Chapter 1

Introduction and Overview

The high-performance green building movement is said to be the most successful environmental movement in the United States, certainly the fastest-growing and highly successful at creating partnerships with a broad cross section of manufacturers, builders, and others who are not often allies with environmentalists. In addition to having enormous success, the green building movement provides a model for other sectors of economic endeavor about how to create a consensus-based, market-driven program that has rapid uptake, not to mention broad impact. With respect to buildings, unprecedented forces are reshaping the building construction industry, forcing professionals engaged in all phases of building construction, design, operation, financing, insurance, and public policy to fundamentally rethink their roles in the building delivery process. The main impetus is the *sustainable development* movement, which is changing not only physical structures but also the workings of the companies and organizations that populate the built environment, as well as the hearts and minds of individuals who inhabit it.[1] Fueled by examples of personal and corporate irresponsibility and negative publicity resulting from events such as the Enron debacle and the Wall Street mutual fund and stock trading scandals, *accountability* and *transparency* are becoming the watchwords of today's corporate world. Heightened corporate consciousness has embraced comprehensive sustainability reporting as the new standard for corporate transparency. *Corporate transparency* refers to complete openness of companies about all financial transactions and all decisions that affect their employees and the communities in which they operate. Major companies such as DuPont, the Ford Motor Company, and the Hewlett-Packard Company now employ *triple bottom-line reporting,*[2] which refers to a corporate refocus from mere financial results to a more comprehensive standard that also includes environmental and social impacts. By including these cornerstone principles of sustainability in their annual reporting, corporations acknowledge their environmental and social impacts and ensure improvement in all arenas.

Still, other major forces such as *climate change* and the rapid depletion of the world's oil reserves threaten national economies and the quality of life in developed countries. Both are connected to our dependence on fossil fuels, especially oil. Climate change, caused at least in part by increasing concentrations of human-generated carbon dioxide, methane, and other gases in the Earth's atmosphere, is believed by many authoritative scientific institutions and Nobel laureates to profoundly affect our future temperature regimes and weather patterns.[3] Much of today's built environment will still exist during the coming era of rising temperatures and sea levels; however, little consideration has been given to how human activity and building construction should adapt to potentially significant climate alterations. Global temperature increases must now be considered when forming assumptions about passive design, the building envelope, materials selection, and the types of equipment required to cope with higher atmospheric energy levels.

The *oil rollover point* describes the time when peak worldwide production of oil will occur and when approximately 50 percent of the world's oil supply will have been depleted (see Figure 1.1).[4] At the rollover point, the energy value of oil (the amount of energy into which the oil can be converted) will be less than the energy needed to extract it. Experts predict that between 2010 and 2020, oil prices will skyrocket as production falls and demand begins to exceed supply, sending shock waves through a world economy predicated on growth subsidized by cheap energy. The Chinese economy officially grew 9.3 percent in 2005 with some estimates that it will continue at this rate and others stating that it will grow 9.5 percent in 2007. China produced about 2 million automobiles in 2000, tripling to about 6 million in 2005. China's burgeoning industries are in heavy competition with the United States and other major economies for oil and other key resources such as steel and cement. The combination of increasingly scarce supplies of oil, rapid economic growth in China and India, and concerns over the contribution of fossil fuel consumption to climate change will inevitably force the price of gasoline and other fossil-fuel-derived energy sources to increase rapidly in the coming decades. At present, there are no foreseeable technological substitutes for the world's rapidly depleting oil supplies. Alternatives such as hydrogen or fuels derived from coal and tar sands threaten to be prohibitively expensive. The expense of operating buildings that are heated and cooled using fuel oil and natural gas will likely increase, along with the cost of fossil-fuel-dependent industrial, commercial, and personal transportation. A shift toward hyperefficient buildings and transportation cannot begin soon enough.

A unique vocabulary is emerging to describe concepts related to sustainability and global environmental changes. Terms such as *Factor 4* and *Factor 10, ecological footprint, ecological rucksack, biomimicry, Natural Step, eco-efficiency, ecological economics, biophilia,* and the *Precautionary Principle* describe the overarching philosophical and scientific concepts that apply to a paradigm shift toward sustainability. Complementary terms such as *green building, building assessment, ecological design, life-cycle assessment, life-cycle costing, high-performance building,* and *charrette* articulate specific techniques in the assessment and application of principles of sustainability to the built environment.

The sustainable development movement has been evolving worldwide for almost two decades, causing significant changes in building delivery systems in a relatively short period of time. A subset of sustainable development, *sustainable construction,* addresses the role of the built environment in contributing to the overarching vision of sustainability. In the United States, the founding of the U.S. Green Building Council (USGBC) in 1993 heralded government and industry's newfound commitment to high-performance green building practices. From 1993 to 1998, a

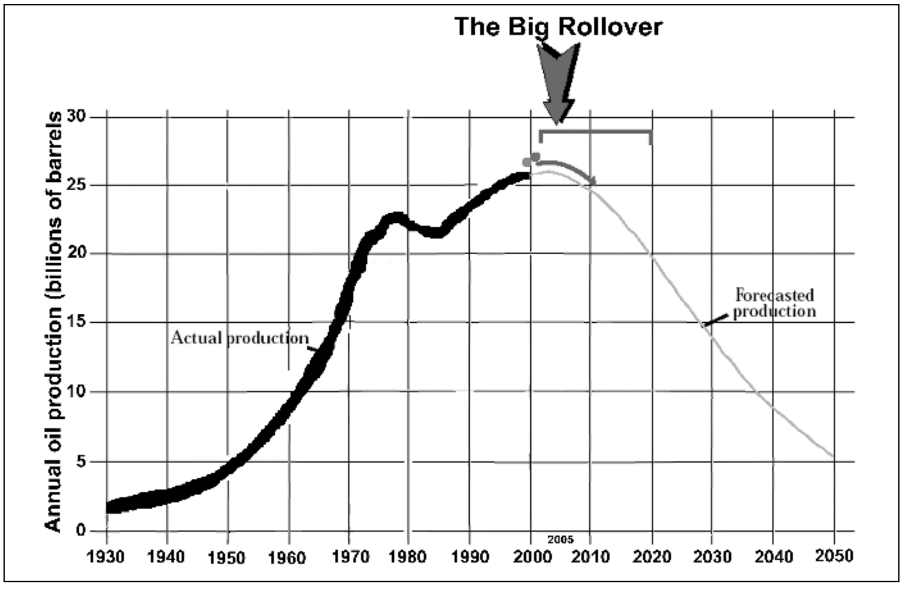

Figure 1.1 The oil rollover point is the year in which the worldwide production rate of oil peaks. Although there are varying points of view as to when this will occur, the probability is that it has already occurred or that it will occur in just a few years. (Drawing by Bilge Çelik.)

USGBC task force diligently developed a rating system to evaluate a building's resource efficiency and environmental impacts. This rating system, Leadership in Energy and Environmental Design (LEED), was the watershed event that precipitated an exponential shift from conventional to sustainable building delivery systems from 1998 on. The LEED rating system removed ambiguity in the loosely interpreted concepts associated with sustainability and green building. LEED's newly articulated, cohesive rating system rapidly gained wide acceptance in both the private and public sectors and has significantly impacted the construction industry in the most energy- and materials-intensive economy in the world. By mid-2006, almost 400 buildings had been certified under the LEED for New Construction (LEED-NC), and over 2,600 were undergoing certification in the United States. Several other LEED rating systems have emerged, including LEED for Existing Buildings (LEED-EB), LEED for Core and Shell (LEED-CS), and LEED for Commercial Interiors (LEED-CI). To date, about 35 percent of USGBC-certified buildings are in the private sector. Private sector acceptance, coupled with support from the federal government and many state governments, has resulted in a near doubling of LEED certifications each year since 1998. If this trend holds, within 10 years high-performance green buildings could constitute the majority of new construction in the United States.

An example of an exceptional LEED-certified building is illustrated in Figure 1.2A–C. The Robert Redford Building, the Santa Monica, California, office of the Natural Resources Defense Council, which opened in November 2003, received a Platinum certification from the USGBC, the highest of the four levels of certification, and was one of just a handful to receive this rating. The building is cooled largely by ocean breezes, uses about one-third of the energy of a typical office building in Santa Monica, obtains 100 percent of its energy from carbon-free renewable resources, and has a 7.5-kW solar array on the roof. An existing building on the site was deconstructed, and 98 percent of its materials were recycled into the new building. The building uses rainwater and graywater (recycled water from sinks) for flushing toilets and landscape irrigation. Waterless urinals in the building each save about 40,000 (151,000 liters) gallons of water a year by not requiring flushing, and the toilets have a dual-flush option, light or heavy, depending on the need. The building also boasts an exceptionally high level of indoor environmental quality due to its use of emissions-free materials and exceptional daylighting for its occupants.

Although other building assessment standards had been developed and implemented, LEED now predominates in the United States and has been wholly or partially adopted in several other countries. Spain, Canada, and China are all considering LEED-based approaches to green building. LEED's wide acceptance has likely resulted from its authors' focus on fashioning LEED as a consensus-based rating system and on creating buildings that would have higher market value. However, their assumption that high-performance green buildings would differentiate themselves in the market through higher exchange value has yet to be fully tested because the first LEED-certified buildings are just becoming operational. But based on experience with energy-efficient buildings, which have a history of commanding a premium in the resale market, the likelihood is that the emerging class of green buildings will have significant added exchange value.

Another organization that has recently emerged as part of the growing green building movement is the Green Building Initiative (GBI). In cooperation with the National Association of Home Builders (NAHB), GBI has helped initiate more than 15 city and state-level green home building programs based on the NAHB's *Model Green Home Guidelines*. GBI's entrance into the market has had several other impacts on this movement. In 2005 GBI became the first organization to earn accreditation as a Standard Developer under the American National Standards Institute (ANSI). Following the trend in corporate America, GBI has led the green building movement toward a higher-profile commitment to consensus and transparency. Following GBI's lead, the USGBC also earned ANSI accreditation in 2006. In the same

(A)

(B)

(C)

Figure 1.2 The Robert Redford Building, offices of the Natural Resources Defense Council (NRDC) in Santa Monica, California, is one of the first Platinum-certified buildings under the USGBC's LEED building assessment standard. (A) The front elevation shows its urban setting and its close connection to the street and the adjoining farmer's market; (B) rear elevation; (C) interior second-floor lightwell. (Photographs courtesy of the NRDC.)

year, NAHB committed to take their green home guidelines through an ANSI consensus process, and organizations including the American Society for Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), National Institutes of Building Sciences (NIBS), and the American Society for Testing and Materials (ASTM) have all announced their intention to promulgate high performance or sustainable building standards. GBI's Green Globes system, originally developed in Canada and one of the newcomers to contribute a commercial building rating systems to the market, is undergoing a technical review by GBI's ANSI technical committee. GBI expects to promulgate Green Globes as an ANSI standard in 2008.

Organization

This book describes the *high-performance green building delivery system,* a rapidly emerging building delivery system that satisfies the owner while addressing sustainability considerations of economic, environmental, and social impact, from design through the end of the building's life cycle. A *building delivery system* is the process used by building owners to ensure that a facility meeting their specific needs is designed, built, and handed over for operation in a cost-effective manner. This book will examine the design and construction of state-of-the art green buildings in the United States, considering the nation's unique design and building traditions, products, services, building codes, and other characteristics. Best practices, technologies, and approaches of other countries will be used to illustrate alternative techniques. Although intended primarily for a U.S. audience, the general approaches described could apply broadly to green building efforts worldwide.

Much more so than in conventional construction delivery systems, the high-performance green building delivery system requires close collaboration among building owners, developers, architects, engineers, constructors, facility managers, building code officials, bankers, and real estate professionals. New certification systems with unique requirements must be considered. This book will focus largely on practical solutions to the regulatory and logistical challenges posed in implementing sustainable construction principles, delving into background and theory as needed. The USGBC's green building certification program will be covered in detail. Other complementary or alternative standards such as the Green Building Initiative's Green Globes building assessment system, the U.S. government's Energy Star Program, and the United Kingdom's BREEAM building certification program will be discussed. Economic analysis and the application of life-cycle costing, which provides a more comprehensive assessment of the economic benefits of green construction, will also be considered.

Following this introduction, this book is organized in three parts, each of which describes an aspect of this emerging building delivery system. Part I, "Green Building Foundations," covers the background and history of green buildings, the most significant rating and assessment systems, and green building design. Part II, "Green Building Systems," more closely examines several important subsystems of green buildings: siting and landscaping, energy and atmosphere, the building hydrologic cycle, materials selection, and indoor environmental quality. In Part III, "Green Building Implementation," the subjects of construction operations, building commissioning, economic issues, and future directions of sustainable construction are addressed. Additionally, five appendixes containing supplemental information on key concepts are provided. To support the readers, a website, www.wiley.com/go/sustainableconstruction, contains hyperlinks to relevant organizations, references, and resources. This website also references supplemental materials, lectures, and other information suitable for use in university courses on sustainable construction.

Rationale for High-Performance Green Buildings

High-performance green buildings marry the best features of conventional construction methods with emerging high-performance approaches. Green buildings are achieving rapid penetration in the U.S. construction market for three primary reasons:

1. Sustainable construction techniques provide an ethical and practical response to issues of environmental impact and resource consumption. Sustainability assumptions encompass the entire life cycle of the building and its constituent components, from resource extraction through disposal at the end of the materials' useful life. Conditions and processes in factories are considered, along with the actual performance of their manufactured products in the completed building. High-performance green building design relies on renewable resources for energy systems; recycling and reuse of water and materials; integration of native and adapted

species for landscaping; passive heating, cooling, and ventilation; and other approaches that minimize environmental impact and resource consumption.

2. Green buildings virtually always make economic sense on a life-cycle cost (LCC) basis, though they may be more expensive on a capital, or first-cost, basis. Sophisticated energy-conserving lighting and air-conditioning systems with an exceptional response to interior and exterior climates will cost more than their conventional, code-compliant counterparts. Rainwater harvesting systems that collect and store rainwater for nonpotable uses will require additional piping, pumps, controls, storage tanks, and filtration components. However, most key green building systems will recoup their original investment within a relatively short time. As energy and water prices rise due to increasing demand and diminishing supply, the payback period will decrease. LCC provides a consistent framework for determining the true economic advantage of these alternative systems by evaluating their performance over the course of a building's useful life.[5]
3. Sustainable design acknowledges the potential effect of the building, including its operation, on the health of its human occupants. A 1984 World Health Organization report suggested that as many as 30 percent of new and remodeled buildings worldwide may generate excessive complaints related to indoor air quality.[6] Estimates peg the direct and indirect costs of building-related illnesses, including lost worker productivity, as exceeding $150 billion per year.[7] Conventional construction methods have traditionally paid little attention to sick building syndrome (SBS), building-related illness (BRI), and multiple chemical sensitivity (MCS) until prompted by lawsuits. In contrast, green buildings are designed to promote occupant health, including measures such as protecting ductwork during installation to avoid contamination during construction; specifying finishes with low to zero volatile organic components to prevent potentially hazardous chemical off-gassing; more precise sizing of heating and cooling components to promote dehumidification, thereby reducing mold; and the use of ultraviolet radiation to kill mold and bacteria in ventilation systems.[8]

Defining Sustainable Construction

The terms *high performance, green,* and *sustainable construction* are often used interchangeably; however, the term *sustainable construction* most comprehensively addresses the ecological, social, and economic issues of a building in the context of its community. In 1994, the Conseil International du Batiment (CIB), an international construction research networking organization, defined the goal of sustainable construction as ". . . creating and operating a healthy built environment based on resource efficiency and ecological design."[9] The CIB articulated seven Principles of Sustainable Construction, which would ideally inform decision making during each phase of the design and construction process, continuing throughout the building's entire life cycle (see Table 1.1).[10] These factors also apply when evaluating the components and other resources needed for construction (see Figure 1.3). The Principles of Sustainable Construction apply across the entire life cycle of construction, from planning to disposal (here referred to as *deconstruction* rather than *demolition*). Furthermore, the principles apply to the resources needed to create and operate the built environment during its entire life cycle: land, materials, water, energy, and ecosystems.

TABLE 1.1

The Principles of Sustainable Construction

1. Reduce resource consumption (reduce).
2. Reuse resources (reuse).
3. Use recyclable resources (recycle).
4. Protect nature (nature).
5. Eliminate toxics (toxics).
6. Apply life-cycle costing (economics).
7. Focus on quality (quality).

RESOURCE-CONSCIOUS DESIGN

The issue of resource-conscious design is central to sustainable construction, which ultimately aims to minimize natural resource consumption and the resulting impact

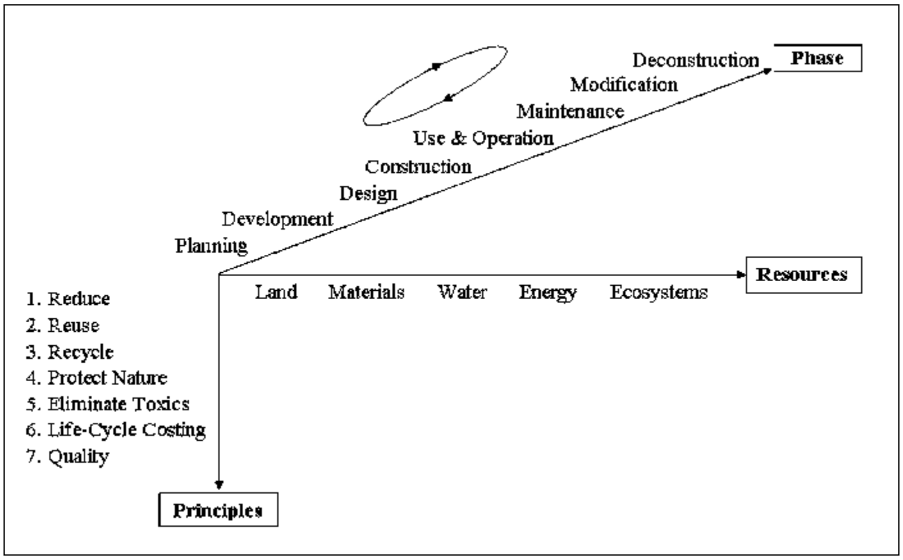

Figure 1.3 Framework for sustainable construction developed in 1994 by Task Group 16 (Sustainable Construction) of the CIB for the purpose of articulating the potential contribution of the built environment to the attainment of sustainable development. (Drawing by Bilge Çelik.)

on ecological systems. Sustainable construction considers the role and potential interface of ecosystems to provide services in a synergistic fashion. With respect to materials selection, closing materials loops and eliminating solid, liquid, and gaseous emissions are key sustainability objectives. *Closed loop* describes a process of keeping materials in productive use by reuse and recycling rather than disposing of them as waste at the end of the product or building life cycle. Products in closed loops are easily disassembled, and the constituent materials are capable and worthy of recycling. Because recycling is not entirely thermodynamically efficient, dissipation of residue into the biosphere is inevitable. Thus, the recycled materials must be inherently nontoxic to biological systems. Most common construction materials are not completely recyclable, but rather *downcyclable,* for lower-value reuse such as for fill or road subbase. Fortunately, aggregates, concrete, fill dirt, block, brick, mortar, tiles, terrazzo, and similar low-technology materials are composed of inert substances with low ecological toxicity. In the United States, the 140 million tons (127 million metric tons) of construction and demolition waste produced annually comprise about one-third of the total solid waste stream, consuming scarce landfill space, threatening water supplies, and driving up the costs of construction. As part of the green building delivery system, manufactured products are evaluated for their life-cycle impacts, to include energy consumption and emissions during resource extraction, transportation, product manufacturing, installation during construction, operational impacts, and the effects of disposal.

LAND RESOURCES

Sustainable land use is based upon the principle that land, particularly undeveloped, natural, or agricultural land (*greenfields*), is a precious finite resource, and its development should be minimized. Effective planning is essential to creating efficient urban forms and minimizing urban sprawl, which leads to overdependence on automobiles for transportation, excessive fossil fuel consumption, and higher pollution levels. Like other resources, land is recyclable and should be restored to productive use whenever possible. Recycling disturbed land such as former industrial zones (*brownfields*) and blighted urban areas (*grayfields*) back to productive use facilitates land conservation and promotes economic and social revitalization in distressed areas.

ENERGY AND ATMOSPHERE

Energy conservation is best addressed through effective building design, which integrates three general approaches: (1) designing a building envelope that is highly resistant to conductive, convective, and radiative heat transfer; (2) employing renewable energy resources; and (3) fully implementing passive design. *Passive design* employs the building's geometry, orientation, and mass to condition the structure using natural and climatological features such as the site's solar insolation,[11] thermal chimney effects, prevailing winds, local topography, microclimate, and landscaping. Since 30 percent of domestic primary energy[12] is consumed by buildings in the United States, increased energy efficiency and a shift to renewable energy sources can appreciably reduce carbon dioxide emissions and mitigate climate change.

WATER ISSUES

The availability of potable water is the limiting factor for development and construction in many areas of the world. In the high-growth Sun Belt and western regions of the United States, the demand for water threatens to rapidly outstrip the natural supply, even in normal, nondrought conditions.[13] Climate alterations and erratic weather patterns precipitated by global warming threaten to further limit the availability of this most precious resource. Since only a small portion of the Earth's hydrological cycle yields potable water, protection of existing ground and surface water supplies is increasingly critical. Once water is contaminated, it is extremely difficult, if not impossible, to reverse the damage. Water conservation techniques include the use of low-flow plumbing fixtures, water recycling, rainwater harvesting, and *xeriscaping,* a landscaping method that utilizes drought-resistant plants and resource-conserving techniques.[14] Innovative approaches to wastewater processing and stormwater management are also necessary to address the full scope of the building hydrologic cycle.

Figure 1.4 The Lewis Environmental Center at Oberlin College was designed by a team of top designers, led by William McDonough, a leading green building architect, and including John Todd, developer of the Living Machine. In addition to the superb design of the building's hydrologic system, the extensive photovoltaic system makes it a net exporter of energy. (Photograph courtesy of Oberlin College.)

ECOSYSTEMS: THE FORGOTTEN RESOURCE

Sustainable construction considers the role and potential interface of ecosystems in providing services in a synergistic fashion. Integration of ecosystems with the built environment can play an important role in resource-conscious design. Such integration can supplant conventional manufactured systems and complex technologies in controlling external building loads, processing waste, absorbing stormwater, growing food, and providing natural beauty, sometimes referred to as *environmental amenity.* For example, the Lewis Environmental Center at Oberlin College in Oberlin, Ohio, uses a built-in natural system, referred to as a "Living Machine," to break down waste from the building's occupants; the effluent then flows into a reconstructed wetland (see Figure 1.4). The wetland also functions as a stormwater retention system, allowing pulses of stormwater to be stored, reducing the burden on stormwater infrastructure. The restored wetland also provides environmental amenity in the form of native Ohio plants and wildlife.[15]

DEFINING *GREEN BUILDING*

The term *green building* refers to the quality and characteristics of the actual structure created using the principles and methodologies of sustainable construction. Green buildings can be defined as "healthy facilities designed and built in a resource-efficient manner, using ecologically based principles." Similarly, *ecological design, ecologically sustainable design,* and *green design* are terms that describe the application of sustainability principles to building design. Despite the prevalent use of these terms, truly sustainable green commercial buildings with renewable energy systems, closed materials loops, and full integration into the landscape are rare to nonexistent. Most existing green buildings feature incremental improvement over, rather than radical departure from, traditional construction methods. Nonetheless, this process of trial and error, along with the gradual incorporation of sustainability principles, continues to advance the industry's evolution toward the ultimate goal of achieving complete sustainability throughout all phases of the built environment's life cycle.

HIGH-PERFORMANCE BUILDINGS, WHOLE BUILDING DESIGN, AND SYSTEMS THINKING

The term *high-performance building* has recently become popular as a synonym for green building in the United States. According to the U.S. Office of Energy Efficiency and Renewable Energy (EERE), a high-performance commercial building ". . . uses *whole-building design* to achieve energy, economic, and environmental performance that is substantially better than standard practice."[16] This requires that the design team fully collaborate from the project's inception in a process often referred to as *integrated design.*

Whole building, or integrated, design considers site, energy, materials, indoor air quality, acoustics, and natural resources, as well as their interrelation with one another. In this process, a collaborative team of architects, engineers, building occupants, owners, and specialists in indoor air quality, materials, and energy and water efficiency utilizes *systems thinking* to consider the building structure and systems holistically, examining how they best work together to save energy and reduce the environmental impact. A common example of systems thinking is *advanced daylighting strategy,* which reduces the use of lighting fixtures during daylight, thereby reducing daytime peak cooling loads and justifying a reduction in the size of the mechanical cooling system. This, in turn, results in reduced capital outlay and lower energy costs over the building's life cycle.

According to the Rocky Mountain Institute (RMI), a well-respected nonprofit organization specializing in energy and building issues, *whole-systems thinking* is a process through which the interconnections between systems are actively considered and solutions are sought that address multiple problems. Whole-systems thinking is often promoted as a cost-saving technique that allows additional capital to be invested in new building technology or systems. RMI cites developer Michael Corbett, who applied just such a concept in his 240-unit Village Homes subdivision in Davis, California, completed in 1981. Village Homes was one of the first modern-era developments to successfully create an environmentally sensitive, human-scale residential community. The result of designing narrower streets was reduced stormwater runoff. Simple infiltration swales and on-site detention basins handled stormwater without the need for conventional stormwater infrastructure. The resulting $200,000 in savings was used to construct public parks, walkways, gardens, and other amenities that improved the quality of the community. A more recent example of systems thinking is Solaire, a 27-story luxury residential tower in New York City's Battery Park (see Figure 1.5). The façade of Solaire contains photovoltaic cells that convert sunlight directly into electricity, and the building itself uses 35 percent less energy than a comparable residential building. It provides its residents with abundant natural light and excellent indoor air quality. The building collects rainwater in a basement tank for watering roof gardens. Wastewater is processed for reuse in the air-conditioning system's cooling towers or for flushing toilets. The roof gardens not only provide a beautiful urban landscape, but also assist in insulating the building to reduce heating and cooling loads. This interconnection of many of the green building measures in Solaire indicates that the project team carefully selected approaches that would have multiple layers of benefit, the core of systems thinking.[17]

STATE AND LOCAL GUIDELINES FOR HIGH-PERFORMANCE CONSTRUCTION

Several states have taken the initiative in articulating guidelines aimed at facilitating high-performance construction. The Pennsylvania Governor's Green Government Council (GGGC) uses mixed but very appropriate terminology in its "Guidelines for Creating High-Performance Green Buildings: A Document for Decision Makers" (1999). The lengthy but instructive definition of high-performance green building (Table 1.2) focuses as much on the collaborative involvement of the stakeholders as it does on the physical specifications of the structure itself.[18]

Similar guidance is provided by the City of New York Department of Design and Construction in its "High Performance Building Guidelines," in which the end product, the building, is hardly mentioned and the emphasis is on the strong collaboration of the participants (see Table 1.3).[19]

The "High Performance Guidelines: Triangle Region Public Facilities," published by the Triangle J Council of Governments in North Carolina (1999), focuses on three principles:

- *Sustainability,* which is a long-term view that balances economics, equity, and environmental impacts
- *An integrated approach,* which engages a multidisciplinary team at the outset of a project to work collaboratively throughout
- *Feedback and data collection,* which quantifies both the finished facility and the process that created it and serves to generate improvements in future projects

Like the other state guidelines, North Carolina's "High Performance Guidelines" emphasize collaboration and process, rather than merely the physical characteristics of the completed building. Historically, building owners have assumed that they were

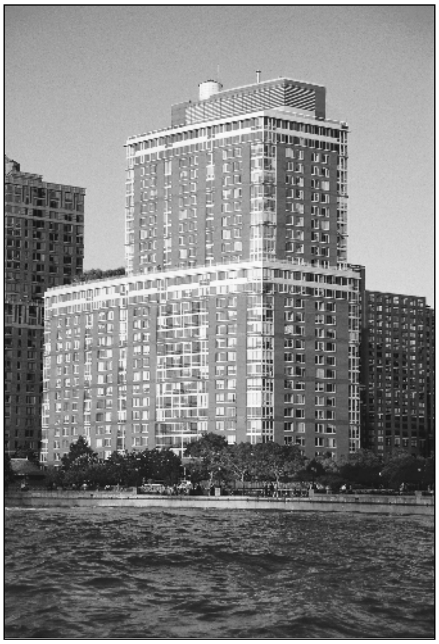

Figure 1.5 Solaire, a 27-story residential tower on the Hudson River in New York City, which opened in July 2003, is the first high-rise residential building in the United States specifically designed to be environmentally responsible. (Photograph courtesy of the Albanese Development Corporation.)

TABLE 1.2

High-Performance Green Building as Defined by GGGC

- A project created via cooperation among building owners, facility managers, users, designers and construction professionals through a collaborative team approach.
- A project that engages the local and regional communities in all stages of the process, including design, construction, and occupancy.
- A project that conceptualizes a number of systems that, when integrated, can bring efficiencies to mechanical operation and human performance.
- A project that considers the true costs of a building's impact on the local and regional environment.
- A project that considers the life-cycle costs of a product or system. These are costs associated with its manufacture, operation, maintenance, and disposal.
- A building that creates opportunities for interaction with the natural environment and defers to contextual issues such as climate, orientation, and other influences.
- A building that uses resources efficiently and maximizes use of local building materials.
- A project that minimizes demolition and construction wastes and uses products that minimize waste in their production or disposal.
- A building that is energy- and resource-efficient.
- A building that can be easily reconfigured and reused.
- A building with healthy indoor environments.
- A project that uses appropriate technologies, including natural and low-tech products and systems, before applying complex or resource-intensive solutions.
- A building that includes an environmentally sound operations and maintenance regimen.
- A project that educates building occupants and users to the philosophies, strategies, and controls included in the design, construction, and maintenance of the project.

benefiting from this integrated approach as a matter of course. In practice, however, the actual lack of coordination among design professionals and their consultants often resulted in facilities that were problematic to build. Now the green building movement has begun to emphasize that strong coordination and collaboration is the true foundation of a high-quality building. This philosophy promises to influence the

TABLE 1.3

Goals for High-Performance Buildings According to the City of New York Department of Design and Construction

- Raise expectations for the facility's performance among the various participants.
- Ensure that capital budgeting design and construction practices result in investments that make economic and environmental sense.
- Mainstream these improved practices through (1) comprehensive pilot high-performance building efforts and (2) incremental use of individual high-performance strategies on projects of limited scope.
- Create partnerships in the design and construction process around environmental and economic performance goals.
- Save taxpayers money through reduced energy and material expenditures, waste disposal costs, and utility bills.
- Improve the comfort, health and well-being of building occupants and public visitors.
- Design buildings with improved performance, which can be operated and maintained within the limits of existing resources.
- Stimulate markets for sustainable technologies and products.

entire building industry and, ultimately, to enhance confidence in the design and construction professions.

Green Building Progress and Obstacles

Although still considered a fringe movement, in the early twenty-first century the green building concept has won industry acceptance, and it continues to impact building design, construction, operation, real estate development, and sales markets. Detailed knowledge of the options and procedures involved in "building green" is invaluable for any organization providing or procuring design or construction services. The number of buildings registered with the USGBC for the LEED-NC building assessment system grew from a few in 1999 to more than 6,000 registered and certified in late 2006. The area of LEED-certified buildings increased from a few thousand square feet in 1999 to over 365 million square feet (34 million square meters) in early 2006. Federal and state governments, many cities, several universities, and a growing number of private sector construction owners have declared sustainable or green materials and methods as their standard for procurement.

Despite the success of LEED and the U.S. green building movement in general, challenges abound when implementing sustainability principles within the well-entrenched traditional construction industry. Although proponents of green buildings have argued that whole-systems thinking must underlie the design phase of this new class of buildings, conventional building design and procurement processes are very difficult to change on a large scale. Additional impediments may also apply. For example, most jurisdictions do not yet permit the elimination of stormwater infrastructure in favor of using natural systems for stormwater control. Daylighting systems do not eliminate the need for a full lighting system, since buildings generally must operate at night. Special low-e window glazing, skylights, light shelves, and other devices increase project cost. Controls that adjust lighting to compensate for varying amounts of available daylight, and occupancy sensors that turn lights on and off depending on occupancy, add additional expense and complexity. Rainwater harvesting systems require dedicated piping, a storage tank or cistern, controls, pumps, and valves, all of which add cost and complexity.

Green building materials often cost substantially more than the materials they replace. Compressed wheatboard, a green substitute for plywood, currently costs as much as 10 times more than the plywood it replaces. The additional costs, and those associated with green building compliance and certification, often require owners to add a separate line item to the project budget. The danger is that during the course of construction management, when costs must be brought under control, the sustainability line item is one of the first to be "value-engineered" out of the project. To avoid this result, it is essential that the project team and the building owner clearly understand that sustainability goals and principles are paramount, and that LCC should be the applicable standard when evaluating a system's true cost. Yet, even LCC does not guarantee that certain measures will be cost-effective in the short or long term. Where water is artificially cheap, systems that use rainwater or graywater are difficult to justify financially, even under the most favorable assumptions. Finally, more expensive environmentally friendly materials may never pay for themselves in an LCC sense.

A summary of trends in, and barriers to, green building is presented in Table 1.4. These trends are an outcome of the Green Building Roundtable, a forum held by the USGBC for members of the U.S. Senate Committee on Environment and Public Works in April 2002.[20]

TABLE 1.4

Trends and Barriers to Green Building in the United States

Trends

1. Rapid penetration of the LEED green building rating system and growth of USGBC membership
2. Strong federal leadership
3. Public and private incentives
4. Expansion of state and local green building programs
5. Industry professionals taking action to educate members and integrate best practices
6. Corporate America capitalizing on green building benefits
7. Advances in green building technology

Barriers

1. Financial disincentives
    - a. Lack of LCC analysis and use
    - b. Real and perceived higher first costs
    - c. Budget separation between capital and operating costs
    - d. Security and sustainability perceived as trade-offs
    - e. Inadequate funding for public school facilities
2. Insufficient research
    - a. Inadequate research funding
    - b. Insufficient research on indoor environments, productivity, and health
    - c. Multiple research jurisdictions
3. Lack of awareness
    - a. Prevalence of conventional thinking
    - b. Aversion to perceived risk

Emerging Directions

Measures to cope with problems of constructability, cost, coordination of drawings, and attention to client requirements have been woven into the high-performance green building delivery system. Three powerful approaches coexist to ensure the creation of a truly high-performance building: performance-based fees, the charrette, and building commissioning. Although none of these concepts is new, each has rapidly gained acceptance among procurers and providers of green construction.

PERFORMANCE-BASED FEES

Ensuring collaboration and cooperation among the building team members during the design and construction phases is a challenge inherent in any building project. The use of performance-based fees (PBFs) has been suggested as an effective and ethical incentive for cooperation in which the savings derived from highly efficient design increase the designers' compensation. Since PBFs are dependent on the building systems' performance and efficiency rather than on initial cost, the greater the savings in electricity, natural gas, liquid fuels, and other resources, the higher the fees earned by the architects and engineers. For example, PBFs were used for the Clackamas Senior High School in Clackamas, Oregon, a 265,000-square-foot (25,000 square meters) facility that opened in April 2002, with a projected energy consumption level 44 percent below Oregon Building Code specifications. Optimizing the building's design meant reducing the mechanical plant size by investing in a high-performance building envelope and low-emissivity glass. Unlike a conventional project, mechanical plant size reduction actually resulted in *increased* fees due to projected energy savings.[21]

Establishing building efficiency goals and objectives at a project's inception is essential for the effective use of PBFs. Presently, practical goals are limited to energy consumption. It is also necessary to define and establish specific methods for quantifying system performance, which are typically expressed in terms of energy use or energy cost per unit of building area and may be impacted by other variables. For example, differences in heating and cooling degree-days, compared to the year in which the building's energy uses were modeled by computer simulation, can make enormous differences in the results.

THE CHARRETTE

According to the National Charrette Institute, "[t]he 'charrette' is often used to describe the final, intense work effort expended by art and architecture students to meet a project deadline."[22] The term originates from the École des Beaux Arts in Paris during the nineteenth century, where proctors circulated a cart, or *charrette,* to collect final drawings while students frantically put finishing touches on their work. Today's charrette brings a wide range of stakeholders together to facilitate a dynamic exchange of ideas, with the benefit of immediate feedback to all participants. An ideal charrette would include the owner, design team, builder, facility managers, members of the community, nonprofit organizations, children—literally anyone affected by the building. By incorporating the building into the fabric of the community, local opposition is lessened; the approval process is expedited; and community concerns, along with owner and builder needs, are addressed in a holistic process. Although not required by the USGBC's LEED standard, the charrette has been an enormously successful feature of the green building delivery process. The role of the charrette in the green building process is covered in more detail in Chapter 4.

BUILDING COMMISSIONING

Building commissioning has also become a standard, critical component of the green building delivery process. According to the Oregon Office of Energy, building commissioning is the process of ensuring that building systems are designed, installed, functionally tested, and capable of being operated and maintained according to the owner's operational needs.[23] Although building commissioning does not specifically address issues of sustainability, it demonstrates how the high-performance building process is improving the overall building delivery industry in the United States.

The building commissioning process has evolved from the mere testing and balancing of heating, ventilation, and air-conditioning (HVAC) systems at the project's completion to include an array of services. Ideally, a commissioning organization becomes involved in the conceptual stage of the project, providing expertise during the design phase. Prior to the completed building's delivery to its owner, the commissioning agent performs a thorough review of all systems, including but not limited to roofing, interior finishes, power, lighting, HVAC, plumbing, fire protection, telecommunications, and elevators. The building commissioning process is covered in depth in Chapter 12.

Summary and Conclusions

The rapidly evolving and exponentially growing green building movement is arguably the most successful environmental movement in the United States today. In contrast to many other areas of environmentalism that are stagnating, sustainable building has proven to yield substantial beneficial environmental *and* economic advantages. The USGBC's market and consensus-based LEED standards have catapulted sustainable construction into wide adoption. Despite this progress, however, there remain significant obstacles, erected by the inertia of the building professions and the construction industry and compounded by the difficulty of changing building codes. Industry professionals, in both the design and construction disciplines, are generally slow to change and tend to be risk-averse. Likewise, building codes are inherently difficult to change, and fears of liability and litigation over the performance of new products and systems pose appreciable challenges. Furthermore, the environmental or economic benefit of some green building approaches has not been scientifically quantified, despite their often intuitive and anecdotal benefits. Finally, lack of a collective vision and guidance for future green buildings, including design, components, systems, and materials, may affect the present rapid progress of this arena.

Despite these difficulties, the robust U.S. green building movement continues to gain momentum, and thousands of construction and design professionals have made it the mainstay of their practices. Numerous innovative products and tools are marketed each year, and in general, this movement benefits from an enormous air of energy and creativity. Like other processes, sustainable construction may one day become so common that its unique distinguishing terminology may be unnecessary. At that point, the green building movement will have accomplished its purpose: to transform fundamental human assumptions that create waste and inefficiency into a new paradigm of responsible behavior that supports both present and future generations.

Notes

1. Sustainability was first defined in 1981 by Lester Brown, a well-known American environmentalist and for many years the head of the Worldwatch Institute. In "Building a Sustainable Society," he defined a sustainable society as ". . . one that is able to satisfy its

needs without diminishing the chance of future generations." In 1987, the Bruntland Commission, headed by then Prime Minister of Norway, Gro Bruntland, adapted Brown's definition, referring to sustainable development as ". . . meeting the needs of the present without compromising the ability of future generations to meet their needs." Sustainable development, or sustainability, strongly suggests a call for intergenerational justice and the realization that today's population is merely borrowing resources and environmental conditions from future generations. In 1987, the Bruntland Commission's report was published as a book, *Our Common Future,* by the UN World Commission on Environment and Development.

2. The World Business Council on Sustainable Development (WBCSD) promotes sustainable development reporting by its 170 member international companies. The WBCSD is committed to sustainable development via the three pillars of sustainability: economic growth, ecological balance, and social progress. Its website is www.wbcsd.org.
3. In November 1992, more than 1,700 of the world's leading scientists, including the majority of the Nobel laureates in the sciences, issued the "World Scientists' Warning to Humanity." The preamble of this warning stated: "Human beings and the world are on a collision course. Human activities inflict harsh and often irreversible damage on the environment and critical resources. If not checked, many of our current practices put at serious risk the future that we wish for human society and the plant and animal kingdoms, and may so alter the living world that it may be unable to sustain life in the manner we know. Fundamental changes are urgent if we are to avoid the collision our present course will bring about." The remainder of this warning addresses specific issues, global warming among them, and calls for dramatic changes, especially on the part of the high-consuming developed countries, particularly the United States.
4. See, for example, Campell and Laherrere (1998).
5. A recent report, "The Cost and Benefits of Green Buildings," made to California's Sustainable Buildings Task Force, describes in detail the financial and economic benefits of green buildings. The principal author of this report is Greg Kats of Capital E. Several other reports on this theme by the same author are available online. See the References for more information
6. From World Health Organization (1983).
7. The losses are estimated productivity losses as stated by Mary Beth Smuts, a toxicologist with the U.S. Environmental Protection Agency, in Marsha Zabarsky (2002).
8. From "Ultra-violet Radiation Could Reduce Office Sickness" (2004).
9. At the First International Conference on Sustainable Construction held in Tampa, Florida, in November 1994, Task Group 16 (Sustainable Construction) of CIB formally defined the concept of sustainable construction and articulated six principles of sustainable construction, later amended to seven principles.
10. Sustainable construction and the model are described in Kibert (1994).
11. *Insolation* is an acronym for **in**coming **sol**ar radia**tion.**
12. Primary energy accounts for energy in its raw state. The energy value of the coal or fuel oil being input to the power plant is primary energy, while the electricity being generated, which has lower energy value due to the inefficiency of the generation system, is simply the output energy. Consequently, primary energy accounts for the losses in energy conversion, generation, and transmission.
13. A description of severe water resource problems beginning to emerge even in water-rich Florida can be found in the May/June 2003 issue of *Coastal Services,* an online publication of the NOAA Coastal Services Center, available at www.csc.noaa.gov/magazine/2003/03/florida.html. A similar overview of water problems in the western United States can be found in Young (2004).
14. An overview of xeriscaping and the seven basic principles of xeriscaping can be found at http://aggie-horticulture.tamu.edu/extension/xeriscape/xeriscape.html.
15. The Adam Joseph Lewis Center at Oberlin College was designed by a highly respected team of architects, engineers, and consultants and is a cutting-edge example of green buildings in the United States. An informative website, www.oberlin.edu/envs/ajlc, shows real-time performance of the building and its photovoltaic system.
16. *The Whole Building Design Guide* can be found at www.wbdg.org.
17. The design approach used in creating Solaire in Battery Park, New York City, plus updates on construction progress can be found at www.batteryparkcity.org. Another website with detailed information and illustrations is www.thesolaire.com.

18. See *Guidelines for Creating High-Performance Green Buildings* (1999).
19. Excerpted from *High Performance Building Guidelines* (1999).
20. The outcomes of the Green Building Roundtable can be found in *Building Momentum* (2003).
21. A detailed description of the application of PBFs to the Clackamas School is available at the RMI website www.rmi.org/sitepages/pid715.php.
22. Information on the recommended approach for conducting a charrette can be found at the website of the National Charrette Institute, www.charretteinstitute.org.
23. Extensive information about building commissioning can be found at the website of the Oregon Department of Energy, www.energy.state.or.us/bus/comm/bldgcx.htm.

References

Brown, Lester. 1981. *Building a Sustainable Society.* New York: Norton.

Building Momentum: National Trends and Prospects for High-Performance Green Buildings. February 2003. U.S. Green Building Council. Available at www.usgbc.org/Docs/Resources/043003_hpgb_whitepaper.pdf.

Campbell, C.J., and J.H. Laherrere. March 1998. "The End of Cheap Oil," *Scientific American,* 273(3), pp. 78–83.

Creating High-Performance Green Buildings: A Guide for Decision Makers. 1999. Pennsylvania Department of Environmental Protection. Available at www.gggc.state.pa.us.

Guidelines for Creating High-Performance Green Buildings. 1999. Pennsylvania Governor's Green Government Council (GGGC). Available at www.gggc.state.pa.us/publictn/gbguides.html.

High Performance Building Guidelines. April 1999. City of New York Department of Design and Construction. Available at www.ci.nyc.ny.us/nyclink/html/ddc/home.html.

High Performance Guidelines: Triangle Region Public Facilities, Version 2.0. September 2001. Available at www.tjcog.dst.nc.us/hpgtrpf.htm.

Kats, Gregory H. October 2006. "Greening America's Schools," available at www.cap-e.com.

Kats, Gregory H., and Jeff Perlman. December 2005. "National Review of Green Schools," a report for the Massachusetts Technology Collaborative, available at www.cap-e.com.

Kats, Gregory H. October 2003. "The Costs and Financial Benefits of Green Buildings," a report developed for California's Sustainable Building Task Force. Available at the Capital E website, www.cap-e.com.

Kibert, Charles J. November 1994. "Principles and a Model of Sustainable Construction," in *Proceedings of the First International Conference on Sustainable Construction,* 6–9 November 1994, Tampa, Florida, pp. 1–9.

Our Common Future. 1987. UN World Commission on Environment and Development, Oxford, England: Oxford University Press. *Our Common Future* is also referred to as the Brundtland Report, because Gro Bruntland, Prime Minister of Norway at the time, chaired the committee writing the report.

"Ultra-violet Radiation Could Reduce Office Sickness." January 4, 2004. Available at the website of the Lung Association of Saskatchewan, www.sk.lung.ca/content.cfm/xtra0129.

World Health Organization. (1983). "Indoor Air Pollutants: Exposure and Health Effect," *EURO Report and Studies,* No. 78.

Young, Samantha. March 10, 2004. *Las Vegas Review Journal.* Available at www.reviewjournal.com/lvrj_home/2004/Mar-10-Wed-2004/news/23401764.html.

Zabarsky, Marsha. August 16, 2002. "Sick Building Syndrome Gains a Growing Level of National Awareness." *Boston Business Journal.* Available at www.bizjournals.com/boston/stories/2002/08/19/focus9.html.