a range of techniques to reduce cooling and other energy costs. Houses are designed for maximum cross-ventilation and feature ceiling fans, reflective window tints, and extended overhangs. Trees will be strategically planted for shade, and white reflective roofs and walls will reduce heating load. Homes will be fitted with energy-efficient appliances (such as air conditioners), solar water heaters, and photovoltaic lighting.

LOCAL OPTIONS

- Educate municipal and private building owners about the cost and comfort benefits of passive solar design.
- Ensure that design team members are knowledgeable about passive solar principles and computer design tools.
- Develop passive solar guidelines for building design that include updated ordinances, codes, and policies to remove barriers to passive solar design and protect solar access.

Building Systems

IMPLEMENTATION ISSUES

Energy efficiency is related to whole-building performance and depends on the efficient design and operation of integrated systems in keeping with the specific function of the building. Building system components include the building envelope, heating and air conditioning, lighting, plumbing, and ventilation. These are affected by the operational requirements of the occupants. A lighting system that employs energy-efficient lighting designs is ineffective if it does not meet the needs of occupants.

Local governments can take advantage of cost-effective, energy-efficient systems and lighting by specifying them in plans for new buildings or renovation of existing buildings. Public awareness about resource-efficient technologies for commercial and residential building can be increased when localities join with utility companies and state and federal entities to provide educational opportunities or incentive programs in the community. Some local governments have passed ordinances or guidelines to require increased energy efficiency in municipal, commercial, or residential buildings.

LOCAL ACTIONS

➤ The county of Santa Barbara, California, has established a voluntary program to promote energy-efficient building design by creating a Building Review Committee that can provide assistance on cost-effective design methods that exceed California energy standards by 15 percent or more for residential buildings and 25 percent or more for commercial developments.

➤ In 1981, San Francisco, California, adopted the *Residential Energy Conservation Ordinance* (RECO), which has reduced by 15 percent the amount of energy used by average homes in the city. RECO may be triggered during the sale of a home or when major improvements are implemented. RECO requires the installation of energy-saving measures followed by a compliance inspection to ensure that the work was completed.

➤ Montgomery County, Maryland, enacted a set of energy-design guidelines that have been in use since 1989 and have resulted in up to 50 percent lower energy consumption in new and retrofitted government buildings without an increase in initial construction costs. These comprehensive technical and procedural guidelines, designed to exceed existing codes and standards, were developed through life-cycle cost analysis techniques. They include the use of high-efficiency lighting systems, control of building energy use through integrated electronic energy-management systems, variable-frequency drives to reduce air-handler fan speed, high-performance glazing systems, and innovative devices such as ice-storage systems instead of conventional cooling systems. The guidelines are accompanied by a "Design Contract Package" that includes sample request-for-proposal forms, contract clauses, scope-of-services documents, and an energy report format to aid county departments in implementing the guidelines.

➤ Houston, Texas, established a building utility use procedure in 1983 for municipal building operators to reduce energy consumption and utility costs without adversely affecting employee productivity or comfort. The procedure includes development of an operations plan for energy management and addresses heating and cooling, ventilation, lighting, domestic hot water, and general maintenance. In the 1990s, the city made a continuing commitment to effective energy management through its involvement with the Green Lights and Energy Star programs, EPA initiatives designed to provide technical assistance to public and private partners interested in upgrading the efficiency of lighting and building systems. The city pioneered the use of private sector energy-performance contracts to upgrade energy systems in public facilities and has established its own Green Lights Revolving Fund to recapture energy savings without the use of private performance contracts. The city is also working with the local electric utility on a number of facility-based demand-side reduction projects, including power factor correction, cool storage, and cost savings from interruptable rates.

- The Maryland Department of Education and the Maryland Public School Construction Program have a variety of initiatives and policies related to energy and environmental impacts of school construction and operation. To manage energy consumption at schools, the state requires monitoring and annual reporting of usage. Energy targets have been established for new and renovated schools, with new-school energy goals of no more than 45,000 Btu per gross square foot per year for a typical operating schedule. The actual energy performance of finished schools is used as a factor in selecting architects for subsequent projects. For new construction or renovation, designs must incorporate life-cycle cost analysis for mechanical and other systems and must employ energy-efficient lighting and integrate daylighting where possible. Designers are also encouraged to follow the indoor air quality guidelines developed by the Department of Education School Facilities Branch. These guidelines also address acoustics for classroom settings and suggest sound-attenuating techniques or internal duct lining, where necessary. In addition, they recommend a comprehensive commissioning of the heating, ventilating, and air-conditioning (HVAC) system to balance components, ensure projected performance levels and train operating personnel.

- The Clark County, Nevada, Government Center was carefully planned and built to minimize impact on the environment and the use of non-renewable resources. The building was designed for maximum energy efficiency with six-inch fiberglass insulation, a tapered and insulated roof, and dual-pane windows with high reflective value. This reduces the amount of heat gain and loss and requires less space conditioning in summer and winter. Heating and cooling needs are met through the use of high efficiency equipment. Cooling is obtained through a variable-speed chiller that tailors the chilled water supply to the immediate level of demand.

  Out of concern for employees and the general public, the designers of the Clark County, Nevada, Government Center paid a great deal of attention to indoor air quality (IAQ). The architect specified materials (such as carpet, carpet glue, paint, sealants, adhesives, and modular furniture) with very low emission levels. This is expected to improve indoor air quality and reduce the amount of outside air required for ventilation —thereby lowering requirements for conditioning the air and reducing building energy usage. The county government is gathering data to measure the actual dollar savings and energy efficiencies achieved through the incorporation of these design features.

- The new San Francisco, California, main library, completed in early 1996, is a large public project where indoor air quality was a major design criterion. The building manager and staff worked with the design team, which included the architects and engineers, as well as an IAQ specialist, to design an environment that promotes health, increases productivity, and reduces potential liability. Items identified as needing special focus included the HVAC system, the use of particle board, the potential for microbial growth, and the choice of carpet, adhesives, paints, furniture, and copy machines. Steps were taken during design, construction, and material selection to minimize problems. The team worked closely with the construction contractor to review the IAQ concepts and priorities. Commissioning procedures were instituted for the system, and a scheduled maintenance plan for the building was recommended.

- The state of Washington Department of General Administration, which plans and manages state facilities, developed strict design requirements in 1990 aimed at averting building-caused health problems. The requirements for new state government office buildings were developed to supplement existing IAQ standards that addressed only industrial work areas. Requirements include a 90-day flushing-out period to help rid buildings of potentially harmful products, careful selection of non-toxic carpets and furniture, placement of copy machines in well-ventilated rooms, designs to provide greatest access to daylight, a smoking ban, and increased outside-air requirements for ventilation systems. In addition, the department stresses the importance of good operations and maintenance practices for HVAC systems as well as educating and training staff in state-owned and managed facilities to recognize, report and track IAQ problems.

LOCAL OPTIONS

- Adopt local guidelines, standards, or codes for energy efficiency and indoor air quality in new construction or building retrofits.
- Involve local building, architectural, neighborhood, and utility representatives in developing energy-efficiency goals for the community.
- Develop building-design guidelines and specifications that include high standards for energy efficiency and indoor air quality for municipal buildings.
- Institute life-cycle cost analysis for local government construction projects.
- Designate or create a lead office to monitor and oversee municipal energy consumption.
- Promote whole-building design and performance training in the local community through partnerships with building diagnostic and heating and air-conditioning contractors, green building associations, utilities architects, and builders.

Building Products

IMPLEMENTATION ISSUES

An increasing number of architects, engineers, builders, contractors, local community associations, and local governments are seeking techniques and materials that improve the built environment, reduce impact on the natural environment, and improve local quality of life. Building green can promote energy and water efficiency, encourage recycling and use of recycled-content products, add to the local economy, and protect the natural resources. Education, training, and creating a sustainable marketplace in the community are vital in developing and utilizing green materials and products.

Many opportunities to use green building materials and products exist in today's marketplace. Local governments can take the lead in identifying these opportunities, utilizing green products, and promoting local entrepreneurship.

LOCAL ACTIONS

➤ Fort Collins, Colorado, and the cities of Crowley and Austin, Texas, no longer allow municipal projects to use cement produced in kilns that burn hazardous waste. Austin, however, promotes the use of cement that contains coal ash from power-generating facilities for construction of municipal projects.

➤ Some local governments have banned the use of tropical woods or have developed voluntary guidelines for avoiding their use. They include Austin, Texas; Harrisburg, Pennsylvania; Santa Monica and San Francisco, California; and Key West, Florida. Howard County, Maryland, has prepared a list of prohibited tropical woods for architects and builders.

➤ In Metro-Dade County, Florida, bid documents for county projects encourage bidders and product manufacturers to use environmentally safe materials, manufacturing processes, and installation methods when providing goods and services. This includes products that are made from recycled materials or are recyclable, have reduced levels of volatile organic compounds (VOCs), or need fewer wet adhesives for installation. Bidders are encouraged to offer removal and recycling of existing carpet as part of their bid response. The request for proposals for the development of the Miami International Airport required bidders to indicate products with Green Label certification as part of the bid submittal.

➤ The Maryland Department of Education has published an overview of green design principles, *Building Ecology and School Design*, a technical bulletin for use by facility planners and architects in the state's public school system when making product and material choices for construction. The bulletin promotes the use of environmental life-cycle assessment and provides a decision-making model to assist in this process. Application of these concepts is illustrated through a detailed examination of options for flooring, including vinyl-composition tile, linoleum, carpet, terrazzo, wood, and ceramic tile, and their associated impacts.

➤ As part of its *Sustainable Building Guidelines*, Austin, Texas, prepared a sample material-selection matrix for architects and builders to assist in the selection of building products. The matrix incorporates conventional selection criteria, such as availability, certification, and cost-effectiveness, with weighted sustainability criteria, such as life-cycle qualities, regional impacts, post-consumer recycled content, indoor air effects, durability, and cost. The guidelines also provide information on locating material manufacturers and suppliers, with an emphasis on regional sources.

➤ In metropolitan Portland, Oregon, the Solid Waste Department of Metro (the directly elected regional government), has published a *Guide to Recycled Products for the Building and Construction Industry*. The guide is organized using Masterformat, the construction industry's standard order format, developed by the Construction Specifications Institute.

➤ A *Sustainable Design Resource Guide* was developed in 1994 by the Denver, Colorado, chapter of the American Institute of Architects Committee on the Environment and the Colorado chapter of Architects, Designers, and Planners for Social Responsibility. The guide, developed for Colorado and the Western Mountain Region, identifies local and regional product sources. Its purpose is to benefit the regional economy, reduce transportation pollution, encourage local environmental businesses, and stimulate awareness and control of local resources. Users are asked to first consider whether the material is needed, and then to analyze function, environmental impact, health considerations, aesthetics, cost, and operations and maintenance factors when considering options. The guide lists regional construction and demolition waste recyclers along with suppliers and manufacturers of resource-conserving or recycled-content materials and building products.

LOCAL OPTIONS

- Establish an advisory group of local architects, builders, product suppliers, waste haulers, and government representatives to research and establish recommendations for green materials and resources for the region.
- Set aside a percentage of the design and construction budget of local government projects for alternative/green materials.
- Establish an environmental purchasing policy that includes life-cycle cost analysis; promotes the use of post-consumer recycled, energy-efficient, and water-conserving products; and promotes the use of local/regional goods and services.

➜ RESOURCES

Resources for the Local Government Information chapters are located in the Appendix.

PART V

The Construction Process

Introduction

This section of the manual highlights specific guidelines for the management of site issues, indoor air quality (IAQ), source control practices, and resources during the construction process. Although construction design documents typically define the responsibilities of a contractor during the construction process, they mainly focus on the design elements that compose the finished product. Rarely do they set environmental guidelines to be followed during the construction phase. Therefore, the design team should work with a construction professional to ensure the adoption of guidelines for this aspect of the project. Typically, these guidelines will appear in a construction contract with specifications that spell out requirements for their implementation (see Chapter 17, “Specifications”).

Many of the guidelines and practices identified in this section should be considered in conjunction with the strategies addressed in other sections of the manual; for example, guidelines for indoor air quality in construction should be coordinated with those for environmentally sound materials selection and ventilation-system design. The integration of such guidelines across the design, development, operations, and maintenance of a building is critical to their successful application.

CHAPTER 19

Environmental Construction Guidelines

Author
Gerard Heiber

General Considerations

★ SIGNIFICANCE

The construction process can have a significant impact on environmental resources. Environmentally conscious construction practices can markedly reduce site disturbance, the quantity of waste sent to landfills, and the use of natural resources during construction. It can also minimize the prospect of adverse indoor air quality in the finished building. In addition to yielding environmental benefits, all of these actions can lower project costs.

In many cases, construction clears and disturbs the site's existing natural resources—native vegetation and wildlife, natural drainage systems, and other natural features—and replaces them with artificial systems such as non-native vegetation and artificial drainage. Waste generated from construction and demolition accounts for about 28 percent of landfill volume. Emissions from new construction materials as well as dust, particulates, and other airborne contaminants generated during the construction process are suspected of causing health problems. In addition, most construction projects today require the use of new virgin materials (adding to the depletion of limited natural raw materials if such materials are not renewable), even when recycled-content, reused, or refurbished materials are sufficient for the intended purpose.

When approaching construction from a sustainable perspective, a builder should ensure that the construction contract and specifications address the design and construction teams' environmental requirements for the construction process. Many of these issues and practices are typically under the direct control of the construction contractor, who was most likely selected by competitive bid.

The construction professional's responsibility is to fulfill the project objectives in accordance with the construction contract, construction drawings and specifications, project schedule, and project budget. The contractor's goal is to build the project for the lowest cost, within the tightest time-frame, and at the highest profit. The contractor is not likely to implement environmental practices unless they involve almost no additional cost, have been required contractually, or are economically beneficial to the contractor.

Teamwork is the key ingredient in a successful construction project. Together, a building's owner, architect, engineers, and contractor should develop guidelines, plans, goals, and practices for the construction process. The joint approach will ensure that the contractor understands—and embraces—a project's general and environmental goals and specifications before the work begins.

☞ SUGGESTED PRACTICES AND CHECKLIST

❑ **The design team can establish and enforce environmental guidelines for construction by doing the following:**
- Incorporating such guidelines into the construction drawings and specifications and monitoring the contractor's compliance during construction.
- Incorporating environmental responsibilities into the construction contract and monitoring the contractor's specific compliance during construction.
- Indicating, in the above guidelines or statements of responsibility, practices required by local, state, or federal environmental regulation.

❑ **In some cases, contractors may need education about environmentally preferable practices in order to take advantage of them.**
The design team can help the contractor understand that an environmentally preferable process can be more economical than—or equivalent in cost to—a conventional one, and can be implemented without a regulatory or contractual requirement.

Site Issues

★ SIGNIFICANCE

The construction process can cause a significant amount of site disturbance. To minimize such disturbance and maximize the use of site resources, a project team should recognize a site's existing natural, cultural, and constructed features and preserve those features through sound design, construction, and management practices (see also Chapter 5, "Sustainable Site Design").

Despite their up-front expense, practices that plan and control site access—and promote efficient and environmentally sensitive use of site features—often translate into cost savings to the contractor, including lowered site-restoration costs after completion of work. For example, preservation of existing trees or geological features in the site design and construction can lessen the need for replanting and other landscaping to achieve shading or privacy goals.

Bear in mind, however, that opportunities to reduce site impacts and tap existing natural resources through environmentally sensitive design vary widely among urban, suburban, and rural sites. Urban sites typically have more design constraints. Rural sites, usually much larger than their urban counterparts, present more opportunities for environmental disturbance—along with more options for resource utilization.

☞ SUGGESTED PRACTICES AND CHECKLIST

❑ **The owner, design team, and contractor should develop, collectively, a staging plan for the project.**

The goal of this plan is to balance the contractor's desire to build cost-effectively with the owner's long-term need to protect valuable site resources and amenities. In many cases, it is in the contractor's best interest to take actions that curb construction's impact on a site, because such actions can sharply reduce site-restoration costs after project completion.

❑ **Develop specific site-protection requirements that the contractor should follow, and require the contractor to submit plans for meeting them.**

Include specific language in the contract and construction documents that tells the contractor how to meet requirements, and develop monitoring and verification criteria.

– Specify requirements for site utilization. Site-utilization specifications ensure a clear understanding of which areas of a site are to be used, and of how the site will be managed. Often, contractors do not tightly control site utilization by subcontractors and workers, so the site is used on a first-come, first-served basis. Such lax site management tends to cause unnecessary site disturbance and discourage efficient use of existing site resources for construction purposes. It requires the constant movement of materials and equipment to allow completion of work. The more often material and equipment are moved, the higher the risk of damage, to both the transferred items and the site itself.

  Typically, site utilization specifications require a contractor to address the following issues:

  a. Where contractors and trades will locate their trailers;
  b. Which areas of the site will be protected, and which areas used for storage and staging;
  c. How waste will be handled and removed; and
  d. How the site will be isolated from public entry.

– Designate specific vegetation for protection throughout the construction process. Specifications must indicate not only the types and locations of vegetation to be protected, but also the methodology for protection.

– Specify requirements for site access. Issues to consider include:

  a. Access requirements of the different trades, for deliveries, installation, and other needs;
  b. How workers access the site and enter the building during the construction process;
  c. How access will change over the course of construction; and
  d. Vehicle-parking accommodations available to workers.

– Specify requirements for site clearing and grading. Issues to consider include:

  a. How the site is to be cleared and graded;
  b. The environmental impacts that may ensue;
  c. How to minimize the square footage areas to be cleared and disturbed and still meet construction, design, and economic needs and requirements; and
  d. Whether the removed topsoil and/or excavated material can be stockpiled for reuse.

– Review the stormwater management plan. Preplanning and management can minimize surface stormwater resulting from construction. Increasing the on-site stormwater-absorption capacity of a building—through the use of piping systems, for example—can reduce flow of stormwater off-site. Other options include the development of an on-site pond that accumulates and releases surface water over time, or the construction of a retention system (such as a retention tank) in the building that slowly releases water into the drainage system or allows water to dissipate naturally. Check local regulations to see if they require a stormwater management plan. Many jurisdictions mandate such plans to protect surrounding sites from anticipated additional surface water and contaminants generated by construction projects.

(See also Chapter 5, "Sustainable Site Design," Chapter 6, "Water Issues," and Chapter 7, "Site Materials and Equipment.")

Construction-Related Indoor Air Quality and Health

★ SIGNIFICANCE

Indoor-air-quality (IAQ) problems caused by construction may be due to (1) dust created by the disturbance of building materials and systems during renovation or demolition; (2) emissions of volatile organic compounds (VOCs) from materials and products; or (3) emissions of combustibles and VOCs from construction equipment or construction processes (for example, welding).

Many construction and building materials emit VOCs or particulates that are potential health hazards or nuisances at low concentrations and require special safety precautions. Introduced into a building during the construction process, such air contaminants can migrate through the building's interior via natural and mechanical ventilation pathways, and linger there well after construction has been completed.

IAQ contaminants move through a building in a variety of ways:

- Through the heating, ventilating, and air-conditioning (HVAC) system (from both the interior and exterior of the building);
- Through pressurization differentials in the interior spaces of the building; and
- Via workers' clothing, where VOCs and combustibles can settle and be released in other sections of the building.

Airborne contamination from various sources—including, for example, VOCs emitted during roof installation—also can filter to nearby buildings, if high concentrations of polluting substances are released near fresh-air intake vents.

Indoor air contaminants may affect building occupants' and construction workers' health and comfort, as well as their productivity. The degree of impact is a function of the type, concentration, and duration of the contaminant exposure. Allergies and hypersensitivities of individuals to specific pollutants are also factors. Typically, indoor contamination associated with construction activities causes short-term acute reactions—eye, nose, throat, or skin irritation, for example. Some short-term exposures may have serious effects—as when, for example, a person is overcome by fumes from a toxic solvent.

It is important to note that each project's construction presents its own unique circumstances, which must be considered on an individual basis. Health concerns, for instance, are generally similar in new construction and in renovation; renovation, however, may be complicated by the presence of occupants throughout the project, raising health issues that demand special consideration.

Guidance for the protection of construction workers is provided by the Occupational Safety and Health Administration (OSHA) as well as by construction-product manufacturers' Material Safety Data Sheets (MSDSs). Indeed, OSHA Hazardous Communication (HAZCOM) regulations (Standard 1926.59) require that MSDSs for all toxic or potentially hazardous materials proposed for use by each construction trade be available at a project site. Building occupants and employers, however, are generally not privy to this information and are thus unaware of potential risks. (See Chapter 13, "Indoor Air Quality," for more information.)

☞ **SUGGESTED PRACTICES AND CHECKLIST**

Administrative Practices

❑ **Develop an IAQ construction management plan.**
The plan should consider the unique circumstances of the project—such as whether it is a new construction or a renovation (with or without building occupants), the planned phasing of activities, and the possible impacts of activities on adjacent buildings—and the cost and benefits of available options and approaches. In many cases, the specifics of a plan used for one building may not work for another. However, the practices noted below may be applied to any building or project.

❑ **Identify potential health hazards and take necessary safety precautions, comply with all "right-to-know" requirements, and obtain MSDS information as necessary.**

❑ **Isolate construction sites from occupied areas.**
Use barriers to prevent the migration of airborne pollutants from areas under construction, and to mitigate any construction noise that may disrupt occupant activities. Coordinate the installation of a barrier with ventilation measures so that airborne contaminants are not dispersed through the HVAC system.

❑ **Schedule noxious work during off-hours.**
If effective controls for potential emissions cannot be practically implemented, schedule activities involving significant airborne pollutants during off-hours, when occupants of the building or adjacent buildings will not be present. Coordinate this measure with ventilation measures, since pollutants need to be flushed out and away from the affected area prior to reoccupancy. Ventilate the site with fresh outside air during and immediately after the noxious activity.

❑ **Tailor IAQ management to the varying requirements of the construction phasing plans.**
The construction process often requires different phases of work (different portions of a building renovated over time, or demolition of a portion of a building at a specific point in the schedule). The IAQ management plan needs to address the varying requirements of the phasing plan.

❑ **Sequence construction steps to minimize contaminant "sinks."**
Wet construction materials—products such as paints, glues, and sealants—release their highest levels of VOCs during the curing period immediately after application, with levels dipping sharply as curing progresses. Certain construction materials—fabric panels, carpets, ceiling tiles, furniture, and movable partition systems, for example—can act as "sinks" for these emissions, absorbing contaminants and then slowly releasing them back into the building over time. Scheduling the application of wet materials prior to the installation of materials known to be "sinks" can reduce the levels of contaminants remaining after construction is completed. Ventilating the building during the application of wet products is equally critical to contamination reduction, as such materials emit high levels of VOCs.

❑ **Test and inspect for potential contaminants (VOCs, particulates, and others).**
Perform tests and inspections to assess the effectiveness of contamination-mitigation strategies and to make necessary adjustments to the IAQ management plan and its implementation.

(See also Chapter 12, "HVAC, Electrical, and Plumbing Systems," Chapter 13, "Indoor Air Quality," and Chapter 15, "Building Commissioning.")

HVAC System Practices

❑ **Flush out newly constructed interior spaces prior to occupancy.**
Flushout of newly constructed spaces with fresh air (at as high a percentage as possible or practical, with 100 percent as the goal) can effectively remove high levels of airborne contaminants prior to occupancy. This activity should be coordinated with measures to protect the HVAC distribution system (for example, the supply-air ductwork and air-handling equipment) so that contaminants are flushed out of the building and not recirculated in the process, contaminating distribution systems and equipment as well as other areas throughout the building (see Chapter 13, "Indoor Air Quality").

❑ **Flush out occupied areas during off-hours.**
When occupancy schedules make flushout impractical, perform the procedure during off-hours (for example, weekends and evenings) for a period of time until contaminant levels are reduced. Complete prior to scheduled occupancy.

❑ **Depressurize the construction work area.**
Keeping the construction area under negative pressure, especially in an occupied building, can help prevent airborne contaminants from migrating into occupied areas. A combination of measures can depressurize the site, such as supplying ventilation into the space under construction, using temporary or existing building exhaust systems to siphon pressure out of the construction area, or supplying positive pressure to occupied portions of the building.

❑ **Pressurize occupied areas.**
Maintaining occupied areas under positive pressure in relation to the space under construction (by ensuring that the air volume supplied to the occupied space is greater than that supplied to the area under construction) can prevent the migration of contaminants from the construction area into occupied sections of the building.

❑ **Increase outside air.**
Increasing outside-air ratios in the air supply to a building dilutes airborne contaminants instead of recirculating them into the building. Increased ventilation, although an appropriate measure for reducing potential contaminants in indoor air, may not be sufficient on its own and may have to be combined with other measures for effective IAQ mitigation.

❑ **Protect ventilation systems and components.**
A building's ventilation system consists of three components: a supply-air distribution system, a return-air distribution system, and air-handling equipment, which also performs filtration. The return-air system recirculates indoor air back through the air-handling equipment and back into the building through the supply-air system. For this reason, the return-air system in a construction area should not be used to exhaust the space unless airborne contaminants are filtered prior to entering the return-air system. Sealing off return-air inlets and establishing alternative exhaust measures (such as removing windows) that work in tandem with the building's supply-air system to provide ventilation can be an effective mitigation strategy. Care must be taken to ensure that the construction space is kept under negative pressure relative to the occupied portion of the building.

(See Chapter 12, "HVAC, Electrical, and Plumbing Systems.")

Source-Control Practices

❑ **Use low-emission products.**
Concerns about indoor and ambient air quality have spurred the development of low-VOC-emission products. Consider low-emission products when they are cost-and-performance-effective; when a building under construction is partially occupied; and when the potential impact of higher-emission products on occupant health and safety is a concern.

- ❑ **Install a temporary local exhaust.**
  Installation of temporary exhaust in a construction area prevents contaminated air from entering the building's return-air system and helps protect the ventilation system's filtration and supply-air distribution channels. Two effective temporary exhaust strategies are (1) removing windows in a space, and (2) using available or dedicated exhaust systems (for example, kitchen or toilet exhaust) that are not tied into the building's overall return-air system.
- ❑ **Install localized cleaning and filtration equipment.**
  When the temporary local exhaust measures mentioned above are not practical, the installation of localized cleaning and filtration equipment to remove contaminants from the air before they enter a building's return-air system can be an effective alternative.
- ❑ **Institute sound housekeeping procedures.**
  Good cleaning, storage, and waste handling and removal procedures can significantly lower the concentration of contaminants in a building. Mechanical rooms (which may be plenums) are often used for storage of construction materials, some of which contain highly toxic substances or high-emission paints, glues, and drywall compounds. If containers of these materials are left open and spill, the potential for contaminating a building's supply-air system and ventilation equipment is great. Thus, attention to storage of potentially polluting materials is an important contamination-control strategy. Frequent cleaning of construction sites with anti-dust sweeping compounds and avoidance of construction-waste storage in certain building areas also help control IAQ contamination.

(See Chapter 13, "Indoor Air Quality," Chapter 16, "Materials," and Chapter 22, "Housekeeping and Custodial Practices.")

Resource Efficiency

★ SIGNIFICANCE

Construction projects typically use large quantities of material, energy, and water resources. Environmental performance improvements can reduce waste, increase efficiency and water conservation, and reduce consumption of natural resources. Potential improvements include the following:

- Efficiently satisfying temporary power and water requirements;
- Reducing waste production with less packaging;
- Reducing waste production through use of materials with recycled content;
- Reducing waste by reusing building materials and demolition debris on the construction site;
- Recycling demolition debris off-site;
- Recycling construction debris; and
- Developing overall efficiency guidelines.

☞ SUGGESTED PRACTICES AND CHECKLIST

- ❑ **Include language in construction documents that promotes energy and water conservation and holds the contractor financially responsible for resource consumption.**
  When a contractor is responsible for payment of a project's utility costs, and energy and water permit fees, it is more likely to curb consumption and reduce associated costs.
- ❑ **To conserve resources, the contractor should:**
  - Monitor energy and water usage to identify areas of waste and abuse, then reduce resource consumption and cost.
  - Install temporary lighting so that most other lighting can be turned off during non-construction hours.

- Install motion sensors for security lighting. Sensors can activate security lighting only as necessary, eliminating the energy waste of round-the-clock lighting.
- Use two different circuits for temporary lighting, one for OSHA-required work lighting and the other for temporary emergency lighting kept on at night for security purposes.
- Wire temporary lighting with the conduit systems installed for the project. Note that the use of new conduit systems is often not allowed for temporary construction lighting, requiring the installation of temporary distribution wiring that is later discarded.
- Use energy-efficient lamps and equipment for temporary lighting. Most temporary lighting on construction projects is incandescent. Consider the use of compact fluorescent lamps, which offers paybacks in reduced consumption (although compact fluorescent lamps are more expensive than their incandescent peers, they use considerably less energy to produce the same quantity of light) and reduced maintenance (compact fluorescent lamps last significantly longer than incandescent lamps, reducing the time and cost associated with lamp replacement and maintenance). Bear in mind, however, that cost-effectiveness varies, depending on such factors as hours of operation, utility consumption rates, replacement costs, and material costs.
- Install low-flow fixtures and appliances for reduced water use during construction. Install a temporary drip watering method for exterior landscaping. Consider rainwater for irrigation (see Chapter 7, "Site Materials and Equipment").
- Reuse captured stormwater and/or construction wastewater on the project site. Settling ponds, for example, can be used during construction, then made into permanent site features.
- Use the building's new or existing HVAC system to provide temporary ventilation or conditioning (heating and/or cooling). Coordinate this use with good IAQ practices so that systems are properly maintained and cleaned. Note that the use of new or existing HVAC systems to provide temporary ventilation for construction is often not permitted (see Chapter 13, "Indoor Air Quality").

❑ **Use products and materials with recycled content, as appropriate and consistent with construction plans and specifications, good IAQ practices, and health recommendations.**

The use of building materials with significant recycled content helps divert recyclables from disposal at the landfill. It also reduces the use of raw materials and, in turn, the depletion of natural resources.

❑ **Use products and materials with reduced packaging and/or encourage manufacturers to reuse or recycle their original packaging materials.**

Such strategies help divert materials from disposal at the landfill and reduce the use of raw materials. The associated reduction in waste and disposal cost can also result in savings to the contractor and developer.

❑ **Purchase materials in a manner that minimizes waste and unnecessary costs.**

For example, purchase nine-foot sheets of drywall if the ceiling height in a building is just under or exactly nine feet.

❑ **Require an on-site recycling system for waste materials (for resale, in the case of metals, or for giveaway to local programs or at curbside).**

Recycling waste materials on-site requires the development of a plan to accumulate, separate, and store the materials until they can be transported to an appropriate market. As part of the plan, identify markets for recyclable materials to determine the economic feasibility of construction waste recycling. Markets for recycled building materials vary throughout the country; typically, however, markets for recycled steel and other metals, masonry, concrete, untreated dimensional lumber, corrugated cardboard, and asphalt exist. In all cases, on-site separation and stringent monitoring of recyclable materials are critical. Contact the local waste management board for more recycling information. (See Chapter 1, "The Economics of Green Buildings," for a construction-waste savings example.)

❑ **Require the recycling and reuse of materials salvaged from demolition.**

Building materials salvaged from demolition may be used as building fill material or insulation, and salvaged ornamental metals, fixtures, and windows may be refurbished and reused. Yet, owners and designers often do not consider recycling materials obtained from demolition, perhaps because they are unaware of potential markets for those materials or are concerned about the potential higher costs and inferior performance of salvaged materials in construction. As more manufacturers demand recycled materials, however, the economic viability of demolition resources is becoming more attractive, and their performance less of an issue.

❑ **Track the actual wastes produced from construction, measuring waste-generation levels against project guidelines for materials' recycling and reuse.**
An effective monitoring program that tracks the actual wastes produced by construction can help ensure that storage bins (when used) are not contaminated by foreign materials and that construction materials scheduled to be recycled are, in fact, being separated. Monitoring the destination of construction materials can also help a project team evaluate the cost-effectiveness of waste disposal versus waste recycling.

➜ RESOURCES

American Society of Heating, Refrigerating, and Air-Conditioning Engineers. *Standard 62-1989, Ventilation for Acceptable Indoor Air Quality*. Atlanta, Ga.: American Society for Heating, Refrigeration, and Air Conditioning Engineers, 1989. Standard for indoor air quality, adopted and used by many jurisdictions to establish HVAC ventilation design guidelines for new buildings and major renovations.

Canada Mortgage and Housing Corporation. CMHC Research Division. *Healthy Materials*. Ottawa, Canada: Canada Mortgage and Housing Corporation, [semiannual]. Periodical focusing on the international status of emission-testing protocol development and standardization. Issued twice yearly.

National Association of Home Builders. NAHB Research Center. *Builders' Guide to Residential Construction Waste Management.* Washington, D.C.: National Association of Home Builders, 1993. A guide to recycling issues and opportunities for home builders, developed from case studies of NAHB projects in the Maryland area.

Sheet Metal and Air Conditioning Contractors National Association. *IAQ Guidelines for Occupied Buildings Under Construction* (Draft). Sheet Metal and Air Conditioning Contractors National Association, 1995. A guide to developing an IAQ management plan for construction in occupied buildings. Identifies issues to consider and options for contaminant mitigation.

State of Washington. Department of Labor and Industries. *Indoor Air Quality in Office Work Environments*. State Chapter 296-62 Washington Administrative Code, General Occupational Health Standards. Olympia, Wash: State of Washington, 1993. Design and specification standard for managing VOC emissions from construction materials and building furnishings to minimize concentration levels at time of occupancy.

Triangle J Council of Governments, Design Harmony Architects, and Abacot Architecture. *WasteSpec: Model Specifications for Construction Waste Reduction, Reuse, and Recycling.* Research Triangle Park, N.C.: Triangle J Council of Governments, 1995. Model specifications for incorporating construction materials with recycled content, and practices to promote waste reduction in the construction process. Formatted by Construction Specifications Institute (CSI) sections.

U.S. Environmental Protection Agency. Office of Air and Radiation. *Designing for Good Indoor Air Quality*. Washington, D.C.: GPO, 1993. A guide that helps design professionals understand the contribution of design to indoor air quality in the buildings they create.

—. Office of Air and Radiation, Office of Atmospheric and Indoor Air Programs. Indoor Air Division. *Building Air Quality: A Guide for Building Owners and Facility Managers.* Washington, D.C.: GPO, 1991. A guide for facility managers and owners defining management practices that can promote good indoor air quality in their facilities. The guide includes useful forms and checklists for developing an IAQ profile of a building, analyzing building IAQ indicators, and mitigating IAQ problems in buildings.

CHAPTER 20

Local Government Information: The Construction Process

Author
Michael Myers

When local governments adopt green policies for the building or renovation of their facilities, they must address a number of issues. First, they will need to educate all parties involved in a green construction project. Next, they will need to ensure that appropriate internal mechanisms—ordinances, procurement practices, building codes, and permitting processes—are in place. Finally, they will need to pay attention to external factors, such as access to environmentally sound materials and an infrastructure for recycling construction and demolition debris, that help to ensure successful results.

Local government environmental professionals should educate policymakers about the life-cycle benefits versus initial costs of a green building project to minimize the potential for later misunderstandings. Elected officials and city or county managers will often understand and support the complexities and benefits of such a project better if they receive an early explanation of its innovative policies and practices.

Building-code offices, procurement offices, and permitting departments, in turn, need information about the nature and scope of a green building project and about alternative building materials and practices in order to facilitate the construction and inspection processes. These government agencies can examine codes and permits to identify any barriers to sustainable construction strategies and, if necessary, assist in securing waivers or devising alternative plans. Their review of local ordinances may reveal that existing policies can address and enforce such factors as watershed protection and native-plant preservation during the construction process, or that updated ordinances need to be put in place.

A jurisdiction's construction manager should be part of the design team that is assembled to develop and implement a green approach. Education of the building contractor by the construction manager and the design team is also necessary if the jurisdiction is to successfully translate its design plans into reality. One approach to this education effort is the use of specifications that clearly delineate environmental practices to be followed during construction (see Chapter 17, "Specifications").

In addition, if the contractor is not familiar with green building techniques or materials, it may not adhere to the desired sustainable practices. If the contractor cannot locate green products in a timely fashion, for example, the construction timetable is likely to suffer, resulting in increased cost to the contractor and to the local government from extended leases on existing facilities or lost revenue from proposed occupants. The local government can take steps to assist the contractor in locating distributors and manufacturers of recycled-content materials and other green products so that purchase and delivery schedules can be met.

Finally, the jurisdiction should ensure that the infrastructure for the recycling of construction and demolition debris is in place from the beginning of construction. If recycling strategies are implemented after construction has begun, recycling rates are likely to be far from optimal, and landfill costs are likely to go up. On-site recycling depends on the ability to collect and sort construction waste and a system to either reuse materials at the site or recycle them within the community.

Other issues local government construction managers should consider are the efficient use of energy and water resources on construction sites and the application of practices and products that promote good indoor air quality during construction. These practices can both save money and provide a safer workplace for construction workers.

LOCAL ACTIONS

- ➤ The city of Austin, Texas, has conducted over 10 years of education and outreach related to the adoption of green building practices. Beginning with the Green Builder Program, Austin sought to provide homeowners and builders with the tools to evaluate the benefits of green practices and products. Since the program's implementation, a city home rating system has provided a market advantage to green builders; local citizens have organized an advocacy group interested in green buildings, and City Council has embraced green building policies for municipal facilities. A commercial Green Builder Program, introduced in December 1995, now targets the private business sector and includes waste reduction and demolition recycling in its checklist of suggested practices.
- ➤ In a related sustainable building initiative, Austin's construction team for its new airport includes an individual responsible for finding recycling opportunities during the demolition phases of the project, which is taking place at the former Bergstrom Air Force Base. Early phases of the project were implemented without recycling guidelines in place, resulting in lost opportunities; however, later phases have been more successful. So far, demolition recycling and the relocation of homes have yielded positive economic consequences.
- ➤ The city of Portland, Oregon, enacted a city policy in 1995 that requires municipal bureaus, contractors, and subcontractors working on city-sponsored construction and demolition projects to aggressively recycle and salvage building materials. The city goal is to recycle or reuse 100 percent of building materials such as wood, corrugated cardboard, metal, drywall, rubble, excavated earth, and land-clearing debris from construction sites. For roadways, underground utilities, and similar projects, the city has set a 90 percent goal for the recycling of asphalt, concrete, crushed rock, and dirt; in demolition, it encourages the salvage of all possible materials, and 90 percent recycling of other materials. Recycling is not required where the practice is not profitable and practical. An important aspect of Portland's policy is the "Bidders Recycling Economics Worksheet," which all bidding contractors must use to evaluate the cost difference between on-site recycling and landfill disposal.

  Effective January 1996, Portland enacted Ordinance #169103, requiring all companies that request a construction or demolition permit with a value greater than $25,000 to comply with a requirement to recycle waste on the job site. To help companies comply, Metro, the regional government in the Portland area, has developed *Construction Site Recycling: A Guide for Architects, Builders and Developers,* which provides specific project examples and a listing of recycling facilities and the materials they accept. Waste haulers are also adapting to the policy change, facilitating compliance by giving contractors the option of using multiple drop boxes at the construction sites. Future plans in Portland include standards for using recycled aggregates in public works projects, thereby completing the recycling loop.

➤ In compliance with the state of New Jersey's 1987 recycling law, Passaic County, New Jersey, requires commercial and government contractors to recycle waste materials generated during construction and demolition. To facilitate cooperation with this requirement, the Clean Builders Association of Passaic County educates contractors about recycling issues and serves as a resource for the county. Rather than merely promoting the county's mandate, the association emphasizes incentives for compliance, such as reductions in landfill use and associated fees.

➤ The Triangle J Council of Governments in Research Triangle Park, North Carolina established a Construction and Demolition Waste Task Force in 1993. The task force is made up of 33 members representing state and local governments, architects, builders, developers, and recycling companies. Its mission is to initiate, encourage, and coordinate efforts to reduce, reuse, and recycle construction and demolition waste in the region. So far, the task force has produced two publications to assist builders: a guide to construction and demolition waste recycling, and *WasteSpec: Model Specifications for Construction Waste Reduction, Reuse, and Recycling,* a manual for architects and engineers. The manual contains model specification language, a checklist of 135 materials typically found in demolished buildings, a model waste management plan, information on estimating recycling costs, and additional green building resources.

➤ Orange County, Florida, opened the Orange County Community Distribution Center (OCCDC) in 1993. Launched with private-sector technical support, the center distributes recycled building materials to non-profit organizations in the community. The center also trains county inmates in marketable skills related to the handling and sorting of recycled materials. In 1994 alone, the center's operations diverted over $600,000 worth of materials from local landfills and reused these materials in the community.

➤ Habitat for Humanity International has set up several community recycling centers around the country, called Habitat for Humanity Re-Stores, that recycle doors, windows, sinks, and other building-related materials and products. Profits from this activity are used to fund new home projects. In 1994, the Austin, Texas, Re-Store diverted 300 tons of usable materials from local landfills, and generated enough sales to build 31 homes.

➤ The city of San Diego, California, Ridgehaven Green Building renovation project requires the contractor to follow specific environmental procedures during demolition and construction. Project guidelines call for cleaning, ventilation, and protection procedures to prevent contamination of the new heating, ventilating, and air-conditioning (HVAC) system and interior space; use of environmentally sensitive building products, non-toxic cleaning materials, and least-toxic pest-control methods; and reuse or recycling of demolition and construction refuse. The procedures provide clear information on local materials-reuse programs and sources of non-toxic cleaning products.

LOCAL OPTIONS

- Educate public and private construction-related entities about green building practices.
- Review your jurisdiction's codes and ordinances to identify and remove barriers to green construction practices.
- Establish a task force to review local government building and renovation policies and procedures and develop specifications that accelerate green construction efforts by including environmental procedures.
- Promote the establishment of a community building-materials recycling center.
- Establish a public/private task force to promote construction- and demolition-waste recycling.
- Direct contractors to local or regional environmental product sources and material-

recycling vendors.

➜ RESOURCES

Resources for the Local Government Information chapters are located in the Appendix.

PART VI

Operations and Maintenance

Introduction

Building operations and maintenance (O&M) significantly impact a building owner's costs, and affect the internal and external building environment. This section describes practices that can enhance environmental quality and the performance of building operations. Used routinely, these practices can lead to substantial economic and environmental benefits, such as reduced energy consumption, better indoor air quality, resource efficiency, and occupant satisfaction.

Building O&M plays several important roles. It should maintain proper building temperature and humidity; promote the ventilation, dilution, and removal of airborne contaminants; and provide other important environmental conditions, such as appropriate lighting and acoustics. It should also ensure the safety and cleanliness of building systems so that they do not generate pollutants and hazards. For example, a ventilation system must sufficiently exhaust and dilute contaminants. It must also be kept clean and free from excessive moisture so as not to generate contamination. Finally, O&M policy and practices can promote resource efficiency by tenants and building occupants.

Operations and maintenance practices are shaped by professional standards, facility characteristics, and an organization's general management policy. For example, an organization's smoking policy determines the extent to which environmental tobacco smoke, an occupant-generated contaminant, needs to be addressed by O&M. The U.S. Environmental Protection Agency (EPA), the U.S. Green Building Council (USGBC), Building Owners and Managers Association (BOMA), and other organizations recommend the prohibition of smoking in buildings. However, where management policy allows smoking in designated areas, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 62-1989 prescribes local exhaust with no recirculation to other parts of the building.

Building use; office equipment, such as computers and copiers; and facility management technologies and practices are constantly changing. Building O&M needs to ensure the quality of the indoor environment when such changes take place during the life of the building. For example, space renovations demand changes in heating, ventilating, and air-conditioning (HVAC) systems and lighting; and the addition of desktop computers, which increase building cooling loads, require corresponding HVAC capacity enhancement. Even changes in the number of people in a space require mechanical and electrical modifications to properly ventilate, heat, cool, and light the space.

The chapters in this section outline procedures for managing a green building throughout its life. Chapter 21, "Building Operations and Maintenance," outlines basic facility management and maintenance practices for indoor environmental quality, and energy and other resource efficiency. In addition, it provides guidelines for reducing environmental impacts during renovation. Chapter 22, "Housekeeping and Custodial Practices," provides step-by-step procedures for managing and maintaining a green building, as well as guidelines for selecting environmentally sensitive cleaning products. Both building manager and maintenance staff can use the chapters to develop their own on-site, environmentally based O&M manual. Chapter 23, "Local Government Information," offers examples of sound O&M practices that local governments have implemented.

CHAPTER 21

Building Operations and Maintenance

Maintenance Plans

Author
Sal Agnello

★ SIGNIFICANCE

The O&M costs throughout a building's useful life far exceed its initial design and construction costs. Expenditures related to the salaries and health of employees working in a building often equal or exceed O&M costs annually. When these factors are considered, together with the impact that sound O&M practices can have on occupant satisfaction and productivity, it is clear that the financial benefits of creating and maintaining quality building environments surpass the costs directly related to facility operations alone.

Codes and professional standards for building design and construction exist to ensure quality buildings. But they alone are not sufficient, because even a properly designed and constructed building will not provide a cost-effective, healthy environment unless it is properly operated and maintained. Unfortunately, implementation of professional standards for quality building environments usually ends upon completion of building construction; sound building O&M is not assured by codes or other regulatory authority. This section is intended as an overview of practices that promote quality indoor environments while conserving resources during a building's operational phase.

☞ SUGGESTED PRACTICES AND CHECKLIST

❑ **Train facility staff to observe standards of care for a building.**
Modern buildings are complex, costly, and likely to expose occupants to risk. Identify and communicate to facility staff applicable American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards, codes, and regulations that minimize such risks.
- Develop policies and procedures for compliance with these standards and documentation of compliance.

- ❑ **Ensure facility staff have enough qualifications and training to operate special equipment.** Develop a plan for continuing education and keep equipment operations manuals readily available.
- ❑ **Establish written O&M policies and procedures for inspection, preventive maintenance, cleaning, and repair of mechanical system components.**
  Operate and maintain the facility according to its design intent and equipment needs, but change practices as the building itself changes and obsolete equipment is replaced.
  - Periodically assess occupancy loads, types of space use, and corresponding ventilation, temperature, and humidity requirements.
  - Establish methods for airflow and thermal parameter measurement.
  - Develop plans and schedules for checking operation of mechanical system components.
  - Develop plan and schedules for checking system cleanliness.
  - Establish a documentation system for repairs and replacement.
- ❑ **Include Material Safety Data Sheets (MSDS) and information on cleaning and pest-control methods in the building's environmental services and housekeeping policies and procedures.**

Indoor Environmental Quality

★ SIGNIFICANCE

Indoor environmental quality is of great importance to the health and productivity of building occupants. It encompasses indoor air quality (IAQ), thermal comfort, lighting, and acoustics. Addressed initially during building design and construction, these issues need to be carefully considered in the ongoing operations and maintenance of a building.

Building IAQ has emerged as one of the most significant building operational issues because of its potential health impacts to building occupants. A building is considered to have good IAQ when contamination levels in its indoor air are below those that cause health problems, ensuring the safety and comfort of building occupants. However, much confusion concerning the definition of IAQ and acceptable levels of contaminants is prevalent in the building industry, and further research and guidance are necessary. Despite this uncertainty, a prudent building manager can use existing industry-accepted practices to address this important environmental issue.

An environmentally sound building not only supplies healthy indoor air, but also provides effective shelter from heat, cold, and moisture. Proper thermal and humidity conditions are as essential as good IAQ to the health, comfort, and productivity of building occupants. Lighting is another factor affecting the quality of the indoor environment, and one directly linked to employee productivity. Good lighting reduces the risk of eyestrain or other discomfort associated with performance of a given task. Acoustics can also be a significant indoor environmental factor. Noise of certain types and intensities can create environmental stress, leading to reduced employee satisfaction and productivity.

(See also Chapter 9, "Daylighting," Chapter 12, "HVAC, Electrical, and Plumbing Systems," Chapter 13, "Indoor Air Quality," and Chapter 14, "Acoustics.")

Indoor Air Quality

Tenant Complaints

❑ **Pay careful attention to the resolution and coordination of tenant complaints.**

In many cases, these complaints indicate potential or actual problems. Early prevention can spare building management future occupant-related problems and liability, including the risk of litigation, worker's compensation claims, poor publicity, lost rent, and lower occupancy levels and rental rates.

- Investigate every complaint.
- Develop policies for communicating with occupants regarding pollutants, use of space, and activities.
- Develop a complaint response form. Refer to EPA's *Building Air Quality Guide* for examples. Aside from helping diagnose facility problems, accurate recordkeeping can document responsiveness to occupant complaints and help protect building management from potential negligence claims.
- Develop follow-up procedures to ensure complaint resolution.
- Bring in IAQ expertise to investigate complicated complaints.

Building Monitoring

❑ **Monitor your buildings for compliance with the latest environmental guidelines.**

It is important to keep up with technical, regulatory, and professional-practice developments; to review adherence to established O&M policies and procedures; and to monitor the physical parameters associated with a safe and comfortable indoor climate.

- Stay informed of the latest IAQ developments by subscribing to the trade journals, programs, and resources of ASHRAE, the American Society for Testing and Materials (ASTM), International Facilities Management Association (IFMA), BOMA, and other associations.
- Establish measurable environmental guidelines for variables such as outdoor airflow, temperature, humidity, and filtration efficiency. Monitor performance against these guidelines.
- Continuously document the operation of the building's heating, ventilating, and air-conditioning (HVAC) system, particularly outdoor air measurement, filtration performance, exhaust system performance, temperature, and humidity. Use building-control-system technology to assist in this process.
- Follow the Ventilation-Rate Procedure of ASHRAE Standard 62-1989 (*Ventilation for Acceptable Indoor Air Quality)* to monitor, control, and document minimum outdoor airflows, even with variable-air-volume (VAV) systems. Consider available automated technologies such as indirect outdoor-air measurement and closed-loop control technology or outdoor airflow measuring stations for this purpose.
- In spaces with known hazards, such as areas adjacent to indoor parking garages, monitor specific contaminants like carbon monoxide (CO) and radon, the latter especially in below-grade areas located in geographic regions with high radon. Also, use carbon dioxide (CO_2) high-limit alarms for areas with hard-to-predict occupancy, such as conference and assembly areas, where periodic high occupancy levels may result in unhealthy conditions.

IAQ Practices and Maintenance

❑ **Perform regular maintenance on the major components of HVAC systems.**

Regular maintenance keeps HVAC components operating properly to control potential IAQ contaminants and sustain appropriate environmental conditions. Exhausting fumes and odors from a building, filtering out dust and other particulates, maintaining proper humidity, and diluting occupied spaces with outside air are all practices with a proven record of preventing and solving IAQ problems.

Outdoor-Air Intake

- Clean outdoor-air-intake plenums, louvers, screens, dampers, and other components, and check for necessary screening to ensure protection from outside elements. If necessary, retrofit the outdoor-air intake so that it is properly located outside and distanced from building exhausts and outdoor contaminants. When air is exhausted from special odor and contaminant areas (such as restrooms, smoking lounges, and printing areas), enough replacement air must be brought in to prevent the building from becoming negatively pressurized and drawing in outside contaminants through leaks and openings in the building envelope.
- Repair malfunctioning outdoor-air dampers to provide sufficient outdoor air for proper ventilation and exhaust-air makeup, to produce positive air pressure, and to prevent excessive influxes of outdoor air in cold weather from adversely affecting temperature control.
- Continuously measure outdoor airflows through installation of outdoor airflow stations or outdoor-air controllers with VAV systems, ensuring compliance with ASHRAE Standard 62-1989.

Indoor Ventilation and Air Ducts

- Evaluate heating, cooling, and ventilation capacity to see if such capacity matches up with occupancy and equipment loads.
- Check supply fans for coordinated fan size and duct layout, as well as the size of the duct opening and resistance in air velocity, to ensure proper static pressure in the ventilation system. Periodically test, adjust, and balance the system to achieve proper airflow and air distribution to all zones and occupants within the building. Check fans and damper modulation to promote proper space pressurization. Periodically maintain components, filters, and controls in accordance with manufacturers' recommendations.
- Provide sufficient exhaust to areas with significant contaminant-source activity. Install separate ducts from such spaces as laboratories, chemical storage areas, and restrooms to the outside, supply sufficient outdoor air to make up for local exhaust from these areas, and pressurize the areas properly.
- Check diffusers and return-exhaust grills for proper air distribution. Test, adjust, and balance air to reflect the impact of space modifications.
- Use CO_2 sensors as a supplementary ventilation strategy for variable or unscheduled occupancy. This strategy delivers outdoor air to a space when its occupancy produces a certain level of CO_2, triggering a sensor that opens the outdoor-air damper to increase ventilation. It is suggested only as a supplement to other ventilation mechanisms because, by itself, it does not meet provisions of the Ventilation Rate Procedure of ASHRAE Standard 62-1989.
- Inspect ventilation systems for supply-duct leaks and water damage. Repair leaks to prevent short-circuiting of supply and return air, and clean any areas where accumulated dirt may restrict airflow and encourage moisture to accumulate.
- Inspect and periodically replace or clean filters of air handlers and related equipment. Inspect filter tracks for gaps and repair them to prevent bypass of dirty air. Use the control system to monitor air pressure across filters and to determine timely filter servicing; particle counters may also be used for better filter maintenance. Clean clogged coils for unrestricted airflow and heat transfer.
- Provide sufficient outdoor air for combustion to achieve proper pressurization of the boiler room and functioning of flue-gas and exhaust systems.

Temperature and Humidity Control

- Check temperature controls for proper location and design the building zones for proper heating and cooling distribution.
- Inspect duct thermostats, designed to prevent cold outside air from freezing heating coils. Unnecessary activation of these devices could result in thermal discomfort from automatic shutoff of the system.
- Perform preventive maintenance and repair on chillers to ensure sufficient cooling and dehumidification in the building. Insulate piping to prevent condensation and mold and microbial growth. Retrofit or upgrade chillers for quick capture of refrigerants, including those from the building's exhaust room.
- Check and maintain appropriate humidity levels during heating and cooling seasons to ensure occupant comfort and to prevent condensation that could lead to microbial growth. Retrofit systems to provide appropriate humidification or dehumidification capacity as required. Use clean steam rather than treated boiler water for humidification.

Cleaning and Pollutants

- Inspect and test ducts for microbial contamination; replace duct lining in air handlers with cleanable liners treated with antimicrobial additives. Do not leave residue of contaminated lining on the duct metal.
- Inspect return-air systems for integrity and cleanliness to prevent the spread of pollutants from plenum areas such as mechanical rooms.
- Inspect and clean HVAC system components, such as drain pans, to prevent mold and fungus accumulation.
- Inspect and clean self-contained heating and cooling units to prevent and correct contamination from dirt and moisture.
- Clean cooling towers to prevent sediment and film accumulation. Clean and chemically treat water to prevent the growth of microorganisms such as Legionella. Install drift eliminators to prevent water-mist release and re-entrainment of contaminant mists into outdoor-air intake systems.
- Adjust boilers for proper combustion to minimize production of CO and nitrogen oxides.
- Inspect and maintain gaskets and prevent fuel-line leaks and resulting contaminants, fumes, and odors.
- Develop and implement source-control strategies in addition to the above ventilation practices. A comprehensive source-control program needs to address potentially high-pollutant items such as carpet, paint, adhesives, and adhesives and preservatives in furniture.

(See Chapter 12, "HVAC, Electrical, and Plumbing Systems," and Chapter 13, "Indoor Air Quality.")

Thermal Comfort

❑ **Establish temperature and humidity setpoints in accordance with occupancy patterns, scheduling, and outside climate and seasonal variances; follow ASHRAE Standard 55-1992 (*Thermal Environmental Conditions for Human Occupancy*).**

❑ **Use building-control systems (computerized temperature-sensing and control technology) to establish, maintain, and document building climate conditions.**

(See Chapter 12, "HVAC, Electrical, and Plumbing Systems.")

Light Quality

❑ **Adjust lighting levels to types of space use and occupancy, following Illuminating Engineering Society standards.**

- ❑ **Repair lighting fixtures that produce glare, flicker, insufficient illumination on work surfaces, and other conditions that can cause eyestrain, headaches, and other discomfort.**

(See Chapter 9, “Daylighting,” and Chapter 12, “HVAC, Electrical, and Plumbing Systems.”)

Acoustics

- ❑ **Control noise based on the needs of occupants rather than industrial exposure limits (decibels), which are geared toward protection from hearing loss.**
- ❑ **In open offices with little or no privacy, consider noise-masking technology such as “white-noise” generation.**
- ❑ **Inspect and repair or replace noisy HVAC systems, which not only can be stressful and distracting to occupants, but may also indicate mechanical problems or inappropriate design or capacity.**

(See Chapter 14, “Acoustics.”)

Energy Efficiency

★ SIGNIFICANCE

Perhaps the single greatest building O&M challenge is to minimize consumption of energy and other resources in heating, ventilation, cooling, lighting, and other equipment while providing a comfortable, healthy, and productive indoor environment. Fortunately, opportunities for substantial reduction of energy use, and cost savings, abound across all building systems, and energy-efficiency technologies are continually improving, ensuring a steady flow of viable alternatives. It is the facility manager’s responsibility to identify and implement such energy- and resource-efficient options on an ongoing basis.

HVAC performance, for example, can be improved by replacement or repair of worn-out or inefficient equipment with energy-efficient components. Many new, highly efficient HVAC technologies are continually being introduced. These components—which include occupancy sensors, variable-speed drives, automated ventilation control, heat exchangers, and efficient motors—can reduce energy consumption by adjusting the levels of heating and cooling to maintain a healthy and comfortable environment.

Lighting also offers numerous opportunities for energy conservation. In some office buildings, it can represent 40 to 60 percent of total energy costs. The major approaches for saving lighting energy include using natural daylight whenever possible, reducing excessive illumination levels, limiting hours of operation, and increasing lighting efficiency.

Additional energy savings can be found in a building’s water treatment and distribution systems. In general, water-heating energy is conserved by reducing load requirements and distribution losses and improving the performance of water-heating equipment. Finally, building owners and managers can conserve energy by encouraging occupants to select appliances and office equipment with high energy-efficiency ratings.

(See Chapter 12, “HVAC, Electrical, and Plumbing Systems.”)

HVAC

Operation Schedules

- ❑ **Adjust operating hours of heating and cooling systems to levels appropriate for time of year, type of use, and occupancy patterns of the facility.**
- ❑ **Adjust operating hours of ventilation systems according to potential contaminant levels and the need to balance exhaust air.**
- ❑ **Use timing devices to operate exhaust fans only when needed; coordinate with supply fans and building pressurization requirements.**
- ❑ **Use programmable thermostats to schedule and establish heating setpoints for various building occupancy patterns.**
- ❑ **Schedule, control, and document ventilation rates to meet levels prescribed by ASHRAE Standard 62-1989 for type of facility, occupancy lead time, and load.**
- ❑ **Use building-control systems to operate HVAC equipment based on need, minimize simultaneous heating and cooling, and supply thermal conditioning from the most efficient sources.**
  - Set automatic temperature control based on pre-established ranges.
  - Use time-of-day and occupancy-based controls.
  - Supply air-temperature reset control for VAV systems.
  - Supply hot- and chilled-water temperature reset controls based on outside-air temperature and hot- or chilled-water demand.
  - Use economizer control system to bring in outside air for cooling.

Adjustment Control

- ❑ **Adjust space temperature and humidity setpoints to minimize space-conditioning requirements.**

  Do not set these limits below the lowest heating temperature—or above the highest cooling temperature—required to satisfy occupants' needs, in accordance with the thermal requirements of ASHRAE Standard 55-1992.
- ❑ **Lower humidification and raise dehumidification setpoints based on time of year, occupant-generated moisture, and equipment- or material-protection needs, such as those required by wood finishes and electronic components.**

System-Efficiency Improvements

- ❑ **Install air-to-air heat exchangers, which preheat cold outdoor supply air by transferring heat from warm exhaust air.**
- ❑ **Install air-cleaning devices, such as particulate filters, activated carbon, electronic air cleaners, and other mechanisms that clean recirculated air.**
- ❑ **Improve chiller efficiency.**
  - Clean evaporator and condenser surfaces to maintain their heat-transfer capabilities.
  - Treat circulating water in cooling towers with chemical filtering to control scale, algae, and other deposits.
  - Implement control strategies that raise evaporator or lower condenser water temperatures to reduce the differential between them.
  - Install evaporation-cooled or water-cooled condensers rather than replacing air-cooled evaporators.
- ❑ **Improve boiler or furnace efficiency.**
  - Properly adjust fuel-air ratios by installing flue-gas analyzers.
  - Reduce cooling effect of combustion air and cut energy consumption by preheating combustion air and reclaiming waste heat from feed water and fuel oil.

- ❑ **Prevent overcapacity by isolating off-line boilers with control valves and dampers, and replacing equipment with modular units whenever possible.**
- ❑ **Install automatic vent dampers.**
- ❑ **Install automatic boiler blowdown control to remove contaminants that can reduce heat transfer; for oil-fired systems, install air-atomizing and low-excess-air burners.**
- ❑ **Replace constant air-volume systems with variable-air-volume systems.**
- ❑ **Install economizer cooling systems that bring in extra ventilation air when feasible.** This system will work in temperate climates, for example, or in those with large day/night temperature differentials. Control supply-air and hot- or chilled-water temperatures according to heating and cooling load schedules.
- ❑ **Use fans to increase air movement and enhance cooling.**
- ❑ **Reduce fan and pump energy requirements by reducing flow rates (for steam, air, and water) and resistance to the minimum required for operation.**
- ❑ **Use one or more of the following heat-reclamation systems and strategies:**
  - Air-to-air recovery systems;
  - Hydronic recovery systems;
  - Chiller-condenser heat for coincident space- or water-heating needs;
  - Boiler blowdowns and combustion-system flue-heat recovery;
  - Heat-pump systems; or
  - Steam condensate through a heat exchanger.

System Upkeep

- ❑ **Maintain boiler or furnace efficiency.**
  - Clean heat-transfer surfaces.
  - Chemically treat boiler water to prevent build-up of scale, sediment, and sludge.
  - Check flues for proper draft.
  - Check for air leaks in combustion chambers.
- ❑ **Reduce energy losses from the HVAC distribution system.**
  - Repair duct and pipe leaks.
  - Inspect and maintain stream traps to prevent condensate build-up.
  - Insulate ductwork and HVAC system piping.
- ❑ **Replace air filters.**
- ❑ **Remove scale from water and steam pipes.**
- ❑ **Rebalance pipe and duct systems.**

(See Chapter 12, “HVAC, Electrical, and Plumbing Systems.”)

Lighting

- ❑ **Reduce illumination to the level most suitable for a given task.**
  - Clean and maintain lenses, reflectors, and lamps.
  - Reduce lighting levels in accordance with Illuminating Engineers Society (IES) guidelines.
  - Implement a task lighting and ambient lighting strategy.
- ❑ **Adapt lighting levels to occupant needs.**
  - Turn off lights when not needed.
  - Use controls that dim or turn off lights automatically, based on occupancy.
- ❑ **Install the following energy-efficient lighting systems:**
  - Fluorescent lighting;
  - High-pressure sodium lighting, to replace mercury-vapor lamps;
  - Low-pressure sodium lighting, for night-time security; or
  - High-efficiency ballasts.

❑ **Maximize use of daylight.**

❑ **Install dimming controls for use with windows and skylights.**

(See Chapter 9, "Daylighting," and Chapter 12, "HVAC, Electrical, and Plumbing Systems.")

Plumbing

❑ **Reduce hot-water consumption by restricting flow rate with restrictors and low-flow faucets, showers, and other fixtures.**

❑ **Lower hot-water temperatures by setting thermostats at the lowest temperature that meets occupant needs.**
For special needs that require additional heating, install a booster heater.

❑ **Preheat feed water with reclaimed waste heat, such as boiler-flue heat and chiller-condenser heat, from other building equipment processes.**

❑ **Reduce hot-water heating system losses by insulating hot-water pipes and water storage tanks.**

❑ **Use energy-efficient water-heating systems, such as decentralized water heaters that operate only when needed and provide water only at the required temperature.**

❑ **If possible, use smaller water heaters for seasonal requirements.**

❑ **Replace old electric resistance water heaters with heat-pump models.**

❑ **Install automatic flush systems on toilets and urinals.**

❑ **Install automatic shut-offs on sinks.**

(See Chapter 12, "HVAC, Electrical, and Plumbing Systems.")

Plug Loads

❑ **Consider the energy usage of electrical appliances and building equipment in procurement specifications.**

❑ **Select office equipment based on EPA's Energy Star energy-efficiency ratings.**

❑ **Retrofit older equipment with EPA Energy Star-approved controls.**
Such controls can optimize the energy efficiency of older computer monitors, central processing units, printers, and fax machines.

(See Chapter 12, "HVAC, Electrical, and Plumbing Systems.")

Resource Efficiency

★ SIGNIFICANCE

Operation and maintenance of commercial buildings generate substantial amounts of solid waste, much of which can be mitigated by an integrated waste management program. A successful program should first reduce "upstream" waste, such as unnecessary packaging associated with deliveries to a building. Next, it should reduce the waste associated with building operation; that is, paper, glass, newspaper, and other items. Finally, it should minimize the "downstream" to the landfill by reusing or recycling waste materials.

Water conservation is another important issue in building O&M. Reducing water consumption, through retrofitting individual fixtures during regular maintenance or replacing systems during major building renovation, can cut operating budgets and conserve water resources (see Chapter 6, "Water Issues").

☞ SUGGESTED PRACTICES AND CHECKLIST

Solid Waste

❑ **Establish an efficient waste reduction, recycling, and reuse program.**
Any building owner can establish a recycling program. Tenants should assess their operations to determine where source-reduction and reuse programs can be implemented, then take the following steps to launch an effective program:
- Obtain top management support;
- Select a program coordinator and team;
- Analyze all waste streams;
- Identify one or more ways wastes can be reduced, reused, or recycled in each waste stream;
- Plan the program process;
- Train employees and tenants; and
- Continually monitor the program.

❑ **Lower costs of waste disposal through source reduction—that is, purchasing products with less packaging and producing less waste.**
- Purchase supplies in bulk to reduce packaging.
- Work with suppliers to reduce packaging and use returnable packing pallets.
- Set standards for on-site cleaning services, requesting use of only minimal amounts of cleaning chemicals and reusable cleaning rags.
- Photocopy on both sides of paper.
- Use electronic mail to reduce use of paper.
- In the cafeteria, replace disposable plates and utensils with ceramic plates and silverware.
- Provide reusable coffee mugs to employees.

❑ **Minimize toxic waste by recycling items such as lighting ballasts, mercury-containing fluorescent and high-intensity-discharge (HID) lamps, used oil, unusable batteries, and mercury-containing instrumentation.**

Water Conservation

❑ **Reduce building water use.**
- Establish leak-detection programs for air and water distribution systems.
- Reduce water-flow rate and subsequent waste by installing low-flow, water-efficient faucets and other fixtures and appliances.
- Educate facility maintenance staff and occupants about water conservation goals.

❑ **Reduce outdoor water use on grounds.**
- Repair and replace sprinkler heads to avoid watering paved areas.
- Minimize evaporation waste by watering in the morning.
- Shorten watering times to avoid runoff.
- Capture and use rainwater and graywater as practical, when approved by local and state health and environmental authorities.

(See Chapter 6, “Water Issues.”)

Renovation

★ SIGNIFICANCE

The green building guidelines, design process, and team approach developed for new construction can also apply to building renovations. Green renovation practices include use of natural design elements, such as increased daylighting; installation of resource-conserving materials and systems; recycling and reuse of construction and demolition waste; and maintenance of good indoor environmental quality during construction.

While renovation often provides an opportunity to improve indoor-air-quality problems and upgrade HVAC, electrical, solid waste, and water equipment and systems, the process can also have extensive environmental impacts on building occupants. Primary impacts include indoor-air-quality contamination, waste, noise, and hazardous conditions. These can be addressed by scheduling work when occupants are away from a building, placing barriers between the renovation and occupied areas, and providing adequate ventilation.

Of special concern during the renovation process is the increased risk of occupant exposure to hazardous waste. The most common types of hazardous waste include asbestos, lead paint, PCB in the lighting ballasts, PCB transformer fluid, and mercury-containing fluorescent lamps. Proper handling, disposal, or recycling of these materials is critical to ensure compliance with federal environmental regulations. Hazardous materials that are moved off-site can bring long-term environmental liabilities to the building owner or operator when not disposed of properly. A thorough discussion of hazardous-waste topics is beyond the scope of this manual. Refer to EPA and ASTM regulations, standards, and guidelines for additional information.

(See also Part IV, "Building Design," and Chapter 19, "Environmental Construction Guidelines.")

☛ SUGGESTED PRACTICES AND CHECKLIST

Work Scheduling

❑ **Isolate occupants from environmental contaminants generated by construction-related activity in partially occupied areas; and if necessary, relocate hypersensitive occupants from the work site.**

❑ **Schedule work around occupancy times to minimize contamination.**
Contaminants include dust and emissions from paints and chemicals used in wall and floor coverings and their adhesives. It is best that the application of paints and adhesives, carpet installation, and generation of construction dust and other debris *not* occur while areas are occupied. If this is not feasible, then alternative measures need to be instituted that minimize adverse impacts on the health and productivity of occupants.

Barriers

❑ **When renovation takes place during periods of building occupancy, use the following methods to isolate construction activities:**
- Isolate the occupants and the HVAC system serving them from the renovation zone;
- Isolate the renovation zone from occupied areas with physical barriers, such as plastic sheeting, that limit air movement to those areas;
- Take special precautions to keep allergic or sensitive occupants away from the renovation area; and
- Attempt to minimize disruptive noise and other factors that interfere with normal work patterns and hinder comfort.

Ventilation

❑ **Mitigate air contamination with temporary ventilation measures.**
Even with physical barriers in place, renovation-related air contaminants such as dust, paint, and adhesive fumes can circulate through a building via its ventilation system (see Chapter 13, "Indoor Air Quality").
- Exhaust air from the renovation zone directly outdoors. Change ventilation and thermal capacity to match the reconfiguration of space. Keep the area negatively pressurized with respect to other areas.
- Remove window panels or other apertures, if necessary, to manage and dispose of construction-related debris and direct temporary exhaust outdoors.
- If an air-handling system serves both the renovation zone and occupied areas, seal

off the potential return-air paths to prevent dust and fumes from circulating.

– Ensure that filtration is sufficient to deal with particulate debris during the renovation. This is best achieved by supplying the renovation area with 100 percent outside air. Inspect and replace filters frequently. Keep the ductwork of the renovated space free of construction-generated debris.

➜ RESOURCES

INDOOR ENVIRONMENTAL QUALITY

American Society for Heating, Refrigerating, and Air-Conditioning Engineers. *ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality.* Atlanta: American Society for Heating, Refrigerating, and Air-Conditioning Engineers, 1989. The existing HVAC standard for ventilation. Prescribes outdoor airflows for various types of spaces.

American Society for Heating, Refrigerating, and Air-Conditioning Engineers. *ASHRAE Standard 55-1992, Thermal Environmental Conditions for Human Occupancy*. Atlanta: American Society for Heating, Refrigerating, and Air-Conditioning Engineers, 1992.

Bearg, David W. *Indoor Air Quality and HVAC Systems*. Boca Raton, Fla.: Lewis Publishers, 1993. Very technical guidance relating HVAC systems to IAQ. Appropriate for the engineering professional.

Kirihara, Jay, ed. *75 Ways to Improve Your Facility's IAQ*. Milwaukee: Trade Press, 1995. Small paperback compendium of practical IAQ tips from a variety of U.S. experts.

U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Atmospheric and Indoor Air Programs, Indoor Air Division. *Building Air Quality: A Guide for Building Owners and Facility Managers*. Washington, D.C.: GPO, 1991. A guide for facility managers and owners defining good management practices that promote indoor air quality. The guide includes useful forms and checklists to be used in developing an IAQ profile of a building, performing an analysis of building IAQ indicators, and mitigating problems in buildings.

ENERGY EFFICIENCY

American Society for Heating, Refrigerating, and Air-Conditioning Engineers. *1991 ASHRAE Handbook: HVAC Applications*. Atlanta: American Society for Heating, Refrigerating, and Air-Conditioning Engineers, 1991. Detailed information on energy conservation measures pertaining to HVAC systems. Appropriate reference for the engineering professional.

Illuminating Engineering Society of North America. *Lighting Handbook*. 8th ed. New York, N.Y.: Illuminating Engineering Society of North America, 1993. Professional handbook on lighting requirements and measurement.

Thuman, Albert, and Robert Hoshidet. *Energy Management Guide for Government Buildings*. Fairmont Press, 1994. Practical rationales for and guidance on energy management. Includes case studies.

U.S. Department of Energy. *Architect's and Engineer's Guide to Energy Conservation in Existing Buildings*. Vol. 2 of *Energy Conservation Opportunities*. Washington, D.C.: GPO, 1990. Detailed technical handbook on 118 energy conservation opportunities (ECOs), including installations, retrofits, and operational practices. Discusses major building systems such as HVAC, lighting, and water, as well as building envelope.

RESOURCE EFFICIENCY

U.S. Environmental Protection Agency. *Lighting Waste Disposal*. Washington, D.C.: GPO 1994. Discusses management of PCB ballast and mercury-containing lamp waste generated at lighting retrofit projects. Discusses current regulations, costs, packaging, transportation, and record keeping.

———. *Waste Minimization Opportunity Assessment Manual*. EPA Technology Transfer Doc. 625/7-88/003. Washington, D.C.: GPO, 1988. Describes a procedure developed by the Hazardous Waste Engineering Research Lab for identifying waste minimization applications. Will be of interest to those responsible for reducing waste streams and to those interested in learning about waste minimization in general.

Wisconsin Department of Natural Resources. *Business and Commercial Recycling: A Guide to Recycling in the Workplace*. 1992. Booklet on waste reduction, reuse, and recycling programs for commercial buildings and other types of businesses. It also describes how to locate markets for recyclable materials.

RENOVATION

American Society for Testing and Materials. Subcommittee on Green Buildings. *Standard Practice for Green Buildings*. ASTM Standard E-50.06, draft document no. 4.0.1. West Conshohocken, Pa.: American Society for Testing and Materials, 1993. Presented at U.S. Green Building Council, March 6-7, 1995. Washington, D.C. Covers design, operation, and demolition of commercial buildings using practices to promote environmental performance and energy efficiency

Carson, H. Tom, and Doye B. Cox. *Hazardous Materials Management*. West Conshohocken, Pa.: Institute of Hazardous Materials Management, 1992. Study guide for the Hazardous Materials Management certification exam. Covers science principles, federal environmental regulations, and environmental management issues.

Coryell, John, and Jack Cearley. *PCB Compliance Guide for Electrical Equipment*. Washington, D.C.: Bureau of National Affairs, 1991. Reference guide for PCB regulatory requirements associated with electrical equipment used in power distribution systems.

CHAPTER 22

Housekeeping and Custodial Practices

Author

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★ SIGNIFICANCE

Soils, particles, gases, and biocontaminants enter a building in many ways, and their concentration is directly proportional to the level of human activity in the building. Maintaining a quality indoor environment requires special attention to these sources of pollution, which can affect the health of building occupants and maintenance workers. Poor housekeeping can lead to environmental health problems such as Sick Building Syndrome, Building-Related Illness, and Legionnaires' Disease. Adjustments to a building's heating, ventilating, and air-conditioning (HVAC) system, environmentally sound housekeeping procedures, and proper selection of cleaning and other chemicals used and stored in the building can control contaminants, promote healthful surroundings, and preserve a building's appearance.

This chapter provides information that can help building owners and managers establish and maintain a good indoor environment. It suggests key management principles, specific housekeeping and custodial practices, and selection criteria for cleaning products.

☞ SUGGESTED PRACTICES AND CHECKLIST

Management

❑ **Adopt the following 10-point list of suggested management principles as a basic framework for administering an environmentally sound building housekeeping program:**

1. Commit to the continual education of building occupants and custodial staff.
2. Clean to protect both health and appearance.
3. Clean and maintain the building in an integrated manner. Cleaning and maintenance in one area of a building can have major impacts on other areas.
4. Schedule routine housekeeping and custodial services. Frequent, thorough, regularly scheduled housekeeping is the most efficient and effective means to achieve high building performance.

5. Develop procedures to address accidents—for example, air contamination caused by noxious chemical reactions, spills, and water leaks.
6. Minimize human exposure to harmful contaminants and cleaning residues.
7. Minimize chemical and moisture residue when cleaning.
8. Ensure the safety of workers and building occupants at all times.
9. Minimize the pollutants that enter the building. Dilution of chemicals does not eliminate contamination; control at the source is recommended.
10. Dispose of cleaning waste in environmentally safe ways.

Green Housekeeping and Custodial Practices

❑ **Tailor cleaning procedures to building activities, and avoid scheduling conflicts.**
Different areas of a building require area-specific cleaning. A day-care center in an office building, for example, requires different housekeeping procedures—at a different frequency—from those for a conference room in the same building.
- Inform building occupants about scheduled major cleanings and any other events that may affect their health and comfort.
- Coordinate housekeeping with the operation of building air-handling systems to ensure that work performed in one area does not affect others, and that adequate ventilation is available for housekeeping and custodial workers. When possible, schedule tasks so that the building can be fully ventilated after cleaning and prior to occupancy.

❑ **Always follow proper dilution, use, safety, and disposal directions for cleaning products.**
The products selected (see "Cleaning Products," later in this chapter) should be the least toxic possible for the specific cleaning task. When using cleaning products, post appropriate safety signs, such as "Wet Floors" or "Construction Area."

❑ **Develop a baseline as the first step in determining a building's cleaning requirements.**
Not only will a baseline help establish a strategy for the building's custodial program, but it will also identify weaknesses in the program, encouraging continual improvement.

❑ **Conduct an annual baseline review or survey, paying particular attention to changes in adjacent properties, building renovations, or changes in building use (such as requirements of new tenants).**
- Inspect the outdoor environment for contaminants, then inspect the building's interior. Outside pollution sources may include dirt surfaces such as roads, walkways, or shrubbery; fields where pesticides, fertilizers, or other chemicals may be used; soils; poorly draining surfaces, such as flat roofs, roads, and parking lots; trash, including the building's and neighboring trash-collection sites; automobile traffic; and local industries.
- Analyze the building's exterior to determine the routes by which pollutants enter the building. Make sure to look for standing water on roofs, which can seep into a building and create breeding grounds for biocontaminants.
- Inspect the entire building to identify sources or conditions that contribute to pollution, especially biopollutants and particles. Areas to inspect include the following: evidence of living organisms, mold, and mildew in the basement; general dust levels; condensation or paint distortion on or around windows and doorways; discolored ceiling tiles (an indication of water leakage); and odors or musty smells. If any of these conditions exist, perform maintenance and increase the frequency of cleaning.

Targeted Building Inspection Areas

Basements, Crawl Spaces, and Areas Containing Mechanical Systems

❑ **Examine the basement and crawl space for dust, debris, insects, standing water, and moisture damage or seepage.**

Basements or other areas containing a building's mechanical systems require special attention, since such unsanitary areas can promote the spread of pollutants throughout the entire building. Simple problems may require only better ventilation, cleaning, and disinfection; more serious or structural problems, the services of an outside contractor. To test that sump pumps and drains are working properly, simply run water in them for at least five minutes.

❑ **Examine flues, vents, back-draft dampers, fans, and filters, noting their general condition and any obstructions, and making repairs as required.**

Regularly inspect, clean, and replace filters for humidifiers and air-delivery systems.

❑ **Ensure that basements and areas containing mechanical systems have no water leaks or standing water, which could spread biocontamination by way of the HVAC system.**

Remove standing water with a wet/dry vacuum and dispose of it properly. Keep floors clean and dust free. Control high humidity and excessive heat to further prevent the growth of biocontaminants. (Specific maintenance requirements for HVAC systems are found in Chapter 12, "HVAC Electrical and Plumbing Systems," Chapter 13, "Indoor Air Quality," and Chapter 21, "Building Operations and Maintenance.")

Garages, Loading Docks, and Shop Areas

❑ **Examine garages, loading docks, shop areas, and any other areas below ground or at ground level.**

Tracked-in soils, vehicle exhaust, and equipment fumes from these areas can affect the indoor environment; garbage dumpsters, often located in these areas, can be a major source of biocontaminants. The maintenance of these areas is especially critical if they are located near fresh-air vents and heating or cooling towers. If they are, relocate either the trash container or the HVAC component. Also, to avoid contamination from exhaust, ensure that fresh-air intakes are not adjacent to truck-loading areas.

❑ **To keep pollutants out of the living and working spaces of a building, keep garages and loading areas free of excessive wastes, especially dusts, oil, and grease that can be tracked inside.**

- Clean exterior surfaces with high-pressure washers.
- Collect and remove trash frequently.
- Provide adequate ventilation (direct exhaust) as needed to control volatile organic compound (VOC) emissions, especially vapors from stored fuels, lubricants, and solvents.
- If local filter traps and absorbents are used, maintain them regularly.

Floor and Carpet Care

❑ **Pay special attention to carpeted entryways, carpeted entry mats, and carpeting in general.**

An estimated 85 percent of the soil deposited in carpets is brought in by foot traffic, so pay special attention to the first six to nine feet of any carpeted area, where the majority of tracked-in soils are likely to be deposited. Pay close attention also to carpeted areas under any vent fed by unfiltered outside air.

❑ **Base cleaning frequency on the types of activities conducted in a building, as well as on its traffic levels, soil load, and desired appearance.**

High-traffic and prominent areas typically require daily vacuuming—in many cases, several times each day. For efficiency, concentrate on the traffic lanes, which often represent only 25 percent of the total floor area.

- ❑ **Remove dust.**
  Use a vacuum with high-efficiency vacuum bags and High Efficiency Particle Air (HEPA) filters, which capture particles rather than spread them.
- ❑ **Avoid overwetting carpets.**
  Too much water can damage carpets and create ideal environments for biocontaminant growth. Carpeted entryways as well as other high-traffic areas should receive interim cleanings with a bonnet system. Highly effective, these cleanings can be done as frequently as necessary, and require an area to be closed off to traffic for less than an hour.
- ❑ **To remove particles and biocontaminants deep in carpet backing, periodically perform deep cleaning with a carpet extractor.**
  The deep cleaning process requires long drying times and can potentially damage the carpet, so do not deep-clean more than twice a year. Check the carpet manufacturer's instructions.
- ❑ **Dust-mop hard floors frequently.**
  Dust-mopping with a water-based mop dressing is the single most effective way to maintain hard floors. Damp-mop and buff or burnish floors as required. A base of six to 12 coats of floor finish is long-lasting and reduces the frequency of floor stripping and re-coating.
- ❑ **Immediately remove spills on hard floors and carpets.**
  Removing spills minimizes tracking to other areas and prevents the formation of hard-to-remove or permanent stains.
- ❑ **Routinely clean window coverings.**
  In effect, window coverings serve as filters for outside pollutants.

Entrances and Lobbies

- ❑ **Pay special attention to entrances and lobbies.**
  Keep as much soil outside the building as possible by trapping dirt and dust at entries. Furnish entryways with mats, grates, and other devices to remove soil from foot traffic entering the building. Also, use effective air filtration devices.
- ❑ **Both entryways and air-filtration devices require routine maintenance.**
  Establish a procedure for cleaning them regularly, and a plan for keeping them clean and dry in severe weather and during special events, when foot traffic is unusually heavy.

Stairs and Elevators

- ❑ **Keep stairs and elevators free of pollutants.**
  Stairs and elevators act as chimneys or breezeways that draw pollutants from lower to upper floors. These areas must be kept free of dust, bacteria, particles, gas emissions from cleaning products, and, in the case of elevators, emissions from lubricants and other products used in their operation and maintenance. Because of potentially heavy foot traffic, these areas often require frequent inspection and cleaning. Maintain the floors, whether carpeted or hard-surface, as described earlier in this chapter in "Floor and Carpet Care."

Offices, Work Spaces, Classrooms, Libraries, and Living Areas

- ❑ **Develop a cleaning plan for interior spaces.**
  Indoor air pollution can actually be many times higher than pollution outside. Organize cleaning and maintenance schedules to meet a building's required standards of health and appearance, basing plans on the types of activities performed in the building, the number of people occupying it, and other factors that influence soil loads and types.
  - Trap dirt, dust, and other soils at entryways of offices, work spaces, and living areas with proper matting.

- Control dust on interior surfaces. Use a dampened or treated dustcloth rather than a feather duster, to catch and hold dust instead of just moving it around. Periodically dust or clean walls. Make sure that vacuum cleaners are in proper working order, and use high-efficiency bags and HEPA filters.
- Clean telephone receivers frequently with a disinfectant (see "Cleaning Products," later in this chapter), taking care not to damage the equipment. Clean doorknobs, light switches, and other surfaces that come in frequent contact with hands.
- Clean windows and light fixtures to improve lighting.

Food-Preparation and Eating Areas

❑ **Thoroughly clean food-service areas after each food-preparation or eating period.**

Thorough cleaning of food-service areas thwarts biocontamination.

- Clean the undersides as well as the tops of tables.
- Wash floors in these areas daily.
- Vacuum carpets and fabrics daily and deep-clean them monthly or more frequently, as needed. Check the carpet manufacturer's instructions regarding deep cleaning.
- Routinely inspect walls, ceilings, and vents and clean them as required.
- Be sure to remove any food scraps and standing wastewater that can become hosts for fungi and bacteria. Check for these under sinks, dishwashers, refrigerators, and trash cans.
- If the site includes a restaurant or a mid- to high-volume food-preparation area, have perishable refuse picked up daily. Ensure that trash containers are covered, and that pest control is effective.

Washrooms, Restrooms, Showers, and Bath Areas

❑ **Develop a cleaning and maintenance plan for lavatories.**

Lavatories pose special cleaning problems because they offer ideal environments for bacteria and fungi to develop and spread throughout a building. Building occupants often judge the quality of an entire building by the condition of its lavatory facilities.

The frequency of lavatory cleaning should be based on the number of people using the facilities. In high-traffic public washrooms, cleaning may be required many times throughout the day.

❑ **Pay particular attention to any standing water, which can be a source of biocontamination and create unsafe conditions.**

- Regularly mop floors with a disinfectant solution, especially in areas around urinals and toilets.
- Check floor drains for proper function.
- Sanitize fixtures inside and out, along with countertops, mirrors, and any metal surfaces.
- Regularly clean and sanitize showers and bathtubs, including the shower heads, faucets, and handles. Clean the build-up of mold and mildew on bath and shower walls.
- Remove trash daily and sanitize the receptacles. Inspect supplies in paper-towel, toilet-paper, and soap dispensers daily.

Mail, Copy, and Computer Rooms

❑ **Remove dust and other particles from walls and other surfaces with a damp (but not wet) cloth.**

❑ **Damp-mop floors with a neutral-pH quaternary ammonium disinfectant solution that cleans, sanitizes, and minimizes potential static build-up.**

❑ **Periodically vacuum the rooms' ventilation systems to prevent the spread of particles from paper products throughout the building and coordinate removal of paper waste with building recycling efforts.**

- ❑ **Remove stains caused by inks, glues, gums, oils, and toner, and remember to clean light switches and doorknobs to ensure that these chemicals are not spread throughout the building.**
  Establish a procedure for occupants and cleaning crew to follow to remove spills as quickly as possible. Carefully select appropriate cleaners.

Custodial Closets and Storage Areas

- ❑ **Carefully select and properly store potentially hazardous cleaning materials.**
  Kept in large quantities in custodial closets and storage areas, cleaning supplies and equipment can themselves become a source of contamination within a building. This is especially true if the supplies are flammable, corrosive, or reactive. (See "Cleaning Products," later in this chapter.)
- ❑ **Store only properly maintained cleaning equipment and supplies.**
- ❑ **Remove trash and waste products from storage areas, and wash and disinfect their floors, walls, and sinks regularly.**
  Check drains for proper operation. Keep storage areas well-ventilated and dry. Make sure that all waste products—liquid, solid, and gas—are disposed of properly.

Attics and Upper Areas

- ❑ **Frequently check attics for leaks, standing water, dust, and debris.**
- ❑ **Check for pests, birds, and rodents.**

Pest Control

- ❑ **Plan and implement an integrated pest management (IPM) program.**
  IPM is a coordinated approach to pest control that is intended to prevent unacceptable levels of pests (see Chapter 7, "Site Materials and Equipment") by the most cost-effective means and with the least possible hazard to building occupants, workers, and the environment.
- ❑ **Eliminate all sources of food, such as scraps from eating areas and grease in stoves, hoods, and vents.**
- ❑ **Keep refuse in tight containers away from the building.**
- ❑ **Add physical barriers, such as chimney screens and air curtains, where necessary, to prevent pest entry and movement.**
- ❑ **When traps are necessary, use light traps, glue boards, and snap traps.**
- ❑ **When chemical pesticides are necessary, apply them only in targeted locations, using minimal applications on exposed surfaces.**
  Schedule pesticide application during the building's unoccupied hours. Notify occupants in advance, as some particularly susceptible individuals could develop serious illness. Adjust the HVAC system to prevent contamination of other areas, and flush out the affected area with ventilation air before occupants return. Pesticides should be species-specific and of minimal toxicity to humans and non-target species.

Cleaning Products

- ❑ **Select cleaning products which minimize waste and harmful chemicals using the following guidelines:**
  - Reduce the quantity and toxicity of materials and packaging;
  - Purchase products that are durable, reparable, reusable, or returnable;
  - Purchase for recyclability, and coordinate recycling with an established collection system;

– Select products derived from renewable sources, such as detergents and solvents made from cornstarch, coconut oil, and orange peels; and
– Select chemically benign products that minimize harmful exposures, potential health risks, and adverse environmental impacts.

❑ **Keep Material Safety Data Sheets (MSDSs) on file and available for review by workers.**
The U.S. Occupational Safety and Health Administration (OSHA) requires MSDSs for all chemical products used in the workplace. In addition, OSHA requires annual safety training and training in the proper use of all new chemical products. Always follow the manufacturer's recommendations for product use, storage, disposal, precautions, and first aid.

❑ **Consider the following health and safety factors when selecting cleaning products:**
– Look for controlled or moderate pH. Extremely high-pH products (caustics) or extremely low-pH products (acids) are more hazardous than those of moderate pH. Products that are closer to pH 7 are safer than those with extreme pH.
– Identify hazardous ingredients using the MSDSs. In many cases, products containing no OSHA-designated hazardous ingredients are available.
– Avoid products containing a known or suspected carcinogen.
– Select products that are non-irritating or mildly irritating. Some users may be especially susceptible to skin and eye irritation. If information about this hazard is not available, follow the guidelines for controlled pH.
– Select products that protect against accidental poisoning. Typically, products with an LD(Lethal Dose)$_{50}$ above five grams per kilogram are outside the range of accidental poisoning risk. (LD_{50} indicates the amount of material, which, if ingested, would cause 50 percent of test subjects to perish.)
– Choose non-reactive products. This minimizes the risk of mixing two products that produce a toxic gas, fire, or other dangerous reaction. For example, mixing a product containing chlorine with an acid or ammonia gives off poisonous gases.
– Select products containing the *minimum* amount of fragrance and dye needed for safety reasons. While fragrances and dyes have little cleaning value, they help users differentiate between products by color and smell, thereby reducing the risk of inadvertent product misuse. Some fragrances, however, may cause allergic reactions.
– Wear gloves, masks, and other appropriate personnel protective equipment (PPE) according to MSDS and manufacturers' directions.

❑ **Consider the following environmental factors when selecting cleaning products:**
– Select products whose constituent ingredients have been tested for easy biodegradability, the measure of a product's ability to be reabsorbed into the environment. Most cleaning products—at some dilution and over an extended period of time—can be termed "biodegradable."
– Avoid products with demonstrated aquatic toxicity, indicated by a warning against contact with soil or wildlife.
– Eliminate use of ozone-depleting compounds (ODCs). ODCs, considered a major cause of global warming, can still be found in many shops and maintenance garages, especially where painting is done. Closely scrutinize product information for the presence of chlorofluorocarbons (CFCs) and other chlorinated solvents.
– Consider switching to solvent-free or water-based products. Many solvent-based products contain volatile organic comounds (VOCs) that cause smog. Instead of an alcohol-based glass cleaner, use one that is detergent-based. Use water-based wood and gym-floor coatings, and replace chlorinated cleaning solvents with citrus-oil-based, aqueous, and semi-aqueous products.
– Avoid heavy metals, such as lead, cadmium, and zinc, which can cause severe health problems and have a potentially negative upstream impact on the environment. Heavy metals in floor finishes, for example, may enter sewer treatment facilities through disposal in building plumbing. For housekeepers, an added benefit of conver-

sion to non-heavy-metal alternatives is that the stripping solutions necessary to remove metal-free polymers tend to have a mild pH and less associated health risks.

- Avoid products that require disposal as a hazardous waste. Review MSDSs to determine if products require disposal as hazardous wastes.
- Avoid products that require special respiratory protection. However, always use the PPE specified on the MSDS.

❑ **Consider reduced packaging of cleaning products.**

- Select concentrated products and dilute them on-site. Compared to ready-to-use products, concentrated products significantly reduce packaging.
- Utilize portion-control equipment to reduce chemical misuse and waste and to enhance user safety by minimizing user exposure to concentrated chemicals.
- Find out if the product supplier takes back product packaging for reuse.
- When considering the recyclability of packaging, check with your local recycler.

➔ RESOURCES

Berry, Michael A. *Protecting the Built Environment: Cleaning for Health*. Chapel Hill, N.C.: Tricomm 21st Press, 1993. Outstanding resource book covering definitions and causes of indoor pollution, corrective action, and housekeeping procedures.

U.S. Environmental Protection Agency. *Glossary of Terms Related to Health, Exposure, and Risk Assessment*. EPA/450/3-88/016. Washington, D.C.: GPO, 1989. A straightforward glossary of terms.

U.S. Environmental Protection Agency and National Institute of Occupational Safety and Health. *Building Air Quality Guide*: *A Guide for Building Owners and Facility Managers*. EPA/400/1-91/033. Washington, D.C.: GPO, 1991. Very popular and readable practical guide to overall indoor environmental quality in commercial buildings, especially office spaces.

U.S. Environmental Protection Agency and U.S. Consumer Protection Safety Commission. *The Inside Story—A Guide to Indoor Air Quality*. EPA/400/1-88/004. Washington, D.C.: GPO, 1988. A guide to the issues relating to indoor air quality.

CHAPTER 23

Local Government Information: Operations and Maintenance

Author
Michael Myers

IMPLEMENTATION ISSUES

Many buildings owned or operated by local governments have no guidelines or cost estimates for operations and maintenance (O&M) activities. Yet, developing clear O&M procedures can help localities operate facilities more effectively and maintain the integrity of building systems. Requests for proposals (RFPs) and specifications for new municipal buildings can require that architectural and engineering firms, in conjunction with the building manager, provide an O&M plan. For existing buildings, developing plans to maintain quality or upgrade space and function will help assure an extended life cycle and improve occupant satisfaction. Preserving systems through sound O&M practices can allow local dollars to be used for expenditures other than the early replacement of equipment.

O&M practices cover a range of areas, including indoor air quality; heating, ventilating, and air-conditioning (HVAC) system upkeep; recycling and resource efficiency; repairs and renovation; and cleaning practices and products.

LOCAL ACTIONS

➤The Ridgehaven Green Building renovation project being carried out by the city of San Diego, California, features highly efficient energy systems and environmentally sensitive products, and also includes the development of an O&M manual for the building. The manual will focus on maintaining good indoor air quality, waste minimization, ongoing energy efficiency through monitoring and building controls, and water conservation practices.

➤The Maryland Department of Education's School Facilities Branch has developed a series of technical bulletins on indoor air quality for the secondary school system. One of the bulletins, "The Maintenance of Heating, Ventilating and Air-Conditioning Systems and Indoor Air Quality in Schools," addresses O&M practices for HVAC systems. The bulletin also discusses the development of O&M manuals as a valuable tool for staff training and for the continued proper use of the HVAC system.

- ➤The Environmental and Conservation Services Department in Austin, Texas, produced the *Sustainable Design Guidelines Manual* for the new Austin Airport. The chapter on chemical use emphasizes reduction in the use of potentially dangerous chemicals for pest control and cleaning. While all chemicals cannot be completely eliminated, the use of termite shields and sand barriers, caulking of windows and screens, and kitchen designs that facilitate cleaning, can decrease the need for chemical extermination. The manual recommends that cleaning products be carefully screened for toxic chemical content and that they be biodegradable, if possible. It also encourages education of cleaning staff about the products they use.
- ➤The Pennsylvania-based Slippery Rock Foundation has produced *Guidelines for Sustainable Development* to explain and promote green building practices to building owners and renters. The O&M section of the manual provides suggestions regarding energy systems, lighting, appliances, water conservation, recycling, indoor air quality, and the purchase of environmentally sound products.
- ➤Effective operations and management of facilities enables Denver International Airport to reduce the generation of waste, instead of merely dealing with waste that has already been produced. The airport's source-reduction program includes low-flow toilets, drought-resistant grass, energy-efficient lighting, recycling of ethylene glycol from centralized de-icing facilities, and employee "flex" time and telecommuting to reduce vehicle miles traveled.
- ➤The 1990 Energy Policy adopted by Portland, Oregon, calls for a 10 percent increase in energy efficiency in city-owned facilities by the year 2000. The city is working to achieve this goal by retrofitting existing facilities and changing the way they are operated and managed. Portland also offers cash rebates and tax credits as incentives for apartment owners to weatherize. In 1990, Portland began offering O&M training to the operators of boiler heating systems in 10 low-income apartment complexes. Simple maintenance and training at the sites focused on adjustments that could be made at an average cost of $850 per unit. Apartments involved in the project showed an average 10 percent savings compared to operations before the O&M training. This success led to the expansion of the program to other buildings with oil-burner heating systems.
- ➤In 1988, the Municipal Council of Newark, New Jersey, approved an ordinance requiring that proposals for development of 50 or more new single family units, 25 or more new multi-family units, or 1000 square feet or more of commercial/industrial space must incorporate provisions for the separation, collection, and disposal of recyclable material. The city also adopted legislation requiring the purchase of recycled products and launched a business development program, called Planet-Newark, for companies in the recycling business.
- ➤Albuquerque, New Mexico, recycles latex paint and uses it for graffiti removal from buildings. Albuquerque projects an annual savings in excess of $12,000 in disposal costs even after the reprocessing of the paint, and saves an additional $15,000 in new paint costs. This project diverts potential groundwater contaminants from the landfill, provides a less costly disposal method, makes use of an otherwise unusable product and results in a less costly product being available for an important community project.

LOCAL OPTIONS

- ■ Set up an advisory team to evaluate the capital and operating costs of effectively maintaining existing public buildings and provide annual reports on building O&M to document practices and costs.
- ■ Incorporate O&M costs and procedures into the overall cost projections for any new building development.
- ■ Require O&M plans for all municipal or governmental buildings.

- Develop an O&M manual for local government buildings that incorporates green maintenance practices and non-toxic cleaning products.
- Provide information to building occupants on IAQ and water conservation policies and practices.
- Provide training in green O&M practices on an ongoing basis to maintenance staff and building occupants.
- Designate recycling areas as part of floor plans in new or renovated buildings in a manner that promotes efficient recycling

➜ RESOURCES

Resources for the Local Government Information chapters are located in the Appendix.

PART VII

Issues and Trends

Introduction

While progress is being made in achieving sustainability, even greater levels of energy and environmental efficiency, durability, and renewability are possible as green building practices continue to move forward. The benefits of economic savings and increased occupant productivity provide additional incentives to continue research and development in this field. As more public and private entities invest in sustainable practices, even greater opportunities for savings and optimal use of limited resources will emerge.

Sustainable building practices are being adopted by an increasing number of building owners, both public and private, for both new construction and renovations. At the local government level, green building initiatives, including the adoption of public policy and practices, are expanding each year in cities and counties across the United States. Many of these green building initiatives serve as models for future residential and commercial green programs. In the private sector, building owners and operators from major corporations to small businesses, along with product manufacturers, construction companies, and financiers, are discovering the economic and environmental benefits of green buildings.

The final chapters of the manual address issues that affect the adoption and success of green building practices. Chapter 24, "Local Government Financing," describes green building financing and cost issues for local governments. Chapter 25, "The Future of Green Buildings," discusses developing green building trends and standards, as well as upcoming issues for consideration by building developers, owners, and managers.

CHAPTER 24

Local Government Financing

Editors

Daniel J. Goldberger and Philip Jessup

Deciding to use green building methods and selecting energy- and resource-efficient building materials are only the first steps in the green building process. As with any capital investment project, local governments must also secure the funds necessary for a state-of-the-art green building—often without drawing from already sparse budgets. This section highlights local government financing issues, suggested options, and local government examples.

IMPLEMENTATION ISSUES

Political and Institutional Support

Local government leadership is essential for a successful sustainability project. If elected officials and city or county managers are willing to support potentially larger up-front project costs and the use of innovative technologies and products, the return can be reaped through future economic and environmental savings.

Yet, many institutional barriers exist. For example, in the area of energy use, the extent of consumption may not be apparent if each department, agency, or district is responsible for its own energy bills. Expenditures for energy use may represent only a small amount of each department's budget (usually one to two percent). However, if the energy costs for an entire municipality are taken into account, this can be a sizable expenditure (for example, a $358 million electric utility bill in New York City). Having one person or office coordinate all energy use and track the cost-effectiveness of new measures, such as retrofits of energy-efficient lighting or heating and cooling systems, is a proven way to increase efficiency and profitability.

Another barrier to implementing energy conservation programs occurs when a department's cost savings lead to a reduction in its operating budget for the next year. An alternative is to return part of the savings to the operating or capital budget and apply the rest to programs in the department that implemented the energy-saving measures.

Front-End Costs

One of the greatest hurdles to green building is securing the financial resources to purchase energy-saving systems and environmentally sound building materials that may have higher front-end costs than traditional building products. Local governments with ever-decreasing budgets are reluctant to spend more for building components than would be necessary in the standard "low-bid" system in which the bid with the lowest front-end costs is chosen. While this is a conventional government purchasing practice, it can discourage innovation and reduce a building's life-cycle cost-benefit outcome. Local governments can view financing green products and systems as an investment in long-term cost savings, as well as in the improved health and productivity of building occupants and the environment (see Chapter 1, "The Economics of Green Buildings").

Life-Cycle Costs and Full-Cost Accounting Methods

One way to factor in the long-term benefits of resource-efficient buildings is to analyze life-cycle costs of materials and systems as part of local government procurement decision-making. While some materials or systems may have relatively high purchase prices, their durability, safety, and efficiency over the life cycle of the building can ultimately increase their value over low-cost options. Despite the tremendous pressure for local governments to reduce expenses wherever possible, adopting life-cycle cost analysis as a criterion for procurement can produce long-term savings.

Full-cost accounting is another method of assessing the environmental costs of products or systems. For example, when evaluating the cost of investing in an energy-efficient system, a local government can take into account the cost imposed upon the environment when a less efficient system is chosen. When the cost borne by the environment is added to the purchase price for goods or services, the true cost impacts may alter local government decisions. Using life-cycle cost analysis and full-cost accounting systems, the economic viability of energy-efficient and environmentally friendly buildings will be assessed in a more comprehensive manner in comparison to conventional buildings.

Cream Skimming Versus Deep Retrofits

Local governments may tend to invest in energy-efficiency projects with relatively fast payback times, a practice known as "cream skimming." While these projects initially have much lower investment costs and, therefore, quicker payback, they may have a lower percentage savings in the long run. For example, the use of high-efficiency light bulbs has a payback time of about three years. A short-term payback project is often very attractive to a local government that is hesitant to invest a large amount of capital (or undertake a large debt) for a project.

A more extensive retrofit of energy-efficient systems or the extensive use of green building fixtures and materials in new construction is usually associated with considerably higher initial cost, but the energy savings and environmental benefits are much greater than with a short-term retrofit. The result is a longer payback period with much higher energy- and resource savings. *Figure 1* compares the two types of energy retrofits. As illustrated in the graph, the energy savings of the more comprehensive retrofit becomes significantly higher over time than those of a simple retrofit.

Figure 1

SIMPLE CUMULATIVE CASH FLOW PER FIXTURE

Source: ICLEI: Profiting From Energy Efficiency.

Financing Options

There are many alternative forms of financing available to local governments, including some that provide positive cash flow from the outset. Traditional financing methods include allocating local government funds for building systems, issuing bonds, or taking out loans. Alternative financing can include third-party financing and lease-purchase agreements.

LOCAL OPTIONS

Self-Financing

Self-financing of resource-efficient buildings is achieved through budget allowances from operating or capital funds. This option expends scarce financial resources, but also allows the local government to retain control of system operation and to receive all of the savings, which can be used to retire the debt on the project. For environmental measures such as energy efficiency, funds can be allocated to the capital budget so that expenditures are carried as an investment rather than an operating cost.

Some local governments or municipal utilities have established revolving funds in which a percentage of energy savings are reinvested for new efficiency projects. Thus, an initial investment essentially becomes an environmental endowment whereby energy savings from one project fund the creation of another. This allows energy savings to grow through continued building retrofits and purchasing of high-end energy efficiency systems in new buildings.

Direct Borrowing

Direct borrowing allows for project funding without increasing the government's capital budget. Local governments can borrow money from commercial banks, pension funds, insurance companies, or other financial institutions, and then use the savings from the funded project to pay the financing costs. While the local government maintains control of the project and receives all of the potential savings, it also assumes the entire risk for the project.

Bonds are similar to loans and can generally be offered at lower interest rate since the interest on them is tax-free. Bonds are generally more complex to arrange than loans since legal fees and processes can be extensive. General obligation bonds are a typical means of issuing debt and usually require a referendum vote. Revenue bonds are issued in direct anticipation of future savings from the financed project and are typically reserved for large projects, such as co-generation plants where the energy savings and sales can be projected with relative certainty.

Third-Party Financing

Utilities, large energy equipment manufacturers, or other private businesses often undertake performance contracts with public or private entities as a means of financing energy-efficiency retrofits. These third parties will finance and install an energy-saving system in return for a share of the energy cost savings for that site during the length of the contract. After the expiration of the contract, the local government owns a more efficient system and can allocate savings to other portions of its budget. The following table (*Table 1)* shows the varying financial methods available to local governments to work with a third-party financier under a performance contract.

Table 1

PAYMENT TO ENERGY PROVIDER/FINANCIER	ADVANTAGES
Fixed Percentage - practice of "shared savings" where the contractor/provider receives a set percentage of the savings over the previous energy consumption for a set period of time.	There is a definite incentive for the contractor to maximize efficiency. The income for the local government increases with that of the contractor.
Direct Payout - the contractor receives all of the savings for a set period of time. Commonly known as a "fast payout."	The local government is divested from the contractor as quickly as possible and receives all of the savings from that point onward.
Fixed Saving - "chauffage" agreement where the local government is guaranteed a level of saving, with any shortfalls met by the contractor or any excesses paid to the contractor for a set period of time.	The local government can set precise budgets during the length of the contract and then adjust to real levels at the end of the contract.
Flat Fee - in this "energy savings" agreement the contractor is paid a set fee for energy services. If the building uses less energy, the contractor keeps the difference. If the building uses more, the contractor pays the difference.	This is contracted service delivery that allows local governments to set their budgets well ahead of time.

Since newer, energy-efficient systems are much more cost-effective over their life cycle than older systems, an improved system will usually result in energy savings that are greater than monthly payments for the system improvements, thus resulting in a short payback period. After the payback period, the new system continues to be a source of financial savings.

Energy Service Companies

Many private companies are realizing the potential profits of energy financing and have specialized in energy-efficiency equipment financing and installation. These enterprises are known as energy service companies (ESCOs) that specialize in retrofitting buildings with state-of-the-art energy equipment. In most cases ESCOs are for-profit companies that can finance, plan, and manage a retrofit project.

Energy-efficiency projects are generally arranged so energy savings are greater than monthly financing costs, thus establishing a positive cash flow for the project. In some cases the municipality arranges for its own financing and then pays the ESCO to install and possibly manage the system. In this case, the ESCO serves as a specialized engineering firm and is paid for its services. In many cases, the ESCO arranges for financing (either through its own resources or through a third party). Financing through an ESCO may result in higher financing costs since ESCOs do not receive interest rates as favorable as municipalities.

ESCOs are interested in achieving the highest efficiency possible, not only as a means to secure future contracts but also because their payment from the building owner is generally arranged as a portion of the energy savings (as described in *Table 1*). In a typical program, the ESCO will usually split all of the savings, or any savings above a guaranteed level, with the owner. For higher-risk projects and unusual situations, the ESCO may ask for a higher percentage of the upside profit.

ESCOs will usually audit energy expenditure before the retrofit project and monitor after the project's completion to guarantee energy savings. Additionally, some ESCOs will assume responsibility for all or part of building operations. Municipal managers may be uncomfortable with this arrangement and may fear displacement of municipal workers. If municipal employees are involved with the ESCO from the beginning, the subsequent sharing of knowledge and expertise can actually increase the retrofit's effectiveness and the facility manager's expertise in the long run. Involvement of municipal managers and their staff during the entire retrofit (from audit through commissioning) is considered essential for project success.

The ESCO industry has matured tremendously over the past few years. A range of companies now offers a wide variety of services to municipalities and private building owners. Municipalities that contract with the ESCOs will find that they:

- offer specialized financial and technical expertise and experience;
- guarantee energy savings and therefore minimize the financial risk;
- offer a range of creative financing options;
- perform building energy audits and suggest cost-effective energy technologies and measures; and
- assume the administrative burden of monitoring and verifying energy costs.

Lease-Purchase Agreements

Lease-purchase agreements offer the local government a "save now, pay later" option for energy-efficiency projects. Through this arrangement, a third party provides the equipment for the efficiency project, and the local government makes payments on the equipment from the savings achieved by the program. At the end of the lease agreement, the local government assumes ownership of the equipment or may purchase it for a greatly reduced price. The two primary benefits of this option are that leases to local governments are tax-deductible and, therefore, can often be obtained at a low price. In addition, the lease can be carried off the balance sheet by the local government. (See Chapter 25, "The Future of Green Buildings," for more information on green leases.)

LOCAL ACTIONS

The following section is an overview of some local government programs that have successfully used a variety of financing options for green buildings.

➤ The city of Phoenix, Arizona, established the Energy Conservation Savings Reinvestment Plan in 1984 to promote continuing energy improvements in the municipal sector. The program received $50,000 in seed money from state oil overcharge funds. Each year, half of the documented savings from each project is returned to the city's general fund. The other half is reinvested in the energy-efficiency program fund. By 1986, annual energy savings were over $1 million, which allowed the fund to reach its allowable limit of $500,000 a year (recently raised to $750,000 to compensate for inflation). The fund has financed retrofits resulting in $18 million of audited savings from 1978 to 1992.

➤ The Sacramento Municipal Utility District in California established the Conservation Power Financing Program (PFP) in 1990. The PFP provides rebates and loans to private sector businesses for energy-efficiency projects. The utility began this demand-side management program because it realized that financing projects that reduce consumer demand (through retrofit of high-efficiency systems and conservation measures) is more profitable than increasing energy production to meet demand. While the rebates from this program are being phased out (already down from 75 percent credit on investment to 35 percent), building operators throughout the municipality are realizing the potential energy savings and positive environmental impacts that result even without the rebate.

➤ The city of Chicago, Illinois, is currently undertaking a comprehensive energy retrofit program for its buildings. Part of this program includes a Department of General Services retrofit of 45 police stations and city libraries, funded by bonds and utility vendors. Debt on the project will be repaid by short-term savings from lighting retrofits and long-term savings from the installation of digital controls for HVAC systems.

A unique feature of the installation contract is the direct involvement of the city building management tradespeople, who will also receive training in the ongoing maintenance and operation of the control systems. Estimated energy cost savings for just five of these retrofitted facilities are $273,700 annually.

- ➤The Environmental and Conservation Services Department in Austin, Texas, assists municipal planners by providing guidelines for energy efficiency systems and green building practices and products. The city uses life-cycle cost analysis when determining budgets and funding for new buildings and the retrofitting of existing buildings. This allows Austin to look beyond the initial costs of materials and systems and focus instead on long-term sustainability.

NOTE

This chapter was adapted from *Profiting from Energy Efficiency: A Financing Handbook for Municipalities,* Dan J. Goldberger and Philip Jessup, editors (Toronto: International Council for Local Environmental Initiatives, 1994).

CHAPTER 25

The Future of Green Buildings

Author
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Introduction

To many in the building industry, investment in green building practices may be a leap of faith. Further research and successful examples of sustainable building will advance this developing technology and provide direct proof of its economic and health-related benefits, encouraging its greater adoption. More research is needed in life-cycle cost analysis over the full spectrum of building fabrication, ownership, operation, and reuse/disposal. As the data become more widespread and the impacts—including external costs associated with pollution, waste, and environmental-resource consumption—of conventional practices become better known, green building practices will become more widespread.

The green building movement has started to gain momentum. Each year yields additional demonstration projects; dozens of new efficient and healthy technologies; and expanded research, standards, codes, and regulations. This chapter provides information on new developments in these areas and new issues that should be considered by the building industry and building owners.

These include rating systems to evaluate a building's environmental performance, certification programs for green building products, and the adoption of green building standards and practices by recognized standard-setting organizations. The availability of increasingly sophisticated computer software programs also fosters the growth of green building practices by making it easier to identify and evaluate options for a building project. Other new trends and emerging concepts affecting the building industry include performance-based contracts, remanufacturing and product leasing, telecommuting and "virtual offices," and efforts to mitigate natural-disaster losses through improved building practices.

Building-Rating Systems

Green building-rating systems are used to evaluate new or existing buildings based on their environmental performance. Reviewers issue credits in each performance category and assign an overall environmental performance rating to the structure. With public acceptance, rating systems can change the way designers, building owners, and tenants evaluate buildings. Following is a brief review of several rating programs.

Building Research Establishment Environmental Assessment Method/New Offices

The Building Research Establishment in England has developed a voluntary assessment method for new building designs, known as the Building Research Establishment Environmental Assessment Method (BREEAM)/New Offices, Version 1/93. Its objectives are to encourage designers to become more environmentally sensitive; create a demand for buildings that are "friendlier to the environment"; stimulate a market for environmentally sound buildings; raise awareness about large-impact buildings and lessen their burden on the environment; and improve the indoor environment and health of occupants. The assessment covers three main areas of environmental issues: 1) global issues and the use of resources, 2) local issues, and 3) indoor issues (*Figure 1*).[1]

Other BREEAM assessment methods have been established for existing offices, industrial units, supermarkets, new housing, and other building topics. The version for existing offices assesses the operation of buildings based on their environmental policies and management, and is supported by an Environmental Management Toolkit.

BREEAM/NEW OFFICES ASSESSMENT CATEGORIES

Global Issues and Use of Resources

- CO_2 emissions resulting from energy use
- Acid rain
- Ozone depletion from CFCs, HCFCs, and halons
- Natural resources and recycled materials
- Storage of recyclable materials

Local Issues

- Legionnaires' Disease arising from wet cooling towers
- Local wind effects
- Noise
- Overshadowing of other buildings and land
- Water economy
- Ecological value of site
- Cyclists' facilities

Indoor Issues

- Legionnaires' Disease from domestic water systems
- Ventilation, passive smoking, and humidity
- Hazardous materials
- Lighting
- Thermal comfort and overheating
- Indoor noise

Figure 1

Building Environmental Performance Assessment Criteria

The Building Environmental Performance Assessment Criteria (BEPAC) is a voluntary Canadian method for evaluating the environmental performance of both new and existing office buildings.[2] It was developed in collaboration by many sectors of British Columbia's building industry. The method includes criteria to assess ozone-layer protection, environmental impacts of energy use, indoor environmental quality, resource conservation, building and siting considerations, and transportation impacts. BEPAC is intended to advance standard practices and achieve efficiencies beyond those required by building codes. BEPAC standards are consistent with the current best practices and are intended to lead industry toward a higher level of environmental responsiveness.

BEPAC is applied in the field by trained assessors and offers a certificate of design and management performance for qualifying buildings and tenancies. Four modules—base building design, base building management, tenancy design, and tenancy management—offer criteria ranging from interior to local and global issues. The BEPAC certificate tallies points across the individual criteria and provides a comprehensive profile of the building's performance. BEPAC also recognizes innovations in design and management with a special citation.

ISO 14000

The International Organization for Standardization (ISO) is a non-governmental organization comprised of national standards bodies.[3] More than 120 countries have full voting membership in ISO, with the United States represented by the American National Standard Institute (ANSI). ISO has traditionally sought to harmonize existing technical national/regional standards and more recently is moving towards promulgation of process standards. ISO standards are voluntary and mainly technical in nature; they are written on a consensus basis by Technical Committees made up of voting members.

ISO 14000 is a series of environmental standards and guideline documents in the areas of environmental management systems, audits, performance evaluation, labeling and product standards, and life-cycle assessment. Because of the international focus of the standards, they are expected to have wide-ranging impacts in the global marketplace by becoming a condition of doing business internationally. In the United States, the federal government anticipates that establishment of these international standards will help level the playing field between American and international businesses and will result in progress toward worldwide environmental improvement.

The Environmental Management Standard (ISO 14001) has been adopted by ANSI in the United States and is expected to be adopted internationally in 1996. Certification to ISO 14000 standards will require governments and industry to systematically manage, measure, improve, and communicate the environmental aspects of their operations. The standards will influence the design, manufacture, and marketing of products; the selection of raw materials; the types of environmental data that is gathered; and how this data is communicated to governments and to the public.

U.S. Green Building Council — Proposed National Rating System

The U.S. Green Building Council (USGBC) is a nonprofit coalition formed by the building industry in the United States. Its membership includes approximately 100 organizations—both public and private—representing major national product manufacturers, building owners, utility companies, research institutions, and universities. Participating cities include Austin, Texas; Phoenix, Arizona; and San Diego, California. The council has drafted a proposed national commercial environmental building rating system.[4] The goal is to strike a balance between known effective practices and emerging concepts regarding environmental performance and energy efficiency, with the intent that it will be updated as technology and knowledge advance. The proposed rating system, undergoing development through the USGBC consensus process, will apply to both new and existing commercial office buildings.

Product Certification

Several entities specializing in product certification for the building industry have recently emerged in the United States. Two of the principal organizations, Green Seal and Scientific Certification Systems, adopt standards for building products based on their own guidelines. Both entities solicit varying degrees of public comment, although neither follows a full and open consensus process such as that followed by the American Society for Testing and Materials (ASTM). Once a standard has been developed, Green Seal and Scientific Certification Systems review manufacturers' product information. If the product information and associated specifications and performance data exceed the standard, a product receives the organization's certification and associated seal.

Green Seal

Green Seal is a nonprofit organization devoted to environmental standard setting, product certification, and public education.[5] Green Seal's intent is to reduce, to the extent technologically and economically feasible, the environmental impacts associated with the manufacture, use, and disposal of products. Underwriters Laboratories Inc., is Green Seal's primary testing and inspection contractor. Green Seal certifies products in over 50 categories and has awarded its seal of approval to nearly 240 products, including some building industry products, such as compact fluorescent lamps, water-efficient fixtures, paints, windows, window films, water heaters, sealants and caulking compounds, adhesives, luminaries, and anti-corrosive paints.

In addition to identifying products that are designed and manufactured in an environmentally responsible manner, Green Seal offers scientific analysis to help consumers make educated purchasing decisions regarding environmental impacts and encourages manufacturers to develop environmentally sound products.

Scientific Certification Systems

Scientific Certification Systems (SCS) is a private scientific organization. Its mission is to advance the private and public sectors toward more environmentally sustainable policies, product design, management, and production.[6] SCS has created the following programs relevant to sustainable building practices:

- *Environmental Claims Certification*—A system for verifying the accuracy of environmental claims about products.
- *Life-Cycle Assessment and the Certified Eco-Profile*—A procedure for assisting organizations in performing life-cycle assessments, including an environmental profile, review of advantages and tradeoffs, development of improved strategies, and documentation of achievements. The Certified Eco-Profile provides an environmental profile of a product and its packaging.
- *Forest Conservation Program*—A project that identifies sustainable forest management practices and uses an indexing system to rate forest operations.

U.S. Environmental Protection Agency—Proposed Guidance for Environmentally Preferable Products

To carry out its commitment to minimizing the environmental impact of products and services it purchases, the federal government, under Executive Order 12873, is developing a guidance for executive agencies to use when purchasing goods and services. The guidance is being prepared by the U.S. Environmental Protection Agency (EPA), which has encouraged public comment to ensure that the final document is comprehensive, reasonable, and practical. The proposed guidance is not regulatory, but is designed to help federal agencies apply their $200 billion-a year-federal purchasing power toward creating a demand for environmentally preferable products. General guiding principles have been established, along with recommendations for issuing policy directives and applying the principles to pilot acquisitions.[7]

Building Standards

Environmental concerns are becoming increasingly important elements in the development of standards. Several building-oriented standard-setting activities and developments are discussed below.

American Society for Testing and Materials—Green Building Standard Activities

The American Society for Testing and Materials (ASTM) is a voluntary, consensus-based standard-setting organization. Its membership includes approximately 30,000 technical professionals from the public and private sectors. In 1992, ASTM's Green Building Subcommittee, E-50.06, was formed. The subcommittee is working on green building-oriented standards for both commercial and residential buildings and operations. Some of the ASTM standards under development are listed in *Figure 2*.[8]

American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standards

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) is a technical society of engineers and other parties. It conducts research and technical programs and develops standards. ASHRAE has several green building-oriented standards that are referenced throughout this manual. *Figure 3* includes a brief discussion of several standards that are being revised.[9]

The Construction Specifications Institute

The Construction Specifications Institute (CSI) is a membership organization of technical specifiers and manufacturers' representatives that provides guidance on specifications and other technical matters.[10] CSI has begun to include environmental issues in its programs and services. One of its projects is the preparation of a guide for incorporating environmental concerns into contract documents. The guide, when complete, will focus on environmental terminology, research and development (with regard to manufacturers' product information), design and construction, and project evaluation (including operations and maintenance and monitoring). CSI is also expanding its standard Spec-Data sheet of manufacturers' product information to include environmental criteria. (See Chapter 17, "Specifications," for more discussion on environmentally oriented specification format.)

Illuminating Engineering Society

The Illuminating Engineering Society (IES) of North America is a technical membership society of lighting design and provider professionals, that provides standards for lighting systems within the building industry.[11] It is co-sponsor of standards with ASHRAE, such as 90.1-1989 (Energy-Efficient Design of New Buildings). IES is working on new standards for better lighting quality, as well as working on upgrading the lighting and power sections addressed in the new ASHRAE 90.1 standard. Credits will be given for lighting controls and daylighting; the measures will be performance-based (see Chapter 9, "Daylighting").

Design Tools

The U.S. Department of Energy (DOE), in cooperation with industry groups, has developed computer-based tools for building design as well as research. The tools are used by designers, builders, professionals, utilities, and government to analyze buildings and building systems and their inter-relationships, and to compare alternatives. The design tools model the building envelope dynamics required for passive solar strategies, daylighting, HVAC, and lighting, based on occupancy requirements. The tools enable predic-

ASTM STANDARDS UNDER DEVELOPMENT

Life-Cycle Assessment—E-50.06.01

- **Guide for Environmental Life-Cycle Assessment of Buildings and Building Materials.**
  Provides general guidance for a common framework to use life-cycle assessment as a tool for evaluating the environmental implications of buildings and building products.
- **Guide for Conducting an Environmental Life-Cycle Inventory Analysis of Buildings and Building Materials.**
  Describes methods for carrying out an environmental life-cycle inventory analysis.
- **Guide for Conducting an Environmental Life-Cycle Impact Assessment of Buildings and Building Materials.**
  Recommends a framework for carrying out an environmental life-cycle impact assessment. Outlines a procedure to characterize and assess the effects of resource requirements and environmental residuals previously identified through a life-cycle inventory. Provides guidance on defining and analyzing environmental impacts.
- **Terminology for Life-Cycle Assessment of Building Materials.**
  A standard compilation of the terminology used in this area.

Commercial Green Building Standard Practice—E-50.06.02

A compilation of standard practice for the design, construction, operation, and demolition of commercial buildings using environmentally sound energy-efficiency techniques.

Residential New Building Guide—E-50.06.03

A guide to improving the environmental performance and sustainability of low-rise residential buildings in the areas of specification, construction, operations, maintenance, renovation, adaptive reuse, recycling, and demolition.

Sustainably Harvested Wood—E-50.06.05

A guide to assessing whether wood is sustainably harvested through environmentally sound forestry management practices.

Environmentally Preferable Cleaners/Degreasers—E-50.06.06

A guide to assist in the development of environmentally preferable products following a life-cycle-improvement approach.

Sustainable Site Planning—E-50.06.08

A guide for green landscaping, Xeriscaping, and pollution prevention.

International Standard on Energy Efficiency—E-50.06.09

Standard provides a method for calculating the costs and benefits of energy decisions.

Source Separation of Recyclables in Commercial and Multi-Tenant Buildings— E-50.06.10

A guide for source separation programs.

Figure 2

ASHRAE STANDARDS UNDER REVISION

Energy-Efficient Design of New Buildings—90.1-1989

The new version of this standard entails a complete revision that will incorporate life-cycle factors. Two tiers of energy design are included. Tier 1 is more conventional and will provide for approximately 25 percent higher energy efficiency than the 1989 version of the standard. Tier 2 is for utility rebate programs and higher-than-code performance levels and will provide for 50 percent higher energy efficiency than the 1989 version. The revised standard was scheduled to be issued for public review in early 1996.

Ventilation for Acceptable Indoor Air Quality—62-1989.

Ventilation rates in this updated standard will be revised for densely and sparsely occupied spaces. Ventilation calculations will take into consideration the number of occupants and building components that contribute to source contaminants. The standard was expected to be issued for public comment in spring 1996.

Thermal Environmental Conditions for Human Occupancy—55-1992

A standing standard project committee (SSPC) has been recently formed for the purpose of maintaining and revising the standard to conform with new technology as it develops.

Figure 3

tion of the effect of architectural design on energy use, peak loads, and other performance variables. The goal is to determine design and system solutions that yield energy savings within project budgets, and thus provide positive cash flows over the life of the incremental investment.

During the previous decade, energy software development concentrated on upgrading existing algorithms to properly model solar energy systems, daylighting, thermal storage, and other emerging technologies and systems.[12] More recently, load-calculation software has replaced the utilization of tables. The increased capability of computers is enabling the use of hourly energy simulation software and sophisticated analysis for all building types. Energy software tools have moved away from line input-based user interfaces to Windows-based interfaces, and computer-assisted design (CAD) systems now include extensive databases and object-oriented graphics. The following sections describe several software programs currently in use or under development. (Additional information is provided in the "Resources" sections of Chapters 9, 10, 11, and 12.)

DOE-2.1E

DOE-2 is a public-domain computer program for energy analysis developed by Lawrence Berkeley National Laboratory (LBNL), a DOE laboratory operated by the University of California. Well-suited for large commercial buildings, the program calculates a building's energy use and life-cycle costs based on its location, construction, operation, and HVAC systems. It is useful in evaluating building system design, building retrofits, energy budgets, and life-cycle costs and benefits. The program can explore trade-offs between design alternatives and allows for performance of detailed parametric studies of building system variations to allow designers to increase savings and reduce first costs.

DOE-2.1E, released in January 1994, includes four main calculation sections: loads, systems, plant, and economics. The program calculates the hourly heating and cooling loads for up to 128 zones. It uses hourly weather data and incorporates thermal-storage effects of building elements. It also simulates select daylighting systems and electric-lighting controls.

The systems module simulates the operation of secondary HVAC distribution systems, incorporating outside-air requirements and operating and control schedules. Multiple system options are provided. The plant component of the program simulates the operation of a building's HVAC systems, including conventional central plants and plants with on-site generation, waste-heat recovery, and electricity sell-back.

The economics section of the program analyzes the cost of a building's energy sources and calculates the present value of the building's life-cycle costs including fuel, electricity, equipment, operations, and maintenance. These features are very useful in determining the costs of different design and renovation alternatives and calculating of utility rebate incentives.

BLAST

The U.S. Army Construction Engineering Research Laboratories (USACERL) developed the Building Loads Analysis and System Thermodynamics (BLAST) system to help designers calculate building loads and select the optimal HVAC system for a building. The BLAST family is a comprehensive set of computer programs that create energy models, perform energy analyses, and predict energy system performance and life-cycle cost in buildings.

Specific programs in the BLAST family, in addition to BLAST itself, include: BTEXT, a BLAST input pre-processor; LCCID, the Life-Cycle Cost in Design program; SOLFEAS, a solar feasibility program; WTHRPT, weather data reporting; and REPWRT, a report writer for BLAST data. There are other supporting programs as well, such as comfort reporting on an annual basis and assisting in defining inputs for their chillers, heat pumps, and other equipment. The BLAST Support Office (BSO) was established at the University of Illinois at Urbana-Champaign, Department of Mechanical Engineering, to provide strategic support for users of the BLAST family of programs.

SERI-RES

SERI-RES is a general purpose thermal analysis program for residential and small commercial buildings. It was developed by a team from the National Renewable Energy Laboratory (NREL) and Ecotope Group for use by architects, engineers, consultants, building researchers, building code officials, utility analysts, and others. The method of analysis used in the program is simulation. A thermal model of the building is created by the user and translated into mathematical form by the program. The equations are then solved repeatedly at time intervals of one hour or less for the period of simulation, usually one year. The program allows the user great flexibility in choosing the level of detail to be used in modeling a building. It can be used in a quick and cursory way to evaluate general options at low cost and, at a later stage, to perform detailed analysis of the final design.

The program is meant to have enough generality to accurately model almost all residential buildings and most small commercial buildings. It is particularly suitable for the analysis of various types of passive solar buildings. Special provisions are made for the analysis of attached sunspaces, thermostatically controlled fans, rockbin thermal storage, and vented Trombe walls.

Next Generation of Design Tools

PowerDOE

PowerDOE is a new building-energy simulation program being jointly developed by DOE and the Electric Power Research Institute. The program is based on DOE-2 with a graphical user interface, making it easier to operate than DOE-2. Key interface features include on-line help, mean-driven input, graphical results, building-component libraries, CAD package linkage, and building description option. The program can be linked to the Building Design Advisor, a multimedia-based design support environment that can assist in making energy-related design decisions.

PowerDOE is designed with an open architecture, allowing third-party users to add modules to the core program. One example is a link to the SPARK HVAC simulation program (described below). Results can be displayed as graphs, tables, or spreadsheets. Competing energy-efficient measures can be reviewed via a graphical comparison of parametric runs. A Windows-based version of PowerDOE was scheduled to be available in Spring 1996.

SPARK

The Simulation Problem Analysis and Research Kernel (SPARK) is under development by LBNL and California State University at Fullerton. The program will make it possible to construct plant and innovative system models beyond the scope of DOE-2. It will accomplish this by graphically connecting HVAC components, such as fans, coils and chillers, from a library. A beta test release of the product was expected in the first quarter of 1996.

ENERGY-10

ENERGY-10, Version 1.0 software, along with design guidelines was developed by National Renewable Energy Laboratory (NREL), the Passive Solar Industries Council (PSIC), Berkeley Solar Group, LBNL, and DOE. It is an hourly simulation Windows-environment program for low-rise buildings allowing design evaluation of 16 passive solar and energy-efficient options early in the design process. This allows designers to methodically but quickly evaluate the combination of features that results in the greatest savings of energy and money for a given project. The format compares a reference or base case against a low-energy case that the user modifies with the desired passive solar and energy-efficient options. ENERGY-10 also keeps pace with the evolving building design, allowing the user the determine the effect of proposed changes on energy use during any stage of the process.

Many other energy-related software products, which often use one of the above public domain tools as their simulation engine, are being developed by private vendors and product manufacturers. LBNL is working with the Industry Alliance of Interoperability (IAI) to ensure that energy-design tools can interoperate with all other building-related CAD systems. IAI's goal is to significantly increase the sharing of information in the planning, design, construction, and management of buildings. Future versions of vendor CAD systems will provide an object-based development environment to allow sharing of information across disciplines.[13]

Performance-Based Contracts

Performance-based contracts are emerging as a way of compensating a building's design team based on actual building performance. The performance approach rewards the team for the effort required to produce efficient buildings. Rewards may be determined by comparing the building's actual energy bill with established building energy baseline targets, such as the energy level for a code-compliant building.

City of Oakland — Energy Performance-Based Example

A new 450,000-square-foot building in Oakland, California, provides an innovative example of energy-performance-based contracting.[14] The design/build project set a baseline standard of exceeding California's Title 24 Energy Code by 20 percent. The performance data will be analyzed after two years of building operations. If the building performs better than the baseline goal, the design/build team will receive the sum of five years' worth of energy savings. In the event that the building's performance is below the baseline, the team is liable for fifteen years' worth of the shortfall. Both the potential bonus and downside liability are capped at a maximum of $250,000. A DOE-2 energy simulation model was used to determine the baseline figures. The design team was allowed to develop its own design approach and equipment selections to achieve the energy goals. The energy-related improvements are projected to result in other benefits, including a quality environment with improved comfort, indoor air quality, and satisfaction among building occupants.

Under the traditional practice, design and construction fees are usually based on a percentage of building costs. This provides a disincentive for efficient design since a super-efficient scheme that results in significant downsizing of a building's mechanical system would lower the professionals' fees. In contrast, performance-based contracts are an innovative way for a building owner to share the investment risk and associated energy savings with the design/construction team. In some cases, the design team will finance the cost of the additional energy efficiency measures via a shared savings approach (see also Chapter 24, "Local Government Financing").

Remanufacturing and Product Leasing

Remanufacturing is a process in which worn-out products are restored to "like-new" condition. Remanufacturing is estimated to use one-fifth the energy and one-tenth the raw materials needed to make a product using virgin materials. The process is labor-intensive, which leads to higher employment levels, as opposed to higher levels of resource consumption.[15] Purchasing of remanufactured products such as furniture or light fixtures can yield substantial cost savings compared to the purchase of new products.

The emergence of environmentally based equipment and product leases is another new development. In these leases, manufacturers provide for the full installation, operation, and removal of their equipment or products. Given the totality of these responsibilities, the manufacturer is likely to ensure that the product or equipment operates at the highest level of efficiency over its life. Since the manufacturer is also responsible for the ultimate disposal of the product, the firm will likely attempt to obtain the lowest disposal costs. This creates incentives for reuse and/or recycling of the product. These leasing concepts are now just emerging in the carpet and mechanical equipment fields. Over time, it is anticipated that they will carry over to other building products such as ceiling tile and systems furniture.

Leasing arrangements can also involve mechanical and utility companies providing "conditioned" air to building owners. In lieu of having to purchase and maintain their own mechanical systems, building owners pay fixed monthly fees in exchange for receiving conditioned air within a certain comfort range. This monthly payment is analogous to payment for utility and telephone services. In these cases, the user does not need to worry about the mechanism or costs for providing the service, but only whether or not the service is received as expected.

The purchase and maintenance of all required equipment and distribution systems is included in the scope of the vendor's service. The vendor is also responsible for payment of all associated utility bills, thus having an incentive to integrate energy-efficiency measures to achieve lower costs. The consumer of the service benefits by being able to incorporate fixed annual payments in its budgets, and by reducing the risk associated with fluctuating utility rates (see Chapter 24, "Local Government Financing").

Telecommuting and "Virtual Offices"

The development of mixed-use communities incorporating work-home options is an important new concept for the building industry. With the expansion of telecommunications capabilities, the option of working at home either on a full- or part-time basis has become a viable and compelling option. In 1994, full-time telecommuters reached 9.1 million in the United States, up 20 percent from 1993.[16] Increasing application of this new trend will the impact of commercial buildings and the requisite infrastructure on employers and local government resources. Resulting building square-footage reductions should also occur, allowing organizations to lower their capital expenditures, while maximizing their usage of workspace.

The benefits to employees of telecommuting are many. By working at home, employees are able to cut down on commuting time. Economic savings result from lower gasoline and auto maintenance costs, in addition to the associated personal time savings and benefits. For the concept to take hold, however, employers will have to develop new ways of evaluating employee performance.

Larger-scale national patterns of telecommuting on office-building design could result is a new definition of the use and need for buildings. By eliminating the requirement for employees to commute to work to perform typical office functions, the result is an entirely different office-building layout. Workers might come to the site to attend meetings or discuss projects, which would influence office design to enhance networking and conferencing. Private offices assigned to one employee would rarely be needed. Shared offices, or the new concept of "hoteling" (temporarily assigning) work spaces, could become the norm.

Natural Disasters, Property Insurance, and Green Buildings

Since 1986, the insurance industry has paid approximately $68 billion in catastrophe losses associated with natural disasters. The losses are primarily due to wind-related perils, such as hurricanes, tropical storms and tornadoes (representing 70 percent of the total losses), as well as earthquakes and fires. Hurricane Andrew in the Southeast United States in 1992 and the Northridge earthquake in California in 1994 resulted in losses of billions of dollars. In 1994, the second-worst year on record, losses totaled $13 billion. Much of the nation's population growth is occurring in coastal areas where there is greater risk of hurricanes and other wind perils. Experts have predicted a rise in sea level over the ensuing decades. Significant coastal erosion is already occurring, affecting properties insured at an estimated $3 trillion in the Atlantic and Gulf regions alone.[17]

New practices to mitigate future losses to the insurance industry are being advocated primarily due to the leadership of DOE Office of Energy Efficiency and Renewable Energy, the Federal Emergency Management Agency, the Insurance Institute for Property Loss Reduction (an insurance industry association), and the Electric Power Research Institute's (EPRI's) Disaster Recovery Business Alliance. An insurance industry study sponsored by EPRI examines types of electric power-related losses after natural disasters. It identifies technologies that could mitigate loss and enhance recovery. In certain regions, for example, renewable energy could serve as an uninterruptible back-up system for power users, including communications systems, buildings, and equipment.[18]

Studies have indicated that increased global warming trends may be linked to the increase in natural disasters. There is growing support within the insurance industry for an increase in energy-efficient practices that could help reduce greenhouse gases. The insurance industry is also advocating disaster-resilient and environmentally sound construction methods.

The financial impacts of natural disasters dwarf many other risks associated with buildings, such as poor indoor air quality. Building insurers, local governments, and building owners will benefit from an investigation of green building practices that minimize the risk of future disasters through careful consideration of siting, materials, and design factors. Reviewing building economics on a life-cycle basis should include a consideration of these increased natural-disaster risks, especially in high-risk areas such as coastal communities and earthquake-prone sections of the United States.

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Appendices

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Appendix 1: Resources for Local Government

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Appendix 2: Glossary

Absorption—The process by which incident light energy is converted to another form of energy, usually heat.

Acid leachate—Water that has become acidic after seepage through landfills; potentially very damaging to fish habitats and drinking water supplies.

Active noise cancellation (ANC)—Reducing a sound field through the interaction of a primary sound source with an actively controlled identical secondary sound that is 180 degrees out of phase.

Adaptation—In lighting design, the process by which the human visual system becomes accustomed to more or less light, resulting from a change in the sensitivity of the eye to light.

Adsorption—Adhesion of the molecules of a gas, liquid, or dissolved substance to a surface.

Allergen—A substance capable of causing an allergic reaction because of an individual's sensitivity to that substance.

Ambient lighting—Lighting in an area from any source that produces general illumination, as opposed to task lighting.

Ancillary Materials—All those additional inputs, materials, items, and things necessary to complete the process and result in the "Primary Output." *(J.A. Tshudy, Part IV, Section C)*

Artificial sky—An enclosure that simulates the luminance distribution of a real sky for the purpose of testing physical daylighting models (e.g., a hemispherical-dome or mirror-box artificial sky).

A-Weighting—System of modifying measured sound-pressure levels to simulate the response of the human ear to different sound frequencies.

Bacteria sink—Porous material that allows the growth of biological contaminants within the material.

Baffle—A single opaque or translucent element used to diffuse or shield a surface from direct or unwanted light.

Bakeout—A process used to remove VOCs by elevating the temperature in an unoccupied, fully furnished, and ventilated building.

Ballasts—Electrical "starters" required by certain lamp types, especially fluorescents.

Bioaerosol—An aerosolized particle originating from a living thing.

Biodiversity—The tendency in ecosystems, when undisturbed, to have a great variety of species forming a complex web of interactions. Human population pressure and resource consumption tend to reduce biodiversity dangerously; diverse communities are less subject to catastrophic disruption.

Bioengineering—The use of living plants, or a combination of living and non-living materials, to stabilize slopes and drainage ways.

Biological contaminants—These include bacteria, viruses, molds, pollen, animal and human dander, insect and arachnid excreta.

Blackwater— Wastewater generated from toilet flushing. Blackwater has a higher nitrogen and fecal coliform level than graywater. Some jurisdictions include water from kitchen sinks or laundry facilities in the definition of blackwater.

Blown-in batt—A method of installing loose insulation in wall cavities, using a powerful blower and a fabric containment screen.

Brightness—The subjective perception of relative luminance in a space or on a surface.

Building—The complete, outfitted, and furnished "Structure," operational in every way, and ready for immediate occupancy and use. *(J.A. Tshudy, Part IV, Section C)*

Building commissioning (C_x)—The startup phase of a new or remodeled building. This phase includes testing and fine-tuning of the HVAC and other systems to assure proper functioning and adherence to design criteria. Commissioning also includes preparation of the system operation manuals and instruction of the building maintenance personnel.

Building pressurization—The air pressure within a building relative to the air pressure outside. Positive building pressurization is usually desirable to avoid infiltration of unconditioned and unfiltered air. Positive pressurization is maintained by providing adequate outdoor makeup air to the HVAC system to compensate for exhaust and leakage.

Building-Related Illnesses (BRI)—Clinically verifiable diseases that are attributed to a specific source or pollutant within a building and are more serious than Sick Building Syndrome (SBS) condition. The symptoms of the disease persist after the occupant leaves the building, unlike SBS in which the occupant experiences relief shortly after leaving the building.

Candela (cd)—The SI unit of luminous intensity (formerly called the "candle"). One candela equals one lumen per steradian—a specific measure of luminous intensity, in a given direction.

Ceiling cavity—The cavity formed by the ceiling, the plane of the luminaires, and the wall surfaces between them.

Checkdam—Low dam of stone, wood, or other material used for holding and spreading runoff and sediment in a swale.

Clerestory—That part of a building rising above the roofs or other parts, whose walls contain windows specifically intended to provide lighting to the interior.

Closed-loop control—A control system that utilizes measurement of a controlled variable for feedback. Based on the measured feedback, the control system alters its output in an attempt to force the controlled variable to reach a given setpoint.

CO_2-based high-limit ventilation control—A ventilation strategy that monitors the CO2 concentration in a building zone or in the return air duct from the zone. If the CO_2 concentration approaches a predetermined high limit, the outdoor airflow controller is reset to provide additional ventilation. This process supplements standard ventilation-control strategies by providing additional ventilation for unexpected occupancy.

Coefficient of utilization (CU)—The ratio of light energy (lumens) from a source, calculated as received on the workplane, to the light energy emitted by the source alone.

Color (temperature of a source)—In general terms, a means of defining the relative whiteness of a light source, specifically the absolute temperature (degrees Kelvin) of a blackbody radiator having a chromaticity equal to that of the light source.

Commission Internationale de l'Eclairge (CIE)—International lighting commission whose standards, procedures, and definitions are in general use in Europe, but less widely accepted in North America.

Constructed wetland—Any of a variety of designed systems that approximate natural wetlands, use aquatic plants, and can be used to treat wastewater or runoff.

Construction—That complete sequence or series of activities and actions that begin with the building "Site" and results in the completed "Structure." *(J.A. Tshudy, Part IV, Section C)*

Contrast sensitivity—The ability to detect the presence of luminance differences.

Co-product—All those things that result from the process that undergo some further processing to be converted to materials or things that have subsequent use and/or value. *(J.A. Tshudy, Part IV, Section C)*

Cradle-to-grave analysis—Analysis of the impact of a product from the beginning of its source gathering processes, through the end of its useful life, to disposal of all waste products. Cradle-to-cradle is a related term signifying the recycling or reuse of materials at the end of their first useful life.

Critical zone—Any location in a building with contaminant sources sufficiently strong enough that proper control of ventilation, with no margin for error, is crucial for maintaining the immediate comfort of occupants. Critical zones may include conference rooms, smoking rooms, cafeterias, washrooms, auditoriums, or anywhere occupancy can rapidly change.

Cullet—Crushed, waste glass that is returned for recycling.

Cut-off angle—The critical viewing angle beyond which a source can no longer be seen because of an obstruction (such as a baffle or overhang).

Daylight factor (DF)—The ratio of daylight illumination at a given point on a given plane, from an obstructed sky of assumed or known illuminance distribution, to the light received on a horizontal plane from an unobstructed hemisphere of this sky, expressed as a percentage. Direct sunlight is excluded for both values of illumination. The daylight factor is the sum of the sky component, the external reflected component, and the internal reflected component. The interior plane is usually a horizontal workplane. If the sky condition is the CIE standard overcast condition, then the DF will remain constant regardless of absolute exterior illuminance.

Decibel (dB)— Unit of sound level or sound-pressure level. It is ten times the logarithm of the square of the sound pressure divided by the square of reference pressure, 20 micropascals.

Demand-controlled ventilation (DCV) (CO_2 based)—A ventilation-control strategy in which the concentration of CO2 is the measured variable that is controlled to a setpoint by modulating outdoor airflow. With this strategy, only human source contaminants are considered. CO2DCV will not comply with either procedure of ASHRAE Standard 62-1989.

Densitometer—A photometer for measuring the optical density (the opposite of transmittance) of materials.

Detention—In stormwater management, ponding of runoff in pools and basins for water-quality improvement and flood prevention.

Direct component—That portion of light energy, from sources such as the sky or sun, that reaches a specified location without any significant diffusion.

Direct sunlight (beam sunlight)—That portion of daylight arriving at a specified location directly from the sun, without diffusion.

Disuse—That complete sequence and series of activities and actions that eliminate the "Building" in its present form. There are basically two options: (1) demolition and return of the "Building," "Site," and all of its components to the natural environment; and (2) renovation. The renovation option essentially leads back to the beginning of the building life cycle model or to some intermediate stage within that model. *(J.A. Tshudy, Part IV, Section C)*

Economizer controls—HVAC system controls that operate mixed air dampers to mix return and outdoor air to obtain air of a temperature appropriate for "free cooling." Economizer controls are used during periods when outdoor air requires less cooling energy input than return air.

Efficacy—In lighting design, a measure of the luminous efficiency of a specified light source, expressed in lumens per watt. For daylighting, this is the quotient of visible light incident on a surface to the total light energy on that surface. For electric sources, this is the quotient of the total luminous flux emitted by the total lamp power input.

Electromagnetic spectrum—A continuum of electric and magnetic radiation encompassing all wavelengths from electricity, radio, and microwaves at the low-frequency end of the spectrum, to infrared, visible light, and ultraviolet light in the midrange, to x-rays and gamma rays at the high-frequency end.

Embodied energy—The total energy that a product may be said to "contain," including all energy used in growing, extracting, and manufacturing it and the energy used to transport it to the point of use. The embodied energy of a structure or system includes the embodied energy of its components plus the energy used in construction.

Emission rate—Determined by placing a material or furniture into a small or large stainless-steel environmental chamber and measuring the release of volatile vapors from the item over a specified time period. Measured in mg/m2/hr (micrograms per square meter per hour) or mg/m2/hr (milligrams per square meter per hour).

Emissivity—By Kirchoff's Law, for a given wavelength of the electromagnetic spectrum, emissivity of a surface equals its absorptivity and is the reciprocal of its reflectivity.

Energy—All those energy materials and sources required to carry out and complete the process or series of activities for which they are inputs. *(J.A. Tshudy, Part IV, Section C)*

Environmental chamber—A stainless-steel, nonreactive testing device with a known air volume and dynamically controlled air change rate, temperature, and humidity.

Environmental releases—All those outputs and things that result from the process that have no further use or value and are disposed of, emitted, released, lost, or otherwise returned to the environment. *(J.A. Tshudy, Part IV, Section C)*

Equivalent sphere illumination (ESI)—The level of sphere illumination that would produce task visibility equivalent to that produced by a specific lighting environment. The presence of veiling reflections on a task surface reduces the ESI.

Erosion-control fabrics—Clothlike materials used to prevent soil loss. They include geotextiles and fabrics used in silt fences.

Evapotranspiration system—One of the most common forms of wastewater drain fields. This type of system utilizes both evaporation and plant transpiration to dispose of wastewater.

External reflected component—That part of illuminance measured inside a space, on a given plane (or of a calculated daylight factor), that is due to contribution of light reflected from external surfaces.

Feedstocks—The raw material used in manufacturing a product, such as the oil or gas used to make a plastic.

Fenestration—Any opening, or arrangement of openings, in a building (normally filled with glazing) that admits daylight and any devices in the immediate proximity of the opening that affect light distribution (such as baffles, louvers, draperies, overhangs, light shelves, jambs, sills, and other light-diffusing materials).

Fiber optics—Optical, clear strands that transmit light without electrical current; sometimes used for outdoor lighting.

Finger-jointed—High-quality lumber formed by joining small pieces of wood glued end to end, so named because the joint looks like interlocked fingers.

Floor cavity ratio—A number indicating floor cavity proportions calculated from length, width, and height. The floorr cavity is formed by the workplane, the floor, and the wall surfaces between them.

Flushout—A process used to remove VOCs from a building by operating the building's HVAC system at 100 percent outside air for a specific period of time.

Fly ash—The fine ash waste collected from the flue gases of coal combustion, smelting, or waste incineration.

Formaldehyde—A gas used widely in production of adhesives, plastics, preservatives, and fabric treatments and commonly emitted by indoor materials that are made with its compounds. It is highly irritating if inhaled and is now listed as a probable human carcinogen.

Fungi—Parasitic lower plants (including molds and mildew) lacking chlorophyll and needing organic material and moisture to germinate and grow.

Furnishing and outfitting—That complete sequence or series of activities and actions that begin with the "Structure" and results in the completed "Building." *(J.A. Tshudy, Part IV, Section C)*

Generally regarded as safe (GRAS)—A designation given to products (originally foods) that have been in use for many generations without apparent toxic effects.

Geotextiles—Cloth or clothlike materials intended for use in the soil, usually for filtering or containing soil water. Some types are used to prevent or control erosion.

Glare—The effect produced by luminance within one's field of vision that is sufficiently greater than the luminance to which one's eyes are adapted; it can cause annoyance, discomfort, or loss in visual performance and visibility.

Glare index—A value for predicting the presence of glare as a result of daylight entering an area. The glare index is affected by the size and relative position of fenestration, orientation to the sun, sky luminance, and interior luminances. The glare index is similar to the index of sensation and the discomfort glare rating, which are used for electric lighting applications.

Graywater—Wastewater that does not contain toilet wastes and can be reused for irrigation after simple filtration. Wastewater from kitchen sinks and dishwashers may not be considered graywater in all cases. See *Blackwater*

Ground light—Visible radiation from the sun and sky, reflected by exterior surfaces below the plane of the horizon. See *External reflected component.*

High-efficiency particulate air (HEPA) filter—A designation for very fine air filters (usually exceeding 98 percent atmospheric efficiency) typically used only in surgeries, clean rooms, or other specialized applications.

Humus—Decomposed organic material that is an essential component of fertile soil; produced through composting.

Hydrogen sulfide—A very odorous, toxic, and explosive gas produced by some bacteria in the absence of oxygen. It produces acids on contact with water.

Hypersensitivity—Extremely high sensitivity of an individual to certain substances.

I joists—A manufactured wood product so named because its section looks like an upper case I. The top and bottom chord are lumber or laminated wood, and the vertical web is plywood or oriented strand board.

Illuminance—The density of the luminous flux incident on a surface, expressed in footcandles or lux. This term should not be confused with illumination (i.e., the act of illuminating or state og being illuminated).

Impact isolation class (IIC)—A single-number rating system designed to provide a comparison between different floor/ceiling constructions for structure-borne impact transmission between vertically adjoining spaces. The IIC is calibrated so that comparable ratings for sound transmission class (STC) give equivalent degrees of protection. The IIC is measured with a standardized tapping machine to generate impact noise, measuring it in the space below at the one-third octave bands between 100 and 3150 hertz. The IIC is calculated using the ASTM E989-84 "Standard Classification for Determination of Impact Isolation Class."

Indoor air quality (IAQ)—According to the U.S. Environmental Protection Agency and National Institute of Occupational Safety and Health, the definition of good indoor air quality includes (1) introduction and distribution of adequate ventilation air; (2)control of airborne contaminants; and (3) maintenance of acceptable temperature and relative humidity. According to ASHRAE Standard 62-1989, indoor air quality is defined as "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80 percent or more) of the people exposed do not express dissatisfaction."

Indoor Air Quality Procedure—One of two procedures listed in ASHRAE Standard 62-1989 to determine appropriate ventilation rates for buildings. The IAQ Procedure provides a method of measuring and controlling outdoor airflow in order to keep harmful substances diluted to acceptable levels. It is inherently a more rigorous strategy than the Ventilation Rate Procedure because it considers all contaminants. Implementation of this procedure is difficult because of monitoring costs and insufficient knowledge about acceptable concentration levels for the thousands of combinations of potential indoor contaminants.

Infiltration—In stormwater management, entry of runoff into the soil.

Integrated pest management (IPM)—An environmentally sound system of controlling landscape pests, which includes well-timed nontoxic treatments and understanding of the pests' life cycles.

Interior furnishings—Those temporary or semi-permanent systems and components which are generally required for the normal utilization of the "Building" for its intended purpose. Examples, interior design elements, paint, furniture, some types of flooring, ceilings, and walls, etc. *(J.A. Tshudy, Part IV, Section C)*

Invasive vegetation—An exotic plant adapted to very similar growing conditions as those found in the region to which it is imported. Because such a species usually has no natural enemies (pests, diseases, or grazers), it flourishes, disrupting the native ecosystem and forcing out native plant species, resulting in habitat loss, water-table modification, and other serious problems.

Inverse square law—In lighting design, the law that states that the illuminance at a point on a surface varies proportionately with the intensity of a point source, and inversely to the square of the distance between that source and that surface.

Irradiance (E)—The amount (or density) of light energy incident on a surface.

Laminated veneer lumber—A manufactured wood product similar to plywood but made in thick sections with all the grain oriented one way for use as beams.

Lead ventilation—Ventilation of an unoccupied building space immediately prior to its occupancy. Lead ventilation is performed to dilute contaminants from building and HVAC sources to acceptable levels by the time occupants arrive.

Legionnaires' Disease—A sometimes fatal lung infection caused by the *Legionella* bacteria, first identified at a Legionnaires convention in Philadelphia in 1976.

Level spreaders—A stormwater management device installed parallel to a slope that changes concentrated flow to sheet flow.

Life-cycle—The consecutive, interlinked stages of a product, beginning with raw materials acquisition and manufacture and continuing with its fabrication, manufacture, construction, and use, and concluding with any of a variety of recovery, recycling, or waste management options.

Life-cycle assessment (LCA)—A concept and a method to evaluate the environmental effects of a product or activity holistically, by analyzing the entire life cycle of a particular product, process, or activity. Life-cycle assessment is typically described in three complementary phases: inventory analysis, impact assessment, and improvement assessment.

Life-cycle cost (LCC) of material—The costs accruing throughout the service life of a material. Life-cycle costs address the capital costs involved in production, maintenance, and disposal, and can also include other environmentally related capital costs and societal costs.

Light adaptation—The process by which the retina becomes adapted to a luminance greater than about 1.0 footlambert.

Light shelf—A horizontal device positioned (usually above eye level) to reflect daylight onto the ceiling and to shield direct sunlight from the area immediately adjacent to the window. The light shelf may project into the room, beyond the exterior wall plane, or both. The upper surface of the shelf may be specular or nonspecular but should be highly reflective (that is, having 80 percent or greater reflectance).

Lignin—The naturally occurring polymer in wood that binds the cellulose fibers together.

Louver—A series of baffles used to shield a light source from view at certain angles or to absorb unwanted light. The baffles are usually arranged in a geometric pattern.

Lumen (lm)—The luminous flux emitted (within a unit solid angle or one steradian) by a point source having a uniform luminous intensity of one candela.

Lumen method (daylighting)—A method of estimating the interior illuminance from window daylighting at three locations within a room, based on empirical studies.

Luminaire—A complete electric lighting unit, including housing, lamp, and focusing and/or diffusing elements; informally referred to as fixture.

Luminance—Luminous intensity of a surface in a given direction.

Luminous flux—The rate of flow of light, analogous to the rate of flow of a fluid.

Material Safety Data Sheets (MSDSs)—OSHA-required documents supplied by manufacturers of potentially hazardous products. MSDSs contain information regarding potentially significant airborne contaminants, precautions, steps for inspection, health effects, odor description, volatility, expected contaminants from combustion, reactivity, and procedures for cleanup.

Matte surface—Surface from which the reflection is predominantly diffuse, with or without a negligible specular component.

Mineral fibers—Very fine insulation fibers made from glassy minerals that have been melted and spu and are. hazardous to inhale.

Mixed air—The mixture of outdoor air and return air in an HVAC system. When filtered and conditioned, mixed air becomes supply air.

Monitor—A raised section of roof that includes a vertically (or near-vertically) glazed aperture, for the purpose of daylight illumination.

Native vegetation—A plant whose presence and survival in a specific region is not due to human intervention. Certain experts argue that plants imported to a region by prehistoric peoples should be considered native. The term for plants that are imported and then adapt to survive without human cultivation is *naturalized*.

Natural cooling—Use of environmental phenomena to cool buildings, e.g., natural ventilation, evaporative cooling, and radiative cooling.

Nit (nt)—Unit of luminance equal to one candela per square meter.

No-build option—In planning and design, a decision that a site is best used by not building structures or systems on it. Used as a scenario against which the true environmental cost-effectiveness of building concepts can be evaluated.

Noise criteria (NC)—Series of curves of octave-band sound pressure levels from 63 to 8000 Hertz. They are commonly used in the United States to rate interior noise levels.

Noise reduction (NR)—The simple loss of sound level that occurs in passing through a medium. Most often noise reduction refers to a single octave or one-third octave-band noise.

Noise reduction coefficient (NRC)—Average of the sound absorption coefficient of the four octave bands 250, 500, 1,000, and 2,000 Hertz rounded to the nearest 0.05.

Non-point-source pollution—Runoff contamination from an overall site or land use and not discharged from a single pipe, such as sediment from construction sites, oils from parking lots, or fertilizers and pesticides washed from farm fields.

Obsolete building—A "Building" that for one reason or another has reached the end of its current useful life. *(J.A. Tshudy, Part IV, Section C)*

Octave band—A group of frequencies whose lower boundary is one-half of the upper boundary. In acoustics, the first nine octave bands are identified by their center frequencies of 31.5, 63, 125, 250, 500, 1,000, 2,000, 4,000, and 8,000 Hertz. The 31.5 band is also referred to as the band number 0, and 63 Hertz is band number 1.

Offgas/outgas—A process of evaporation or chemical decomposition through which vapors are released from materials.

Open-web wood joists—Wood joists built as flat trusses, using small-dimension lumber for web pieces. These are also available with stamped steel webs.

Orientation—The relation of a building and its associated fenestration and interior surfaces to compass direction and, therefore, to the location of the sun.

Oriented strand board (OSB)—A manufactured wood sheet product made from large flakes of wood pressed together with glue, usually a dry phenolic type. OSB is used for structural sheathing and subfloors.

Oxidizer—Any agent or process that receives electrons during a chemical reaction.

Passive solar design—Designing a building's architectural elements to collect, store, and distribute solar resources for heating, cooling, and daylighting.

Perlite—A lightweight, expanded mineral bead; highly flame-resistant and with good insulating value.

Phenolic laminate—A high-pressure laminated sheet made from paper and phenol formaldehyde resin, commonly used for furniture and kitchen cabinet surfaces.

Photocells—Light-sensing cells used to activate controllers at dawn or dusk.

Photometer—An instrument for measuring photometric quantities, such as luminance, luminous intensity, luminous flux, and illuminance .

Photovoltaic—Generation of electricity from the energy of sunlight, using photocells.

Plasticizers—Chemicals added to soft plastics to preserve their flexibility. These agents offgas slowly, eventually rendering the plastic brittle.

Point method—A method of estimating the illuminance at various locations in a building, using photometric data.

Polyethylene terepthalate (PET)—A polyester plastic used widely in soft drink bottles.

Polymers—Any molecule chain made up from repeated elements, for example, plastics and adhesives.

Polypropylene—A common flexible plastic usually spun into fiber for rope and woven goods.

Post-consumer recycled material—A reclaimed waste product that has already served a purpose to a consumer, such as used newspaper, and has been diverted or separated from waste management systems for recycling.

Powder coating—A durable finishing method for metals using a dry, powdered plastic that is heat-fused onto the surface. No solvent is required and practically no waste produced.

Pre-consumer recycled material—A material that is removed from source gathering or production processes (such as scrap, breakage, or returned inventory) and returned to the original manufacturing process or an alternative process. Pre-consumer recycled materials have not yet reached a consumer for the intended use.

Pressure dose—A method of pumping wastewater to subsurface leaching fields in which soils or slopes are a limiting factor. Typical leach fields operate with gravity.

Primary input—A thing or things that represent the key or fundamental elements that are operated upon by the process and lead to the "Primary output" of the process. For a specific life cycle analysis, the "Primary inputs" of each process in the life cycle sequence need to be clearly defined in terms of what, when, and where. In general, the "Primary input" of one process will be the "Primary output" of the previous process. *(J.A. Tshudy, Part IV, Section C)*

Primary output—The thing, item, or article that represents the intended goal of the process. For a specific life cycle analysis, the "Primary outputs" of each process in the life cycle sequence need to be clearly defined in terms of what, when, and where. *(J.A. Tshudy, Part IV, Section C)*

Radiant energy (radiation)—Energy traveling in the form of electromagnetic waves, measured in units of energy such as joules, ergs, or kilowatthours.

Rainscreen—A method of constructing walls in which the cladding is separated from a membrane by an airspace that allows pressure equalization to prevent rain from being forced in. Often used for high-rise buildings or for buildings in windy locations.

Recycled material—Material that would otherwise be destined for disposal but is diverted or separated from the waste stream, reintroduced as material feed-stock, and processed into marketed end-products.

Reflectance—The ratio of reflected light flux to incident light flux.

Reflected glare—Glare resulting from specular reflection of high luminances in polished, or glossy, surfaces in the field of view. See also *Veiling reflection*.

Reflection—The process by which incident light flux leaves a surface, or medium, from the incident side, without a change in frequency.

Releasable adhesives/dry adhesives—A dry, tacky adhesive that holds a carpet or other finish in place but can be easily removed. After removal it leaves no residue and can be reattached.

Remanufacturing—Industrial process in which worn-out products are restored to "like-new" condition.

Renewable—A renewable product can be grown or naturally replenished or cleansed at a rate that exceeds human depletion of the resource.

Renewable energy technologies—Active, passive, and photovoltaic strategies integrated into building design.

Return air—Air that has circulated through a building as supply air and has been returned to the HVAC system for additional conditioning or release from the building.

Reverberation time (R_T)—The amount of time it takes for sound to decay 60 decibels in a given space. It is a function of room volume and amount of sound absorption provided by surface finishes in the room. Optimum levels are determined based on room volume and space usage.

Rhinitis—Inflammation of nasal mucous membrane.

Room cavity—The cavity formed by the plane of the luminaires, the workplane, and the wall surfaces between these two planes.

Room criteria (RC)—Similar to NC and NR, but from 16 to 8,000 Hertz and more recent. RC also rates noise for rumble or hiss.

Room ratio (RR)—A number indicating room proportions, or the ratio of room length to width. Room ratio is equal to 5.0/room cavity ratio.

Sediment basin—A depression in the soil that is placed to retain sediment and debris on-site.

Shallow trench system—A type of drain field used in conjunction with a graywater system that allows for shallow placement of distribution pipes and use of the graywater for irrigation.

Shear braces—A bracing system, usually using metal brackets or straps, which eliminates most structural wall sheathing.

Sick Building Syndrome (SBS)—According to the EPA and NIOSH, Sick Building Syndrome is defined as "situations in which building occupants experience acute health and/or comfort effects that appear to be linked to time spent in a particular building, but where no specific illness or cause can be identified. The complaints may be localized in a particular room or zone, or may be spread throughout the building." Occupants experience relief of symptoms shortly after leaving the building.

Sinks—Surfaces that tends to capture volatile compounds from air and release them later. Carpets, gypsum board, ceiling tiles, and upholstery are all sinks.

Site—The natural location intended for the "Building," altered, modified, and prepared to the point where "Construction" activities for the "Structure" can be initiated. *(J.A. Tshudy, Part IV, Section C)*

Site selection and preparation—That complete sequence or series of activities and actions that begins with the natural environment and results in some specific geographic location defined in terms of boundaries, and altered and modified to the point where it has become the building "Site" ready for "Construction" to begin. *(J.A. Tshudy, Part IV, Section C)*

Skylight—A relatively horizontal, glazed roof aperture for the admission of daylight.

Slipforms—Concrete forms that are advanced for another pour after the concrete has set.

Sludge composting—Process of composting treated municipal sewage waste with organic matter for use as a soil amendment.

Sodium silicate—A liquid used in asbestos encapsulation, concrete and mortar waterproofing, and high-temperature insulations (also called "water glass"). This substance is nontoxic when cured but caustic when wet.

Solar altitude—In solar analysis, the vertical angular distance of a point in the sky above the horizon. Altitude is measured positively from the horizon to the zenith, from 0 to 90 degrees.

Solar azimuth—In solar analysis, the horizontal angular distance between the vertical plane containing a point in the sky (usually the sun) and true south.

Solar radiation—The full spectrum of electromagnetic energy including visible light from the sun. When solar radiation strikes a solid surface or a transparent medium such as air or glass, some of the energy is absorbed and converted into heat energy, some is reflected, and some is transmitted. All three of these effects are important for effective passive solar design.

Sound power level—Reported in decibels, it is 10 times the logarithm to the base of 10 of the ratio of the total sound power in watts to a reference power of 10^{-12} watts.

Sound pressure level (SPL)—Reported in decibels, it is 20 times the logarithm to the base 10 of the ratio of sound pressure to a reference pressure of 20 micropascals.

Sound transmission class (STC)—A single-number rating designed to provide a comparison between the noise losses of different structures for building-design purposes. The STC is calculated from the noise reduction at the 16 one-third octave bands between 125 and 4,000 Hertz. The American Society for Testing and Materials has published a standard, ASTM E413-73, "Standard Classification for Determination of Sound Transmission Class."

Sound—Minute changes in air pressure of 2×10^{-10} to 2×10^{-3} of an atmosphere at the rates of from 20 to 20,000 times per second.

Spectrophotometer—An instrument for measuring the transmittance and reflectance of surfaces and media as a function of wavelength.

Stressed skin—A structural panel with the sheathing permanently bonded to the frame or core to increase its strength.

Structure—The completed building envelope on the "Site," externally and internally complete, including all opeating systems ready for its "Interior furnishings." *(J.A. Tshudy, Part IV, Section C)*

Sun-bearing angle—The solar azimuth angle relative to the horizontal direction a building surface is facing. Often referred to as the "relative solar azimuth."

Superabsorbent materials—Various artificial materials capable of holding several times their own weight in water. Used in granular form, these are mixed with earth to increase the amount of water held in the soil, the length of time it is held before drying, and its availability to plants. Humus serves this purpose.

Superplasticizers—Chemical additives for concrete that increase the fluidity of the mix without excess water.

Supply air—The total quantity of air supplied to a space of a building for thermal conditioning and ventilation. Typically, supply air consists of a mixture of return air and outdoor air that is appropriately filtered and conditioned.

Sustainable—The condition of being able to meet the needs of present generations without compromising those needs for future generations. Achieving a balance among extraction and renewal and environmental inputs and outputs, as to cause no overall net environmental burden or deficit. To be truly sustainable, a human community must not decrease biodiversity, must not consume resources faster than they are renewed, must recycle and reuse virtually all materials, and must rely primarily on resources of its own region.

Synergy—Action of two or more substances to achieve an effect of which each is individually incapable. As applied to toxicology, two exposures together (for example, asbestos and smoking) are far more risky than the combined individual risks.

Thinset—A modified portland cement and sand mortar used for tile setting. May contain an acrylic additive for strength.

"Tight" buildings—Buildings that are designed to let in minimal infiltration air in order to reduce heating and cooling energy costs. In actuality, buildings typically exhibit leakage that is on the same order as required ventilation; however, this leakage is not well distributed and cannot serve as a substitute for proper ventilation.

Topsoil—The uppermost soil horizon (layer), containing the highest amounts of organic material; depth varies greatly from region to region.

Transmission loss (TL)—Noise reduction corrected for wall area and room absorption.

Transmission—The process by which incident flux leaves a surface, or medium, on a side other than the incident side, without change in frequency.

Transmittance—The ratio of transmitted flux to incident flux; measured by a transmissometer.

Trombe wall—A south-facing masonry wall that is covered with glass spaced a few inches away. Sunlight passing through the glass is transformed into heat at the wall's surface, which either migrates into the building interior or is thermosyphoned to interior spaces through vents.

Ultraviolet radiation (UV)—Any radiant energy within the wavelength range of 0.001 to 0.38 micron; high-energy components of light capable of damaging materials and increasing skin cancer risk.

Unit factors—An estimate of the environmental costs (for example, raw materials, energy pollution, and solid waste) associated with a unit of a material, such as a ton of steel or a cubic yard of concrete.

Urethanes—A family of plastics (polyurethanes) used for varnish coatings, foamed insulations, highly durable paints, and rubber goods.

Use and operation—That complete and ongoing sequence and series of activities and actions that are required and occur during the life of a "Building" from the point where occupancy and operation begin to the point where it becomes obsolete, and as a result, is no longer occupied or used. *(J.A. Tshudy, Part IV, Section C)*

Variable-air-volume (VAV)—A method of modulating the amount of heating or cooling effect that is delivered to a building by the HVAC system. The flow of air is modulated rather than the temperature. VAV systems typically consist of VAV boxes that throttle supply airflow to individual zones, some mechanism to control supply-fan flow to match box demand, and the interconnecting ductwork and components.

Veiling luminance—Luminance superimposed on the retinal image that reduces its contrast.

Veiling reflection—Specular reflection superimposed upon diffuse reflection from an object that partially, or totally, obscures the details to be seen by reducing the contrast. Controlled by distributing the source over a larger area, relocating the source out of the reflected field of view, changing the task surface specular reflectance (or tilt), or relocating the observer.

Vermiculite—A naturally occurring silicate mineral that can be expanded by heating into a noncombustible insulating pellet.

Visual angle—The angle subtended by an object, or detail, at the point of observation.

Visual performance—The quantitative assessment of the performance of a visual task, taking into consideration speed and accuracy.

Volatile organic compound (VOC)—Chemical compounds based on carbon and hydrogen structures that are vaporized at room temperatures. VOCs are one type of indoor air contaminant. Although thousands have been identified in indoor air, only a few are well understood and regulated.

Water budget—The estimated water use within a facility. Flow rates of fixtures and appliances, occupancy, and landscape needs are calculated.

Water harvesting—Collection of both runoff and rainwater for various purposes, such as irrigation or fountains.

Water reclamation—Reuse of effluent from wastewater treatment facilities through irrigation, land application, or other recycling methods.

Watershed—Area of land that, as a result of topography, drains to a single point or area.

Wetland—In stormwater management, a shallow, vegetated, ponded area that serves to improve water quality and provide wildlife habitat.

White noise—Sound that has constant energy per frequency.

Window-to-floor ratio—The ratio of total, unobstructed window glass area to total floor area served by the windows, expressed as a percentage. This value can also be further subdivided by solar orientation (such as south-facing window-to-floor ratio).

Workplane—The plane at which work is usually done and on which the illuminance is specified and measured. Unless otherwise indicated, this is assumed to be a horizontal plane, 30 inches (0.76 meter) above the floor.

Xeriscape™—A trademarked term referring to water-efficient choices in planting and irrigation design. It refers to seven basic principles for conserving water and protecting the environment. These include: (1) planning and design; (2) use of well-adapted plants; (3) soil analysis; (4) practical turf areas; (5) use of mulches; (6) appropriate maintenance; and (7) efficient irrigation.

Zenith—The point on the skydome directly overhead, the 90-degree solar altitude angle.

Appendix 3: Abbreviations

ADR Alternative dispute resolution
AIA American Institute of Architects
ASID American Society of Interior Designers
ASLA American Society of Landscape Architects
ASHRAE American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASTM American Society for Testing and Materials

BEPAC Building Environmental Performance Assessment Criteria
BOMA Building Owners and Managers Association International
BREEAM Building Research Establishment Environmental Assessment Method
BRI Building-Related Illnesses
BTU British thermal units

cd Candela
CIE Commission Internationale de l'Eclairge
CFC Chlorofluorocarbon
CPU Central processing unit
CRT Cathode ray tube
CSI Construction Specifications Institute
CSTC Ceiling sound transmission class
CU Coefficient of utilization
CX Building commissioning

dB Decibel
dB(A) A-weighted decibel
DDC Direct digital control
DOE U.S. Department of Energy
DSM Demand-side management

E Irradiance
EMF Electric and magnetic fields
EPA U.S. Environmental Protection Agency
ERC Environmental report card

GRAS Generally regarded as safe

HAZCOM OSHA Hazard Communication Standard 1926.59
HCFC Hydorchloroflourocarbon
HID High-intensity discharge (lamps)
HEPA High-efficiency particulate air (filter)
HVAC Heating, ventilating, and air-conditioning
IAQ Indoor air quality
IES Illuminating Engineering Society
IFMA International Facility Management Association
IIC Impact isolation class
IPM Integrated pest management
KWH Kilowatt-hour

LAN Local area network
LCA Life-cycle assessment
LCC Life-cycle cost
lm Lumen

MCS Multiple chemical sensitivities
MDF Medium-density fiberboard
MSDS Material Safety Data Sheet
MVOC Microbial volatile organic compound

NAAQS National Ambient Air Quality Standards
NIOSH National Institute of Occupational Safety and Health
NIST National Institute of Standards and Technology

O&M Operations and maintenance
ODC Ozone-depleting compound
OSHA Occupational Safety and Health Administration

PC Personal computer
PCB Polychlorinated biphenyls
PET Polyethylene terepthalate
PPE Personnel protective equipment
PUC Public utility commission
PV Photovoltaic
PVC Polyvinyl chloride

RFP Request for proposal

SBS Sick Building Syndrome
SCS Scientific Certification System
SI Systeme International (Metric System)
SOLF Solar optic lens film
SOW Statement of work
STC Sound transmission class

TES Thermal energy storage
TMY Typical meteorological year
TVOC Total volatile organic compounds

UV Ultraviolet radiation

VAV Variable-air-volume
VCP Visual comfort probability
VCM Vinyl chloride
VDT Visual display terminal
VOC Volatile organic compound

Appendix 4: Contributing Writers

- **Loren E. Abraham, AIA, IDSA**, president of Environmental Research Group in Charlottesville, Virginia, has over 20 years of professional experience in the building and construction industry. His primary expertise lies in the fields of daylighting, energy efficiency, and life-cycle assessment (LCA) protocols for buildings and building products. He is a licensed architect, researcher, and successful industrial designer with numerous patents for innovative daylighting systems, computer-integrated manufacturing software, and various hardware systems. He is also a leading proponent and practitioner of sustainable design, having served on the President's Task Force "Greening of the White House," and as chairman of the Passive Solar Industries Council (PSIC). He has served on ASTM Green Building and Life Cycle Committees and is a founding member of the U.S. Green Building Council.

- **Sal Agnello** is manager, Indoor Quality Environments for Johnson Controls, Inc. His responsibilities include developing and marketing new products and services for indoor environmental control, and management of commercial and institutional buildings from the perspective of occupant health, comfort, and productivity. His input to the development of IAQ practice in the building operations area has included testimony at the OSHA Indoor Air Quality hearings, participation at international forums on indoor environmental research and practice, and publication of facilities management articles. He holds a B.A. degree from Marquette University, and master's degrees from the University of Wisconsin-Madison. He is a member of the International Society for Indoor Air Quality and Climate.

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- **Anthony Bernheim, AIA**, is a principal with the architecture, interior design, and planning firm of Simon Martin-Vegue Winkelstein Moris (SMWM) in San Francisco. He has been the project manager for SMWM on numerous large public projects, including, most recently the new San Francisco Main Library. He is an advocate for the design of green and sustainable buildings and has recently developed indoor air quality strategies and a building commissioning process for the San Francisco Main Library. Mr. Bernheim has presented and published papers and conducted seminars and workshops on indoor air quality and building commissioning. He is a member of the American Institute of Architects and the International Society of Indoor Air Quality and Climate. He is also an adjunct professor at the School of Architectural Studies, California College of Arts and Crafts, and has taught classes in building technology (including indoor air quality) and professional practice.

- **Clark C. Bisel, P.E.**, is a principal at Flack & Kurtz Consulting Engineers, LLP, in San Francisco. He spearheads the design of large scale projects in the San Francisco office, and leads the mechanical/electrical design team during the preliminary design phase to ensure that all specific project requirements are met. He is actively involved in the analysis and implementation of mechanical and electrical systems, including the application of state-of-the-art technology such as thermal storage, daylighting, passive solar and central heat-pump design, and building systems automation. Mr. Bisel has completed design projects exceeding 30 million square feet of space for various building types including mixed-use, high-rise commercial developments, data centers, museums, and hospitality facilities.

- **William Burke, AIA**, is an architect and writer who lives in San Francisco. He is currently working on the Vital Signs Curriculum Materials Project, which aims to improve energy and environmental awareness among architecture students. Mr. Burke is a staff member at the Center for Environmental Design Research at the University of California, Berkeley. He was the 1995 Chair of the American Institute of Architects San Francisco Chapter's Task Force on the Environment and was the principal author for PTI's "Local Government Sustainable Buildings Guidebook."

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- **Bruce K. Ferguson** is professor of Landscape Architecture at the University of Georgia. His projects include goals for urban water conservation in the California Water Plan, and conservation of irrigation water on the White House lawn. He is the author of 130 professional articles and the book Stormwater Infiltration. He earned a B.A. degree at Dartmouth College and an M.L.A. degree at the University of Pennsylvania. He is a past president of the Council of Educators in Landscape Architecture and a Fellow of the American Society of Landscape Architects.

- **Daniel J. Goldberger** is director of the Green Buildings Program for the International Council for Local Environmental Initiatives (ICLEI). The program helps local governments overcome technical and financial barriers to upgrading their facilities' energy efficiency. He has been involved with the creation and supervision of the Ontario Municipal Energy Improvement Facility program, as well as with U.S. EPA's voluntary programs. He has co-authored *Profiting from Energy Efficiency!*, and is co-authoring a similar publication for U.S. DOE's Rebuild America program. Mr. Goldberger has over 12 years of commercial banking, real estate development, energy and environmental experience. He holds a Masters Degree in International and Public Affairs, with a concentration in International Finance and Banking from Columbia University in NYC.

- **David A. Gottfried** is president of Gottfried Technology Inc. The firm provides consultation to management on building-related environmental and resource-efficiency issues. It also performs environmental building seminars and education and is involved in the development and promotion of emerging industry technologies. Mr. Gottfried is a co-founder and vice-chairman of the U.S. Green Building Council, and founder and past chairman of ASTM's Green Building Subcommittee. He has a degree in engineering and resource management from Stanford University.

- **Gerard Heiber** is chief operating officer of Sigal Environmental, Inc., and is responsible for directing consulting services provided to building owners, designers, and managers in the areas of energy conservation, indoor air quality, and green building materials and practices. His experience includes over three years of green building consulting, over twelve years in the implementation and construction administration of large commercial projects, and five years of public works management consulting. Mr. Heiber has been a major participant in the development of national programs to promote the concept of green buildings in the building industry, integrating indoor air quality, energy performance, and the environmental performance of materials into the construction and design process. Mr. Heiber's efforts have included the founding (along with other Sigal Environmental, Inc. staff) of the ASTM Green Building Subcommittee E-50.06 under the Pollution Prevention Committee which is currently developing standards and guidelines in green buildings. He is also an active participant in the Green Building Council, developing a market-based green building rating system for the building industry.

- **Lisa Heschong** is an architect and partner of the Heschong Mahone Group in Fair Oaks, California. She received her masters degree in architecture from the Massachusetts Institute of Technology and has specialized in all aspects of energy efficiency in buildings. She is the author of Thermal Delight in Architecture and has taught at various universities. Most recently she has been teaching the Federal Relighting Workshops for the U.S. Department of Energy.

- **Philip Jessup** is responsible for the overall management and direction of the International Council for Local Environmental Intiative's (ICLEI's) Cities for Climate Protection Campaign, a project whose purpose is to strengthen the capacity of local governments to reduce energy use and greenhouse gas emissions. His work with ICLEI also includes project development and management of the Green Buildings and Green Fleets programs; organization of workshops and summits; creation of publications; and fundraising. Mr. Jessup has worked for close to 10 years on energy and environment issues in a variety of professional capacities in the U.S. and Canada. He has been with ICLEI since its inception five years ago.

- **Barbara C. Lippiatt** is an economist in the Office of Applied Economics, Building and Fire Research Laboratory, at the National Institute of Standards and Technology (NIST). She is developing economic decision-making software tools to efficiently design and manage buildings. She has applied these decision tools to a wide variety of building problems, including selecting environmentally benign building materials, measuring productivity impacts of design decisions, identifying cost-effective fire-safety strategies, rating historic buildings, and selecting cost-effective energy and water conservation investments. Two of her software publications have been on the National Technical Information Service's Bestseller list; another is being distributed by the 65,000-member National Fire Protection Association. She serves on the ASTM Green Buildings Subcommittee, and is leading the development of a standard for evaluating environmental and economic impacts of building materials over their life cycle.

- **John D. Longman** is a principal with the international acoustical and audiovisual consulting firm, Cerami & Associates, based in New York City. He specializes in architectural and building services acoustics consulting with major developers, architects, engineers, and interior designers on a wide range of commercial, residential, industrial, and environmental projects—both within the United States and throughout the world. Mr. Longman was educated in London and has specialized in building acoustics for over 12 years.

- **Dru Meadows** is manager of the "Green Team" at BSW International. Ms Meadows chairs the American Society for Testing Materials Committee on Green Buildings, and represents BSW on the Board of the U.S. Green Building Council. She served on the Construction Specifications Institute's Ad Hoc Environmental Issues Committee and is an honorary member of the CSI Los Angeles Chapter Environmental Affairs Committee. She serves on the advisory board for the Product Emission Testing Laboratory and on the local construction board for Habitat for Humanity. In 1993, Ms. Meadows received an Appreciation Award from the City of Los Angeles in recognition for her contributions to the city's environmental affairs.

- **Michael Myers** is a Program Manager with the Department of Energy, and is a Team Leader for the Residential Building Programs. He manages research initiatives and management practices to improve new and existing housing. Previously, Mr. Myers was the Director of Energy Services for Austin, Texas, and managed the development of the City of Austin's Green Builder Program which received international honors at the United Nations Conference on Environment and Development. He previously worked for the cities of New York and San Antonio. Mike is on the Washington, D.C. Habitat for Humanity's GreenHome Advisory Board of Directors, and is a member of the Chesapeake Sustainable Council. Mr. Myers has a M.S. degree in Urban Studies from the University of Texas at San Antonio.

- **William G. Reed, AIA** is the studio principle of the Hillier Group's Washington, D.C., office and specialist in green building and sustainable planning initiatives firm-wide for the fourth largest architectural firm in the nation. Mr. Reed regularly lectures and consults on green building and community sustainability design issues to organizations, government agencies, and private developers. He serves as co-chair of the ASTM Residential Green Building Subcommittee and as a regular instructor for the Passive Solar Industries Council, and is a member of the U.S. Green Building Council.

- **David Rousseau** is president of Archemy Consulting Ltd. in Vancouver, Canada, and Senior Research Associate at the University of British Columbia School of Architecture Environmental Research Group. His training is in environmental studies, architecture, planning, and health sciences, with many years of practical experience in the building industry as a specialized design consultant in the fields of environmental planning and healthy buildings. In addition, he writes and lectures extensively and has won several design and research awards, including a 1995 Progressive Architecture Research Citation for the BEPAC Program (co-recipient); a 1992 Joel Polsky Research Award from the Foundation for Interior Design Education Research; the 1992 first prize in the Canada Mortgage and Housing Corporation Healthy Housing Design Competition, Infill Category, (co-recipient); and the 1990 National Research Council, Canadian Construction Research Board award for research innovation (co-recipient).

- **Kim Sorvig** is a licensed landscape architect and professor at the University of New Mexico's School of Architecture and Planning. He was trained in botany and ecology at the Royal Botanic Gardens in London (Kew Gardens) and received his Master of Landscape Architecture degree from the University of Pennsylvania. He is contributing editor of Landscape Architecture Magazine. In practice and research, he specializes in landscape design that conveys interpretive information, such as botanic gardens, historic sites, memorials, and sacred spaces.

- **Dr. James A. Tshudy** is a manager of environmental product performance for Armstrong World Industries where he is responsible for the environmental performance of all Armstrong products worldwide. His efforts focus on understanding and applying environmental life cycle concepts to product performance, indoor air quality issues, and strategic environmental management systems for corporations. Dr. Tshudy serves as the Chairman of ASTM Subcommittee E50.06.01, Life Cycle Assessment of Building Materials.

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