CHAPTER 1

Introduction

Overview

Environmental issues have moved into the mainstream of our culture. Growing environmental crises face each new generation. Since the first edition of this book, just five years ago, these challenges have become greater. The United States uses more energy than it did five years ago. The United States is more dependent on foreign oil than it was then. The scarcity of safe water has become more of an issue in many parts of this country. As we move toward greater awareness of these challenges, we are slowly building a collective momentum, not only toward solving these problems, but toward recognizing the opportunities they offer us. These opportunities can lead us to a new generation of buildings and communities that are healthy, productive, and enhance our quality of life. It is an exciting time—many of the things that we strive to do to move toward a truly sustainable built environment are practical and feasible today. Perhaps the biggest challenge is simply to get started. This guide is designed to help you do just that.

WHAT IS SUSTAINABLE DESIGN?

Sustainability has been defined by the Brundtland Commission, 1987, as "meeting the needs of the present generation without compromising the ability of future generations to meet their own needs." Sustainability represents a balance that accommodates human needs without diminishing the health and productivity of natural systems. Since the first edition of this book, HOK and many other firms have created many new and innovative designs. It is now more common than not to talk about and act on the sustainable design goals for new projects. Nevertheless, none of these buildings are truly sustainable; they represent only steps in that direction.

In these times of rapidly rising world population, increased demand on resources, and continued pollution, sustainability is quickly becoming the dominant issue of our time. It is an issue that each of us, individually and as institutional representatives, can and should address in our daily work.

Unfortunately, our current economic accounting system does not recognize the value of depleted resources or the cost of pollution and diminishing biodiversity. If it did, our current practices would no longer appear to be economically justifiable. However, the search for sustainability highlights waste and lost opportunities in our current practices that can serve as the engine for development of improved solutions. Increasingly, people are realizing that environmental and economic sustainability go hand in hand.

While environmental and economic sustainability is the goal, sustainable design is the means we as designers have to contribute to that goal. Sustainable design moves away from extractive and disposable systems that are energy-intensive, resource-inefficient, and toxic, toward cyclical, closed-loop systems that are restorative, dynamic, and flexible.

ENVIRONMENTAL IMPACTS OF BUILDINGS AND CONSTRUCTION

The construction and operation of buildings contributes significantly, directly and indirectly, to most of our environmental challenges. Buildings are tremendous consumers of resources and generators of waste. The industrial processes used to manufacture building materials and equipment contribute to waste and pollution as well. Buildings and the infrastructure that supports them consume open space and displace habitat. Poor indoor environments can inhibit productivity, and in some cases, can even threaten the health of building occupants.

According to the Worldwatch Institute, buildings in the United States use 17 percent of the total freshwater flows and 25 percent of harvested wood; they are responsible for 50 percent of chlorofluorocarbon (CFC) production, use 40 percent of the total energy flows, generate 33 percent of CO_2 emissions, and generate 40 percent of landfill material as a result of construction waste.

The environmental impacts of buildings are eroding our very quality of life. According to the U.S. Environmental Protection Agency (EPA), one-third of all buildings suffer from "sick building" syndrome. Our open space is being consumed by sprawl, and our communities are being overcome with traffic and congestion.

DID YOU KNOW . . . ?

Every day the worldwide economy burns an amount of energy the planet required 10,000 days to create—the stored solar energy is burned and released by utilities, cars, houses, factories, and farms.

—Paul Hawken, *The Ecology of Commerce* (New York: HarperCollins, 1993), 21–22.

SUSTAINABLE DESIGN GOALS

Sustainable design recognizes the interdependence of the built and natural environments; it seeks to harness natural energy flows and biological processes, eliminate reliance on fossil fuels and toxic materials, and improve resource efficiency. In the short run, the impact of these changes will be to reduce the environmental impact of our designs. In the long run, the goal is to create buildings that are not only not harmful but actually part of natural systems and restorative of those systems. Sustainable design is concerned with the quality of our environment as a whole system. Much of this book is focused on individual buildings. However, issues related to land use, community planning, and regional planning are also of primary importance. In the end, the goal is to create buildings and communities that are part of the natural world, living off of nature's abundance but being regenerative and supportive of all other living systems.

DID YOU KNOW . . . ?

Every year the United States paves more area than did the Roman Empire during its entire existence.

— Kim Sorvig, *Porous Paving,* Landscape Architecture (February 1993), 66.

OPPORTUNITIES FOR IMPROVEMENT

The good news is that there are many ways to improve our work without increased costs or program sacrifices. Sustainable design in buildings and construction means taking a holistic view. It means making buildings and infrastructure that use land, material, energy, and water resources efficiently; that improve the health of ecosystems; and that address health issues relating to the indoor environment. For nearly every conventional building product and system used today, there are environmentally preferable alternatives. In most cases, there are practical and affordable choices with significantly improved environmental performance. By embracing sustainable land-use planning, we preserve and enhance habitats and make our communities more livable. The overall goals that guide these decisions are summarized below:

GLOBAL GOALS

Waste Nothing

Reduce construction, remodeling, and building operations waste.
Take a "less is more" approach to resource use.
Design for flexibility and long-term use.
Encourage resource reuse; avoid use of scarce materials.

Adapt to Place

Use indigenous strategies.
Strive for diversity.
Fit form to function.

Use "Free" Resources

Use renewable energy and material resources.
Use materials and resources available locally and in abundance.

Optimize Rather Than Maximize

Seek synergistic solutions.
Reduce reliance on mechanical systems.

Create a Livable Environment

Protect sensitive and endangered ecosystems.
Support restoration of degraded natural systems.
Promote development of pedestrian-friendly, mixed-use communities.
Create healthy environments free of toxic materials.

Provide daylight and views, and direct connections to nature.
Provide for personal control.
Create opportunities for personal expression.
Seek opportunities to improve social equity.

ECONOMIC BENEFITS

When fully integrated into the design effort, sustainable design can lead to a variety of economic benefits. These include the economic benefits of energy, water, and materials savings, as well as reduced maintenance and other operational costs. These benefits have been verified in recent studies of completed green buildings, which we reference in the Economics section later in this guide. Numerous studies highlight the connection between healthy buildings and increased productivity, with green buildings producing increases from 2 to 15 percent. Green buildings provide additional benefits to building owners and occupants by limiting risks, such as liability due to poor indoor air quality. Finally, green buildings can contribute to positive public relations. Public concern about these issues will continue to grow, and with it will come increasing demand for solutions and support for those who are seeking those solutions.

WHY WE WROTE THIS BOOK

The HOK Guidebook to Sustainable Design was written to serve as a desktop reference for design professionals, including architects; mechanical, electrical, and plumbing (MEP) engineers; interior designers; site planners; landscape architects; civil engineers; and facility consultants. Since the first edition, we have been told that it has been equally useful for contractors, owners, developers, and others involved in the design industry.

The guide was created by and for design professionals to support our project work. As such, it is an ongoing work in progress that represents our current working knowledge of these issues. As we have been working to address sustainable design issues and opportunities in our work, we have come to understand that we need two things: a greater base of information to inform our decision making, and a revised and expanded design process. Both are needed; without a deeper understanding of the myriad impacts our buildings have on the global environment, our communities, and our homes and workplaces, we are unable to see where the opportunities are for improvement. Likewise, without a design process that is more inclusive and more rigorous in the pursuit of integrated design solutions that require multidisciplinary collaboration, sustainable design cannot be recognized and developed fully.

We hope that this book will continue to demystify sustainable design and the sustainable design process and make them more tangible for designers, facility managers, and owners alike.

WHY WE HAVE DEVELOPED A REVISED EDITION

This edition is organized in a fundamentally different way than the first edition. The original, which was published before the LEED green building rating system was developed, focused on defining the issues, strategies, and technologies that are part of a sustainable building design. The idea that we have had reinforced most in the years since the first edition is the importance of process in achieving outstanding sustainable buildings. What we have seen in our own work and the work of others is that truly the best sustainable designs are "integrated" design solutions, which come from integrated teams with a clear, systematic process. Process has more to do with the final success of a sustainable building design than any building material, technology, or system. With this in mind, we have reorganized the design guidance portion of this book around the design process. The design process is broken down into ten key steps, with the important issues to be addressed highlighted at each stage.

The other major change is that this book was developed to be complementary to LEED. The Process Guidance chapter is organized by major LEED category and a detailed cross-reference is provided between individual LEED credits and the resources in this book to make it easier to find the appropriate technology, systems, materials, or other tips.

DID YOU KNOW…?

Buildings are responsible for 136 million tons of construction and demolition waste in the United States (approx. 2.8 lbs/person/day).

—U.S. EPA, 1998, "Characterization of Building-Related Construction and Demolition Debris in the United States."

HOW TO USE THIS BOOK

The material in this book has been organized to allow for easy use as a reference document. As noted, it is keyed and cross-referenced to LEED credits. The first chapter provides an overview of issues and goals for sustainable buildings. This is followed by a discussion of economics, which is, in turn, followed by a discussion of the sustainable design process. Finally, a description of the postoccupancy evaluation process is provided. Included in this are a series of "lessons learned" from the evaluation of several of our buildings that have been occupied for a number of years.

The second chapter of the book goes into detail about each stage of the process. It includes a checklist of the key tasks to be undertaken at each stage, with detailed project actions that provide specific information on how each of the issues on the checklist should be implemented. A graphic key indicates which team members would typically be responsible for implementing the action. Actions that identify more than one responsible team member indicate that collaboration is called for to address the issue properly. This is followed in the third chapter by building-type-specific discussions, with key issues, opportunities, and strategies that we have found to be particularly important in these facilities.

The fourth chapter of the book contains case studies of HOK projects that apply these principles. The projects that were selected represent both new and renovation projects for a broad range of project types, including office buildings, interiors, research laboratories, courthouses, museums, a stadium, a resort, and urban planning. While most of the projects are built, some of them are still in design or under construction at the time of this second edition. For several, we have included findings of postoccupancy evaluations to see how they have performed over time and to discover and share lessons learned.

The last part of the book contains a detailed glossary and references for further research. The reference list of books, periodicals, and Internet sources is intentionally concise to provide readers with our recommendation of the best and most accessible resources currently available. Many of these resources are available online, making them even more convenient for project teams.

DID YOU KNOW . . . ?

We have decimated 97% of the ancient forests of North America, and globally we are losing 27,000 species a year largely due to the 500,000 trees that are cut every hour in tropical forests.

— Paul Hawken, *The Ecology of Commerce* (New York: HarperCollins, 1993), 29.

TEN KEY STEPS

The following ten steps are the key process steps that form the organizational framework of this book. We recommend that these be used to guide an integrated team approach to sustainable design.

Step One: Project Definition

Owner, client representatives, and design team leaders should establish and clearly embed sustainable design tasks in the scope of work, document these in the contract agreement, and coordinate these with the project schedule.

Step Two: Team Building

Seek design team members who are experienced and committed to sustainable design and working collaboratively. Assemble the full design team and identify sustainable champions for the owner and the design team.

Step Three: Education and Goal Setting

Engage team in discussion of sustainable issues and opportunities, including cost and schedule impacts. Then hold a sustainable goal session with all team members to set broad goals and measurable outcomes, such as a LEED target. Review design criteria and standards and challenge those that work against integrated sustainable solutions.

Step Four: Site Evaluation

Analyze the site to identify constraints and sustainable opportunities. Evaluate the microclimate and macroclimate to determine solar and wind availability and orientation, potential thermal sinks, and rainfall. Inventory plant and animal species and their habitats. Identify transportation networks, and cultural and/or historical resources that should be preserved.

Step Five: Baseline Analysis

Develop baseline energy and water analysis; establish budgets and compare with benchmarks and project sustainable design goals. Explore potential for renewable energy, financial incentives, and/or utility rebates for energy efficiency, water, and renewables.

Step Six: Design Concept

Use an integrated and collaborative design process to embed sustainable strategies within a design concept that is responsive to the project site and the regional ecosystem.

Step Seven: Design Optimization

Explore, test, and evaluate a broad range of solutions to discern those with greatest potential. Engage the entire design team in a multidisciplinary approach to seek synergies in the development and refinement of building and site systems.

Step Eight: Documents and Specifications

Carefully document all project requirements. Engage in a process to update and improve contract documents and specifications to ensure that sustainable goals, including materials, systems, and other requirements, are being incorporated.

Step Nine: Bidding and Construction

Engage design team, contractor, and owner in a collaborative approach to bidding, buyout, procurement, construction, and commissioning to deliver a healthy, environmentally responsible facility that meets project sustainable design goals.

Step Ten: Postoccupancy

Engage design team and building users in discussion to discover ways to improve building operations, maintenance, and occupant satisfaction. Undertake a postoccupancy evaluation to evaluate hard and soft metrics and to identify lessons learned.

LEED® GREEN BUILDING RATING SYSTEM

In 1993, the U.S. Green Building Council was formed by a consortium of building owners, suppliers, contractors, governmental agencies, architects, engineers, and others involved in the business of creating buildings. The purpose was to transform the building industry toward healthy, profitable, sustainable facilities. One of the first steps the Council took was the formation of a green building rating system. LEED, which stands for Leadership in Energy and Environmental Design, was developed in the late 1990s, a pilot version was tested, and LEED Version 2.0 was formally introduced to the public in the spring of 2000. LEED was envisioned and created to be a living document, and it has been updated twice. LEED Version 2.2 is expected to be released in the fall of 2005. In addition, LEED for Existing Buildings and LEED for Commercial Interiors were released in 2004. Other versions as well as detailed building specific application guides are either being planned or in production.

DID YOU KNOW . . . ?

Buildings consume at least 40% of the world's energy. They thus account for about a third of the emissions of heat-trapping carbon dioxide from fossil fuel burning, and two-fifths of acid-rain–causing sulfur dioxide and nitrogen oxides.

—David Malin Roodman and Nicholas Lessen, *Building Revolution: How Ecology and Health Concerns Are Transforming Construction*, Worldwatch Paper 124 (Washington, D.C.: Worldwatch Institute, 1995), 24.

LEED has clearly become the standard in North America for rating environmental effectiveness of buildings and has attracted a very wide and growing following. Similar efforts are now underway throughout Europe and Asia. At the beginning of Chapter Two of this guide is a detailed cross-reference between LEED criteria and the information in this guide.

LEED was created through a consensus process involving many stakeholders to help move the building industry toward more sustainable practices. It has been successful because it is rigorous, transparent, and easy to use. Design team members can track their progress toward earning a LEED rating throughout the course of the project themselves, without the need for specialty consultants. As such, it can be used as a tool to introduce, promote, and guide comprehensive and integrated green building design.

The rating system is based on a series of prerequisites and credits, with a total of 69 points. The design team must verify that all of the prerequisites have been met and earn a minimum total of 26 points to get a certified rating. Likewise, a minimum of 33 points earns a Silver rating, 39 points earns a Gold rating, and 52 points earns a Platinum rating. Most of the credits are performance-based, which means that they measure the degree of improvement relative to a recognized standard, rather than requiring the use of specific design strategies or technologies.

For more detail information on LEED and a copy of the rating system to download, see the USGBC Web site at www.usgbc.org.

Economics

There has been a tremendous surge of interest in sustainable design for many reasons. The primary reason is based on concern about the environmental challenges that we face and a desire to address them in the design of the built environment. Simply stated, it is the right thing to do. In addition, it is increasingly clear that sustainable design improves the performance of buildings and increases user satisfaction and productivity. Sometimes overlooked is the fact that *it makes economic sense.*

Many of the projects featured as case studies in this book have been completed on very modest budgets. We have found that sustainable design does not have to cost more and may cost less. Using the design guidance in the checklists and project actions in this book and using LEED as a metric, design teams will be able to identify many opportunities for improved building performance and reduced environmental impacts that are cost-neutral. It is just a matter of developing an increased awareness of sustainable design issues and opportunities.

This guide also provides numerous examples of projects where sustainable design strategies have led the design teams to discover synergies that result in first-cost savings *and* operational cost savings.

However, when the owner has the ability to make decisions based on life cycle economics, the range of opportunities does expand. We strongly advocate a life cycle approach to decision making wherever possible.

We and many others have also found that the sustainable design strategies add real value to the projects. Each of the case studies included in this book contains a section on the economics surrounding the project, and each concludes with a section on the benefits of the design. Many of these provide insights into the broad range of benefits that result from a sustainable approach.

SUSTAINABLE DESIGN DOES NOT HAVE TO COST MORE

A lot can be done within traditional first-cost constraints. Integrated design solutions allow for cost shifting within a conventional budget. For example, increased expenditures on the building envelope and improved lighting can lead to reductions in the size and the cost of mechanical systems.

A design process that is more rigorous in seeking out efficiencies and eliminating waste also provides economic benefits. Many of these savings are small when considered in terms of the overall budget; however, they can allow for meaningful upgrades in other areas. For example, low-impact site development leads to reduced earthwork and more balanced cut and fill, elimination of irrigation systems, and reduced stormwater requirements. The funds that would have gone to installation of an irrigation system, for instance, can be shifted to another part of the budget.

EXAMPLES

- Santa Clarita: To reduce costs on their new office building, the City of Santa Clarita project used heavy timber construction with long spans, rather than the typical steel-braced frame. This solution allowed for the ceiling to be eliminated and for the wood structure to be exposed.
- National Wildlife Federation: Bioretention areas in the parking lot naturally treat stormwater and contribute to a network of rich and diverse wildlife habitat areas on the site. It did not, however, add cost to the project because the bioretention areas enabled the team to build a much smaller stormwater retention area, or dry pond.

A SHIFT TO LIFE CYCLE ECONOMICS EXPANDS OPPORTUNITIES

Even though it is not necessary to spend more to create a green building, a shift to life cycle economics does expand the opportunities for improving building performance. By considering first cost together with operating and maintenance costs, periodic replacement, and residual value, designers help their clients choose options that make sense over the long term.

Long-term owner-occupants of buildings clearly have an interest in life cycle economics. Speculative builders can also benefit from increased life cycle value, provided the added value can be measured and translated into increased market value.

Before the project budget is fixed, the issue of life cycle economics should be clearly addressed. Will decision making be based on life cycle costing or first-cost economics? This is a fundamental distinction. Then, if life cycle costing will be used, assumptions regarding the life cycle, discount rates, fuel cost escalations, and so on need to be clearly established.

If life cycle costing is going to be used to justify decision making, it is very useful to have a mechanism to increase funding for the project if it is warranted. In some cases life cycle costing is used within fixed budget constraints. Another approach is to work within a fixed budget that has a contingency amount set aside to pay for life cycle cost-effective upgrades. Yet another approach is to secure special financing for life cycle cost-effective upgrades through energy service contractors (ESCOs).

EXAMPLES

- Stadium Australia: Use of innovative, ecological design strategies reduced energy use by over 30 percent and potable water use by over 50 percent, and boosted the recycling of waste streams. These strategies required some additional first-cost investment; however, the payback for this project provides significant economic benefits for years to come.
- Emory University: At the Whitehead Biomedical Research Building, the additional cost incurred to achieve a LEED Silver rating was estimated at 1.5 percent of the building's total construction cost. Emory's savings in energy costs alone over the decade after completion will make up for the additional first cost.

MANY CREATIVE FINANCING OPTIONS CURRENTLY EXIST FOR GREEN BUILDINGS

Many design professionals continue to see cost as the primary impediment to sustainable design despite a large and growing body of evidence to the contrary. In fact, in some ways sustainable buildings are easier to finance than standard buildings. A number of creative financing mechanisms are available to teams that are willing to seek them out. Some of these include utility incentive programs, manufacturer discounts, government programs, and ESCOs.

EXAMPLE

- San Mateo: The 22,000 square feet (SF) of rooftop-mounted photovoltaic panels at the San Mateo County Sheriff's Forensic Laboratory and Coroner's Office were cost-justified through nearly $800,000 in rebates from the local utility — Pacific Gas and Electric Company — which paid for almost half the initial cost of the panel system.

SUSTAINABLE DESIGN IMPROVES THE VALUE OF BUILDINGS

In addition to reduced construction, operating, and maintenance costs, sustainable design produces buildings that are more valuable to owners and occupants. As a rule of thumb, reductions in annual operating costs can be multiplied by 10 (capitalization rate) to estimate increased building value.

While some of the benefits can be easily quantified, others are more qualitative. Sustainable design features tend to produce a better indoor environment that improves productivity and employee retention. Improved indoor air quality reduces the risk of future liability and also contributes to productivity. Finally, the buildings are easier to lease and sell because they are generally viewed very positively by the market.

DID YOU KNOW . . . ?

What is the most cost-effective, environmentally benign new energy source? Ceiling insulation and double-glazed windows can produce [by saving] more oil than the Arctic National Wildlife Refuge at its most optimistic projections, at about one-twentieth the cost.

— Paul Hawken, *The Ecology of Commerce* (New York: HarperCollins, 1993), 171–79.

IMPROVED PRODUCTIVITY

Anecdotally, there is little question that users prefer buildings designed with sustainable attributes. Daylight, views to the exterior, personal temperature and lighting controls, fresh air — ideally with operable windows — and improved indoor air quality are almost universally requested by users regardless of building type, size, or location. When given these things, they universally respond positively. The connection between sustainable building design, user satisfaction, and increases in productivity seems to be a logical conclusion.

Thankfully, there is a growing body of evidence that supports the anecdotal evidence. For example, a study by the Heschong Mahone Group compared classrooms with daylight versus classrooms without daylight in three different California schools. Children in daylit classrooms performed up to 20 percent better than those without daylit classrooms. Carnegie Mellon University's Center for Building Performance and Diagnostics compared numerous productivity studies. Fifteen studies found productivity increases from 0.48 percent to 11 percent with improved ventilation alone. Access to a natural environment produced increased productivity from 0.4 percent to 18 percent. Additional studies reported significant lower health complaints with proximity to windows. The new ASHRAE Adaptive Comfort Standard is based on studies that show that users will not only tolerate a wider temperature range in their working environment if they have operable windows but actually prefer it.

EXAMPLE

- San Mateo: The Center for the Built Environment (CBE) occupant satisfaction survey at the San Mateo Forensics Laboratory showed overall very high occupant satisfaction, with air quality in all spaces significantly higher than the CBE average. A large majority of users surveyed stated that the air quality enhanced their ability to get work done. These results indicate that the goals of a "great place to work" are being met along with environmental goals.

RECENT STUDIES

Our experience in the cost of sustainable design is not unique. Many others have had similar experiences. This parallel experience is documented in three recent and comprehensive studies concerning the cost of LEED. All of these are worth studying. The following is a brief summary of each.

Costing Green

A Comprehensive Cost Database and Budgeting Methodology

by Lisa Fay Matthiessen and Peter Morris, Davis Langdon

July, 2004

www.dladamson.com/Attachment%20Files/Research/costinggreen.pdf

Davis Langdon is an international professional consulting firm specializing in construction cost control and project management. They did a comprehensive study of 60 projects that were pursing LEED where they had full cost information. They looked only at construction cost. This is a summary of their findings.

1. Site location was a major factor in achieving higher LEED ratings levels without additional cost.
2. Additional commissioning was the only point that required an early commitment by the design team.
3. Many points depend on the end-user. Large university campuses and corporations, for example, are more likely to have strong facility departments, which generally mean a higher level of requirements that parallel LEED credits for their projects, such as building commissioning.
4. Higher point levels generally indicate a higher level of integrated design, with some points costing money but others saving money.
5. Most projects that achieved LEED did so without additional funding and within their original budget.

They also looked at 138 projects that were a mixture of LEED and non-LEED projects. They found the following:

1. There was no statistical difference between LEED and non-LEED projects in terms of cost for identical building types.
2. While there was wide variation in building cost based on the program requirements within a building type, there were no differences with regard to whether or not a building was a LEED project.

The Cost and Financial Benefits of Green Buildings

A Report to the California Sustainable Building Task Force

by Greg Kats, Principal Author, Capital E
October, 2003

www.cap-e.com/ewebeditpro/items/O59F3259.pdf

The study was to assess the cost and benefits of green public buildings using LEED for the state of California. They studied 33 public buildings and assessed in detail the additional cost of each component of the building over that of a convention building of the same design. The following is a summary of key findings:

- Average additional cost of green was slightly less than 2 percent.
- Investment in green yielded average life cycle savings of ten times the original investment.
- The earlier green was introduced into the design process, the lower the cost.
- LEED Level

LEED Level	Average Cost Premium	Energy Saving
Certified	0.66%	28%
Silver	2.11%	30%
Gold	1.82%	48%

(Platinum was too small of a sample to be meaningful.)

GSA LEED Cost Study

by Steven Winter and Associates
October, 2003

www.ccb.org/docs/GSAMAN/gsaleed.pdf

The GSA asked Steven Winter and Associates to study the cost of LEED for two building types: new federal courthouses and renovations of federal office buildings. They qualified their findings, noting the following:

- GSA standards already require some aspects of LEED, such as commissioning.
- Each building type offers different opportunities and challenges.
- There were significant differences in site location (urban vs. rural) and location within the country (e.g., climate, context, geology of the area, etc.)
- They did not address issues of return on investment items.

KEY FINDINGS

1. There was no cost correlation between the total point value of LEED points and the true construction cost.
2. There was wide variation in strategies and the cost impact to achieve a given result.
3. Costs of points varied widely depending on the building type.
4. Some credits were very regionally specific in the opportunities that they presented (i.e., recycling, local material, water cost, and sewage connect fees).

Cost Increase Range for New Courthouses	
Certified	-0.04% to +1%
Silver	-0.33% to +4.4%
Gold	+1.4% to 8.1%

Cost Increase Range for Office Renovation	
Certified	+1.4% to +2.1%
Silver	+3.1% to +4.2%
Gold	+1.4% to +8.2%

DESIGNING SUSTAINABILITY

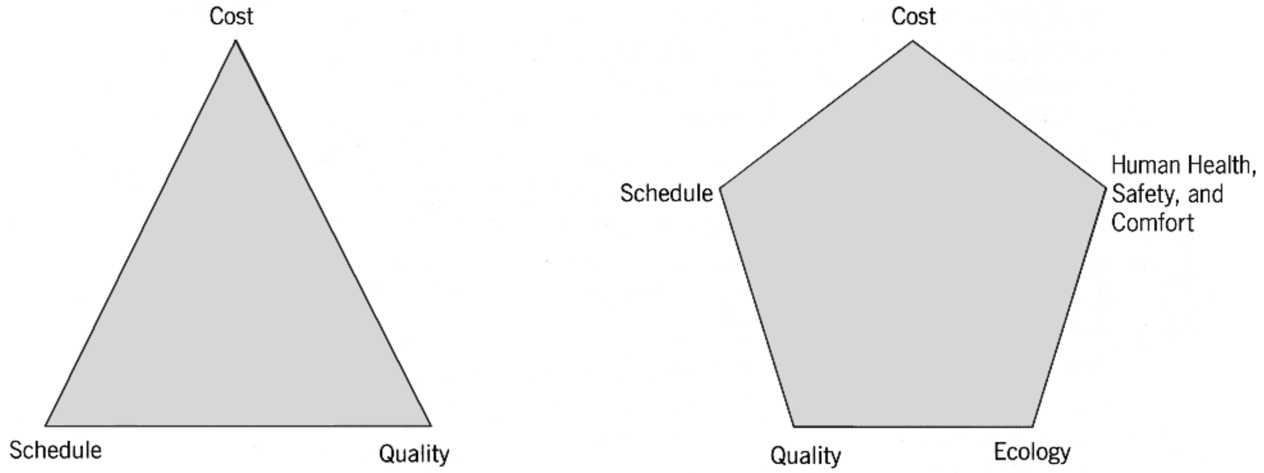
The model for sustainable design is nature itself. Nature is efficient and effective by design, essentially producing no waste. In contrast to nature, the process by which we design, make, and use resources is linear in nature, using energy and producing waste at every step. As we seek to reshape our own processes to eliminate waste, nature is a logical model to study. Specifically, we need to rethink the processes by which we design, construct, and operate buildings and communities in this light.

To adopt nature as our model, we need to convert our linear processes to cyclical processes. The cyclical model of production, for example, has been adopted by the German automotive industry. All materials for a new car are coded to allow easy identification for recycling. When it is at the end of its useful life, a car is returned to a disassembly plant, where it is broken down into component parts to be reprocessed and reassembled into a new car. BMW expects almost total reuse of material when today's cars are recycled. The German electronics industry is following a similar course. This use of closed-loop systems is being repeated in a growing number of industries that are involved with the building industry in the United States, including carpet, furniture, and some equipment manufacturers. The next challenge is to reformulate in a similar fashion the way buildings and communities are designed, constructed, and operated, to ensure that the entire building process is itself cyclical.

A green building or community relates to the world around it in different and more benign ways. At the least, it does a minimum of damage to the world in its construction, use, and ultimate reuse. This idea of minimizing damage cannot be the ultimate goal, as much damage has already been done to the natural world around us. Ideally, sustainable buildings and communities must be restorative, helping to heal the damage that has already been done and creating healthy vibrant places for people. In this way, sustainable buildings and communities become a part of nature, not something in competition with nature.

The new sustainable design process demands that every product, process, and procedure be questioned and reviewed from a new perspective, one that includes the ecological and human health impacts of design decisions. Doing so can result in substantial improvement from an environmental point of view, and it can also lead to more pleasing and productive environments for users, combined with savings for the owner.

The old decision model is based on a balance between cost, schedule, and quality. However, designers also need to become equally familiar with the effect their decisions have on the environment and human health. The new decision model integrates human health, safety, and comfort as well as ecology as deliberate considerations for the decision-making process in the same way that time, cost, and quality are integral to project decisions today.



Old Decision Model

New Decision Model

The old decision model is based on cost, schedule, and quality. The new, expanded decision model integrates human health, safety, and comfort, as well as ecology, as deliberate considerations for the decision-making process.

The concepts outlined below are intended to help you to systematically change the way you and your organization go about the business of designing and delivering the buildings and communities of the future.

GOING BEYOND THE MINIMUMS

Our communities have typically been formed by inadequate planning requirements that frequently ignore the complex interrelationships between the built environment and the natural world. They generally ignore or minimize the long-term implications of the decisions that they influence. Building performance has been measured almost exclusively by minimum code requirements. In other words, the minimum has also been seen as the maximum. Nonetheless, an inefficient building will put tens of thousands of tons of pollutants into the air. A site that doesn't manage its stormwater effectively will cause off-site problems. Communities that don't offer transportation alternatives will continue to suffer from automobile congestion and pollution.

By going beyond minimum requirements and focusing instead on optimum performance on many fronts, we redefine our design problems in a way that opens up many exciting possibilities. We need to challenge ourselves to search for creative solutions that will continue to move beyond minimum performance.

Most of the procedures listed in the Process Guidance chapter of this book are easily accomplished within the framework of conventional technologies and budgets. Fully implemented, these will significantly improve the environmental performance of our buildings and the livability of our communities, while also lowering overall costs. The incremental improvements that can be easily accomplished at this time should be

DID YOU KNOW . . . ?

Increasing materials recycling in the United States to at least 60% could save the equivalent of 315 million barrels of oil per year.

—John E. Young and Aaron Sachs, *Creating a Sustainable Materials Economy,* State of the World 1995 (Washington, D.C.: Worldwatch Institute, 1995).

taken as our new "minimums." Once the shift has been made to a design process based on optimization instead of minimum performance, the next design challenge becomes more open-ended.

With energy use, for example, the initial goal is to use less energy, to be dramatically more efficient. The long-term goal, however, is to move from the use of fossil fuels to the efficient use of renewable energy sources. Great advances have been made in the last decade in both the efficiency and the cost of photovoltaics and wind power. It is now possible to think of buildings and communities that are not only efficient but energy-neutral to the world around them; in some cases, buildings and communities can become net *producers* of energy.

THE NEED FOR INTEGRATED DESIGN

We should not expect to produce fundamentally new buildings using the same traditional design process. To effect change in our building designs, the project delivery process itself must change from a serial collection of discrete tasks performed with little interaction between players to a collaborative and self-conscious effort to integrate design strategies between all disciplines and all players in the project delivery process. This is integrated design. It opens up many opportunities for synergistic benefits.

To achieve the goal of integrated design, the definition of the building team needs to expand in order to overcome the lack of communication present in the traditional design process. Integrated design demands a more inclusive team working much more closely together than is traditionally the case. Community representatives, future users, contractors and subcontractors, and future maintenance staff can all add considerably to the success of the final design solution. For example, when the contractor has been included in the design phase and understands the goals of the project, challenges and calls for substitutions can be reduced because the overall design strategies will be better understood. When the overall project goals are understood, the contractor can often offer creative solutions that will limit environmental impacts during construction.

To improve overall performance, the team needs to optimize the functioning of the whole building as a system. Integrated design means capturing the benefits of multiple systems designed to work effectively together rather than separately. For example, overall comfort can be raised and energy consumption reduced if site design, lighting, window fenestration, air delivery systems, and furniture are thought of *together* rather than as discrete parts of the project. However, capturing multiple benefits requires the engineers, architects, and others to work together to design the components of the system. The result of such coordination can frequently lower the first cost as well as long-term cost. This is the synergy of an integrated design solution.

Integrated design leads to the discovery of design synergies that multiply benefits. For example, integration between mechanical engineers, civil engineers, traffic engineers, and architects can lead to successful low-impact site development that preserves open space while also reducing costs for stormwater management. A raised-floor air distribution

DID YOU KNOW . . . ?

Taken as a whole, climate-sensitive design using available technologies in the United States could cut total energy use by 60% in commercial buildings.

—Worldwatch Paper 124 (Washington, D.C.: Worldwatch Institute, 1995), 38.

system can lower long-term operating costs while also providing for wire management and offering significantly improved user satisfaction. When the budget is evaluated from a holistic perspective, rather than simply line by line, the raised-floor distribution system can also reduce first costs when it is integrated with the design of HVAC, building envelope, and furniture systems.

DID YOU KNOW . . . ?

The United States EPA ranks indoor air pollution among the top five environmental risks to public health. Unhealthy indoor air is found in up to 30% of new and renovated buildings.

— *Sustainable Building Technical Manual* (Washington, D.C.: Public Technology, Inc., 1996), 1.7.

MEASURING PERFORMANCE

Benchmarks allow the entire design team to better understand the value of proposed design solutions. A variety of benchmarking systems have been developed to track typical and improved performance in terms of sustainable design, and many of them are referred to in the project actions sections of this design guide. One especially useful tool for evaluating environmental performance is the LEED Green Building Rating System.

The New Design Process: Ten Key Steps

At the moment, the full impacts of the built environment on the natural world are not fully understood, and the best sustainable design solutions cannot be determined based on intuition alone. The design process outlined below has been shaped to help ensure that sustainable design issues will be understood by all team members, the issues addressed, and solutions found. Awareness of these issues is new, the relationships are new, the holistic view of the built environment is new, and many of the products and materials going into our built environment are new. It would be easy to miss many challenges and opportunities without an extra measure of care in the way we approach the planning, design, and construction process. The process described here has been designed to help make sure that doesn't happen. We have found this process extremely helpful in our own efforts to systematically improve the performance of our buildings.

All of the issues relating to team formation, communication, design procedures, and design tools should be reexamined and reevaluated. There are ten key steps in the facility delivery process where this extra care and deliberation are called for.

1. Project definition
2. Team building
3. Education and goal setting
4. Site evaluation
5. Baseline analysis
6. Design concept
7. Design optimization
8. Documents and specifications
9. Bidding and construction
10. Postoccupancy

DID YOU KNOW . . . ?

How fast is nature disappearing from the Earth? As humanity's ecological footprint grows, the world's wild vertebrate populations shrink. From 1970 to 2000 — the space of one generation — the Living Planet Index documented a 40 percent decline in terrestrial, freshwater, and marine species populations. The world has lost 30 percent of its natural wealth of forests, wildlife, and marine and freshwater species.

— World Wildlife Fund (WWF) International, *Living Planet Report 2004*, WWF International, 2004.

1. Project Definition

Owner, client representatives, and design team leaders should establish and clearly embed sustainable design tasks in the scope of work, document these in the contract agreement, and coordinate these with the project schedule.

Prior to the start of a project, it is typical for the client and design team to agree on the general scope of the project, and to define a scope of services to be provided. This is generally recorded in the A/E contract. Traditionally these documents have not included any language to acknowledge a sustainable design process, sustainable goals, or LEED certification expectations. Experienced owners and design teams, however, will acknowledge the importance of clarifying expectations in the A/E contract.

The contract should make a general statement regarding the owner's commitment to sustainable design and acknowledge a commitment to work with LEED if one has been made. When using LEED, it is best when the team fully commits to its use throughout the project process. If full certification is not possible; the team should still use LEED as a design guide. Other issues that should be clarified include expectations for energy and daylight analysis, commissioning, feasibility studies, energy and water audits, life cycle cost analysis, and other related tasks. Documentation requirements should also be noted, such as a sustainable design narrative or report and drafts of the LEED checklist (with or without detailed documentation) as part of each submittal.

2. Team Building

Seek design team members who are experienced and committed to sustainable design and working collaboratively. Assemble the full design team and identify sustainable champions for the owner and the design team.

The second task is to assemble the full design team, including core consultants and others. Ideally, you will be able to put together an entire team of individuals already experienced in and committed to sustainable design and experienced in working collaboratively. Like most ideals, this is not likely to be the case for some time. In most cases, the team will be made up of individuals and firms with little prior experience with sustainable design and a great deal of uncertainty about how to proceed. This lack of experience should not dissuade anyone. Most pioneering green projects—including many of the case studies in this book—were done by teams who were learning as they went. What matters most is a commitment to improve the design and care in the approach to each aspect of the project.

This having been said, there are some things that can be controlled in assembling teams:

- *Experience.* Demonstrated experience in sustainable design is highly desirable and should be sought out wherever possible. The experience may reside not within a firm as a whole but only with some individuals within a firm. If this is the case, make sure that these people will actually be available for the project.

DID YOU KNOW . . . ?

Global wind power capacity rose another 20 percent in 2004, to approximately 47,760 megawatts—enough to provide power to more than 22 million average homes in Europe.

—Vital Signs 2005 (Washington, D.C.: Worldwatch Institute, 2005), p. 34.

- *Attitude.* After experience, the next most important requirement is attitude. A positive attitude toward creating a truly new and innovative project is an extremely important part of moving toward sustainable design solutions. While there are increasingly more resources to help along the way, there will be frequent frustrations, dead ends, and pressure to fall back on the tried-and-true. The willingness to persevere through these obstacles is critical.
- *Collaborative and inventive working environment.* This is critical to achieve an integrated design. The objective is to create a working atmosphere that challenges conventional thinking and standard solutions. Brainstorm together to develop the team structure and schedule that will support interdisciplinary collaboration.
- *Energy modeling expertise.* The team should be assembled to bring the necessary expertise in key areas. Energy modeling is essential for nearly every project, and ideally the energy modeling capability resides within the engineering team. However, most engineering firms use proprietary design load calculation programs supplied by equipment manufacturers, which are intended primarily to size equipment and do not adequately model the complex, dynamic interactions between building systems that influence the overall performance of the design. If the engineering design firm does not have the capability or experience to use advanced energy modeling tools in-house, an energy modeling specialist should be enlisted to work with the entire team as the design develops. For small projects, where this may not be possible, consider using simplified energy modeling software, such as Energy 10 or ECOTECT. These are less sophisticated energy analysis tools, but they are relatively easy to learn and use and are very affordable.
- *Commissioning agent.* Wherever possible, a commissioning agent should be identified early and included on the team. Commissioning is a systematic process for ensuring that all building systems perform interactively, as a system, according to the contract documents, the design intent, and the owner's needs. Commissioning is increasingly becoming a common part of the start-up of a new building. Ideally, the commissioning process begins early in design and continues through construction, acceptance, and the warranty period to be truly effective.
- *Other specialty consultants.* There are many other specialty consultants who should be considered to supplement the team, depending on the project and the expertise within the core team. An expert in native plantings may supplement the knowledge of the landscape planners. Experts in constructed wetlands, stormwater management, and natural recharge systems may help the civil engineers and the site designers. Specialists in daylighting design might supplement a more conventional lighting designer.

If the team is completely new to the issues of sustainable design, consider retaining outside expertise to help get the team off on the right foot. There are many resources to choose from, including nonprofit organizations, sustainable design consultants, and design firms that offer this service. Initial help could be as simple as a short overview of issues and opportunities, or it could be a more involved effort that helps the team define goals and objectives for the project and sets the initial direction. The goal is to lower the learning curve for everyone involved.

Sustainable Design Champions on the Team

For any project to be successful, many team members will need to contribute their expertise and insights to the development of environmentally preferable solutions. Sustainable design advocates should be identified to oversee the effort to improve environmental performance and to help coordinate the contributions of all members of the team. Ideally, sustainable design advocates should be recruited from within the A/E team to focus the design effort, from the contractor to focus the construction effort, and from within the ranks of the owner's team to represent the owner's perspective and to assist with design reviews.

EXAMPLE

- In the JohnsonDiversey Global Headquarters, the entire team was largely in place from the early programming stage of the project. This included the construction manager staff, key subcontractors and suppliers, and the eventual building manager and his staff, as well as the traditional design team and the owner. Very few of the team members had any previous knowledge of sustainable design issues. Initially, many attended the early work sessions with little understanding and perhaps little enthusiasm. In time, however, the atmosphere changed as individuals began to see not only how they could contribute, but that their help was welcome. Many of the ultimate successes of the project came from the often-unexpected interactions between team members who would traditionally never have gotten to know each other. For example, the furniture supplier and the field superintendent found a way to deliver new furniture to the site without packaging. In another instance, the piping subcontractor was able to make recommendations to the plumbing designers and the structural engineers that made it easier to use standard-length material and thus eliminate a large percentage of the usual waste.

DID YOU KNOW . . . ?

World production of renewable energy sources is increasing rapidly. Production of solar PV cells was an estimated 1,200 megawatts, up 58 percent over 2003 levels and a doubling of production in just two years.

—Vital Signs 2005 (Washington, D.C.: Worldwatch Institute, 2005), pp. 34–36.

3. Education and Goal Setting

Engage team in discussion of sustainable issues and opportunities, including cost and schedule impacts. Then hold a sustainable goal session with all team members to set broad goals and measurable outcomes, such as a LEED target. Review design criteria and standards and challenge those that work against integrated sustainable solutions.

Education of the entire team is critical to achieve a common understanding of sustainable design issues and opportunities. An educational session/workshop should be held to cover basic environmental challenges and opportunities related to design and construction prior to discussion of environmental goals. Time should be taken with the entire team to share information on sustainable design issues and their impact on the project as a whole, including cost and schedule implications. Use the

LEED system as one basis for discussion and evaluation. Include a detailed explanation of the agreed-upon framework for decision making, including life cycle cost analysis. This phase should include an extensive review of similar projects so that everyone can quickly see what others are doing and how to bridge the gap between theory and practice. Once the team has built a common vocabulary and an understanding of the issues involved, it is ready to develop sustainable design goals.

The next step is to clearly establish sustainable design goals. While goal setting at the beginning of a project is common, sustainable design goal setting is not. Sustainable design goals should be identified as somewhat distinct from other project goals so that they receive the attention they deserve. In years to come we can expect that project goals and sustainable design goals will be one and the same. This is clearly not the case today, when merely the phrase "sustainable design goals" will be new to most people in the industry. Sustainable design goals should have their own focus to allow the entire team to arrive at a common understanding.

Goals will tend to be very broad at the beginning — protection of the existing natural environment, for example. Wherever possible, these goals can and should be specific and quantified. See the checklists in this guide as lists of issues to be considered during project goal setting.

Be careful to challenge established rules of thumb that work against integrated solutions. Identify any special program elements that deserve special attention and look at program elements for possible opportunities.

Clarify Decision-making Criteria

Design criteria are the set of requirements and standards that guide the design. Typically these criteria are accepted as givens, and design options are explored only within those parameters. However, many of the solutions that reduce cost *and* environmental impacts come about by challenging basic design criteria, such as lighting power densities, plug loads, parking requirements, stormwater guidelines, and so on. Voluntary industry guidelines produced by the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE), the U.S. Green Building Council, and other organizations should be sought out and incorporated into the design criteria where appropriate. Life cycle cost analysis should be strongly encouraged to determine the highest-value solutions. The methodology for life cycle analysis needs to be discussed and agreed upon, including the duration of the life cycle to be used for economic analysis and the discount rate that will be used for considering the time value of money.

EXAMPLES

- A goal for the new academic building at University of Wisconsin at Green Bay was to use less than 50 percent of the energy of a comparable building that met the stringent Wisconsin Commercial Buildings energy code.
- A goal for the Winrock International Global Headquarters building was to daylight the building such that no electric lighting was required for general ambient lighting during daylight hours.

4. Site Evaluation

Analyze the site to identify constraints and sustainable opportunities. Evaluate the microclimate and macroclimate to determine solar and wind availability and orientation, potential thermal sinks, and rainfall. Inventory plant and animal species and their habitats. Identify transportation networks, and cultural and/or historical resources that should be preserved.

Most projects include some level of site evaluation, however cursory. Expand this effort to truly understand sun, wind, and water patterns. Identify resources that can contribute to energy efficiency and capture "free" energy. Study the ecology, hydrology, and geology of the site, including surveying plants and wildlife resources. Analyze regional impacts on water quality and wildlife habitat. The goal is to design a building that sits lightly on the land, that engages the natural energy flows of the site, and that coexists gracefully with the other living systems on the site. Doing this requires the team to truly understand the site, its resources, constraints, and opportunities.

5. Baseline Analysis

Develop baseline energy and water analysis; establish budgets and compare with benchmarks and project sustainable design goals. Explore potential for renewable energy, financial incentives, and/or utility rebates for energy efficiency, water, and renewables.

Develop baseline energy and water analysis for the project. This information should be represented as gross energy and water use per square foot per year. Calculate energy analysis in terms of site energy and source energy usage. Compare preliminary results with performance benchmarks and project sustainable design goals.

Energy and water "budgets" should be developed for the facility as well, based on evaluation of local utility rate structures for energy, demand charges, water usage costs, and wastewater disposal charges. Explore potential use of renewable energy systems, including financial incentives and/or utility rebates for energy and water efficiency and renewable energy.

Design professionals are familiar with this process in terms of a financial budget through the normal process of systematic cost estimating and value engineering employed throughout the design process. Generally, the profession is not at all familiar with this process in terms of sustainable design goals and the actual performance of buildings. Although we cannot imagine starting a project without a clear understanding of the financial budget, an energy budget is rarely understood and even less commonly discussed and evaluated as part of the design process. One can imagine what would happen if the financial budget was not discussed until the project was complete; it certainly would not be "optimized." The same is true of energy, water use, or any of the other resource conservation measures quantified in the goal-setting phase.

DID YOU KNOW . . . ?

An estimated half of the world's wetlands have been lost since 1900, and destruction continues apace.

—Vital Signs 2005 (Washington, D.C.: Worldwatch Institute, 2005), p. 90.

- Research by the team led to a partnership and cost-sharing agreement with the Wisconsin Public Service Corporation, the local utility for the University of Wisconsin, Green Bay project, as the utility was looking toward a future involving distributed power generation and wanted an opportunity to test photovoltaics. The utility paid for all of the photovoltaics in the project.
- The Santa Clarita Transit Maintenance Facility Team participated in the "Savings by Design" program offered by Southern California Edison. Participation in this program requires a baseline energy model for comparison with the building energy model. Through this program, the owner receives monetary incentives based on a building's energy performance.

EXAMPLES

6. Design Concept

Use an integrated and collaborative design process to embed sustainable strategies within a design concept that is responsive to the project site and the regional ecosystem.

All projects go through a concept design phase of one sort or another. The goal is to develop a concept for the project that clearly embeds sustainable strategies as integral strategies, not as "add-ons." This is where the importance of an integrated design approach and an integrated design team is displayed. To the greatest extent possible, the concept massing, orientation, and siting strategies should minimize energy use while taking advantage of passive solar and wind opportunities. It should also protect and restore natural site features, including wildlife habitat. Where possible it should respond to regional habitat patterns. It should respond to water flows and protect groundwater while making use of rainwater wherever possible to reduce the use of domestic water. It should take advantage of daylighting opportunities, renewable energy opportunities, and natural ventilation opportunities. In short, it should respond as closely as possible to the immediate site micro and regional environment to enable an optimal response to the challenges and opportunities of the site and program. All of these issues and opportunities need to be embedded into a truly integrated concept design that will then be the basis throughout the rest of the design process. Achieving this at the concept design stage will help ensure that the potential of integrated design is realized.

DID YOU KNOW . . . ?

The global market for solar thermal collectors for water and space heating grew by 17 percent in 2004. The energy equivalent of total global installations—about 110 million square meters—far exceeds that of global wind and solar power combined. China accounts for more than half the world's solar heating capacity.

—Vital Signs 2005 (Washington, D.C.: Worldwatch Institute, 2005), p. 36.

7. Design Optimization

Explore, test, and evaluate a broad range of solutions to discern those with greatest potential. Engage the entire design team in a multidisciplinary approach to seek synergies in the development and refinement of building and site systems.

Optimization is a process of design refinement that results from questioning each component and process to achieve the most with the least expenditure of resources. Design optimization involves the careful evaluation of a broad range of solutions so that the best can be discerned from other, less promising options. The best solutions will contain synergies between design disciplines to create an integrated design solution, where a single strategy will provide multiple benefits.

DID YOU KNOW . . . ?

Global forest cover stands at approximately half the original extent of 8,000 years ago.

—Vital Signs 2005 (Washington, D.C.: Worldwatch Institute, 2005), p. 92.

The optimization process works best when applied to building and site systems rather than simply for components. For example, energy minimization must include an active and informed integration of internal equipment loads, lighting, exterior shape and massing, exterior skin, landscaping, and site work. Because the many refinements that lead to an optimized design cannot be determined intuitively, simulation tools are needed to predict future performance.

Sustainable design requires the design team to consider a larger number of issues in the decision-making process. Supplemental research may be required during this phase to understand the environmental impacts associated with design options and to identify preferred approaches, including green building materials selection and integration of emerging technologies as the products, technologies, and associated costs change rapidly.

A process is outlined below for optimizing energy use. This process is designed to get beyond standard solutions. An optimizing process should also be applied to other aspects of the project, including water use, waste generation, materials, site impacts, and indoor environmental quality. The key to improving the overall environmental performance of the facility is to follow a deliberate self-conscious process to question each component of the design. (See the project actions in this guide for specific recommendations on how to achieve design optimization.)

The following steps summarize the process for systematically reducing overall energy consumption. A more detail description of this process follows in the Process Guidance chapter.

Energy Optimization Process

Energy consumption in buildings is the result of a complex set of interrelationships among the external environment, the shape and character of the building components, its equipment and other internal heat sources, and finally the occupant density and patterns of use of the building. Understanding and manipulating these interrelationships is the key to reducing energy use while also improving comfort for the building's users. The following energy optimization process has been developed so that information will be available to the design team when it is most useful, to guide decision making as the building and its HVAC systems are developed.

The best way to understand the complex interactions in a building is through the use of a dynamic energy model, such as the U.S. Department of Energy's DOE-2 building energy analysis simulation. DOE-2 allows the user to model all aspects of the building, including form, orientation, equipment loads, patterns of use, and the like. (Other energy modeling tools are described in chapter 2.) A dynamic model, it calculates the complex interactions between these various elements on a 24-hour, 365-day basis, allowing the design team to understand relationships that were impossible to see in other predictive systems.

The key to understanding building performance as a whole is to carefully and systematically reduce the overall building loads and then to optimize the integration of the various building systems. The first place to look is the overall architectural organization, orientation, massing, roof forms, and so on. Second, look at the building envelope, including landscape options to reduce overall heating and cooling loads. Third, carefully look at and reduce all interior cooling loads. Only when all external loads have been lowered as far as possible should you look at mechanical systems. By reducing overall building loads first, you can reduce not only the operational costs, but also the first capital costs as smaller equipment is specified.

The following steps summarize the process for systematically reducing overall energy consumption.

A. Gather Information

Collect programmatic information, such as space use, population, hours of occupancy, expected equipment, and so on. Also collect climate data, utility rate structures, energy code requirements, site information, and any preliminary building assumptions, such as high-rise versus low-rise and floorplate configuration.

B. Create Base Case Energy Model

Use DOE-2 or another dynamic energy model to create a base case energy model that is specific to the program and the site, and that reflects a design that is minimally compliant with the energy code requirements. Because the design is not very developed at this stage, many assumptions are made by default positions within the program. ASHRAE defines how to do this.

C. Characterize Energy Use and Energy Cost

Using the base case energy model, generate simple pie charts that describe the energy consumption and energy cost by end use for the building. It is important to understand where energy is being used in the facility. For example, buildings can be dominated by internal loads, envelope loads, or ventilation requirements, among others. This begins to give an indication of where major targets are for energy reduction. By itself, however, it is not enough.

Then develop a set of elimination parametrics so that the interaction between components can be seen and the largest targets for energy improvement can be identified. In this analysis, selected components of the energy model are “turned off” one by one. To demonstrate the potential impact of each factor on overall energy use, the equipment load is hypothetically set at zero, occupancy is set to none, glazing is eliminated, the exterior wall is set to an infinite R-value, and so on. Because DOE-2 is a dynamic model, this step allows you to see the effect of the complex interactions of components on overall energy performance. This information provides the design team with some base information on potential energy and cost savings that can be used to guide the development of proposed energy efficiency measures (EEMs).

D. Develop Alternative Design Solutions

Identify strategies to reduce the energy loads for all components of the project, with the major energy uses as the first targets. If lighting and cooling are significant loads, daylighting strategies will be of primary interest. If solar gain is a critical factor, site orientation, landscaping, and building-integrated shading devices should be looked at carefully. Use the DOE-2 energy model to determine the energy savings that result from each alternate compared to the base case. Then analyze the cost and benefits of these strategies to identify the best options.

Because the most valuable solutions capture the benefits of synergies between components, evaluate whole building systems, not just individual strategies. Use this early analysis of potential energy design features to inform the development of the architecture and HVAC systems.

E. Repeat the Process

Because the design process is iterative, the energy analysis needs to be repeated several times to achieve the best results. With various energy conservation measures now incorporated into the design, the relative balance of loads will have changed, and a new set of energy use characterization needs to be developed. The newest iteration will show that the energy loads and costs, which had once been the most significant, may be reduced, with other loads taking their place as the primary targets. A new set of energy conservation strategies needs to be developed to reduce these new loads, and new design synergies may suggest themselves at this point.

This process of (1) identifying the major loads, (2) identifying energy reduction strategies to reduce these loads, and (3) refining the design is done repeatedly until the point where diminishing returns set in. A final DOE-2 run is made incorporating all of the energy efficiency measures included in the design.

F. Follow Up

Just as with a cost model, it is important to follow the progress of the design with periodic updates to the energy model to ensure that the energy budget is maintained. At appropriate stages in the development of contract documents, the various energy-saving design strategies should be reviewed, the DOE-2 energy model modified if necessary, and new runs made to evaluate the status of the design. If new energy efficiency measures can be identified, these may be reviewed and incorporated if the schedule permits.

DID YOU KNOW . . . ?

A 2000 World Bank study projected that on average 1.8 million people would die prematurely each year between 2001 and 2020 because of air pollution.

—Vital Signs 2005 (Washington, D.C.: Worldwatch Institute, 2005), p. 94.

8. Documents and Specifications

Carefully document all project requirements. Engage in a process to update and improve contract documents and specifications to ensure that sustainable goals, including materials, systems, and other requirements, are being incorporated.

Once a set of design decisions has been made, it is necessary to record these in the contract documents and specifications. While this is familiar and common, the use of sustainable design strategies, many of which make use of new products and processes, requires a commitment to continuous updating and improvement of project specifications. Specifications for the handling of construction waste, for example, will be new to many contractors and communities. It will be necessary to tailor the specifications to the local community to avoid misunderstandings and costly misinterpretations. Other examples include allowable volatile organic compound (VOC) emissions of paints and other products, avoidance of toxic materials, and sequencing of finish installation to guard against the introduction of contaminants into the completed building. Materials specifications are particularly dependent upon the dynamics of the current market of environmentally preferable products, requiring continuous updating for each new project. For projects pursuing LEED certification, documentation requirements must be incorporated into the specifications as well. See the project actions in this guide for recommendations on documentation and specification language.

9. Bidding and Construction

Engage design team, contractor, and owner in a collaborative approach to bidding, buyout, procurement, construction, and commissioning to deliver a healthy, environmentally responsible facility that meets project sustainable design goals.

Bidding, buyout, procurement, construction, and commissioning are particularly important steps in delivering a healthy, productive, environmentally responsible facility. The process can become complicated simply because the number of people involved suddenly expands greatly as suppliers, subcontractors, and others enter the picture. With each new player, we likely face a new lack of understanding of the project sustainable design goals and the established processes. Some of the materials and methods may be new and little understood. Substitutions, many not meeting the basic requirements, will be offered as a matter of course. Likewise, many of the construction procedures, while not difficult or more expensive in themselves, may be new to the larger construction team.

The value of the initial team formation and goal-setting sessions becomes evident at this phase. If the construction professionals were not part of those initial sessions, a session should be held at the prebid conference, and at the construction start-up meeting to educate and enlist support. Just as there are sessions for new workers concerning job site procedures and safety, there should be sessions on sustainable design goals and requirements. The greater the understanding of the overall goals, the greater will be the effort to understand and incorporate the products and procedures called for in the project. Unlike many topics, sustainable design has the capacity to quickly command the attention, respect, and engagement of most people. This can only happen, however, if information is shared and help requested. See the project actions in this guide for recommendations on issues to consider during construction.

10. Postoccupancy

Engage design team and building users in discussion to discover ways to improve building operations, maintenance, and occupant satisfaction. Undertake a postoccupancy evaluation to evaluate hard and soft metrics and identify lessons learned.

The typical project ends for most professionals shortly after the opening festivities are over. Yet in many ways things are just beginning. The ideas and concepts that have been developed and documented by the design team have been realized. Was the thinking that guided the design correct? Are people satisfied with the environment within the building? Are they more productive? Does the facility reflect the values of the organization? An evaluation of these "soft" issues can be very instructive for the design team. Likewise, there is much to be learned from analyzing "hard" performance statistics such as energy and water use, and cost of operations.

Studies show that if most existing buildings were only operated as they were originally designed, a 20 percent savings in energy could be achieved. Often this does not happen because those operating the building systems were generally not part of the design process and were not properly informed of the design intent. Additionally, those who designed the systems may not stay in touch to make sure that the system is being operated properly. This is the case for the operation of conventional mechanical systems. As we proceed toward newer, innovative systems and products, the need for education and follow-up becomes even more critical. Once again, the issue of team formation and the early involvement and education of those ultimately responsible for the operations and maintenance of the facility becomes critical.

As the LEED rating system grows in popularity and use, it is important to remember that LEED certification is only the beginning of a process. With the ultimate goal to create a healthy, productive, and environmentally responsible workplace, school, or home, the owner should view the task of running the buildings as one of continual improvement. Continual improvement is in fact the foundation for the LEED Existing Building program. Undertaking a postoccupancy evaluation is one step in that process and may identify many additional ways to improve building operations and occupant satisfaction.

DID YOU KNOW . . . ?

The Forest Stewardship Council reports the area that the area meeting internationally recognized criteria and principles of forest stewardship has grown more than tenfold since 1995, to some 47 million hectares in 60 countries.

—Vital Signs 2005 (Washington, D.C.: Worldwatch Institute, 2005), p. 93.

EXAMPLES

- At JohnsonDiversey Global Headquarters, Stu Carron, Director of Global Facilities and Real Estate at JohnsonDiversey, determined that LEED-EB (LEED for Existing Building) not only fit the headquarters building well since it was built with sustainability principles integrated into its design, but it also made business sense. The company leaders agreed to participate in the pilot phase of LEED-EB and received LEED-EB Gold certification in March 2004. JohnsonDiversey is focused on maintaining and improving on the present level of success of their LEED-EB project and finding ways to integrate LEED-EB requirements and practices into their daily operations (Source: www.usgbc.org/Docs/LEEDdocs/JohnsonDiversey%20Narrative%20Case%20Study%20V5.pdf).

- Federal Project. In one large federal project, the initial energy bills were very low, as predicted. Each year, however, they trended lower still. Why was this? Upon investigation, it was discovered that the building manager had done something different that had resulted in an ad hoc process of continual improvement. New to his job and not understanding mechanical systems very well, he had the entire staff of mechanics in his department take a course for running the energy management software control system. The mechanics had previously simply responded to work orders to open, close, or adjust one component or another. After taking the course, they understood how the system was supposed to work and could understand the performance displayed on the facility department controls computer screens. With this new understanding, because they were continually monitoring and adjusting to improve performance, they developed a much better connection between the intended design and actual operations.

DID YOU KNOW . . . ?

The United States, with less than 5% of the world's population, is responsible for 25% of world total energy consumption and 24% of world total carbon emissions. Per capita energy consumption in the U.S. is more than twice that of Japan and Western Europe.

—EIA, *International Energy Outlook 2004,* April 2004, Table A1, p. 163 and Table A14, p. 177.

USING LEED

The USGBC's LEED Rating System is an extremely useful tool. It helps organize the issues and is generally comprehensive. It sets forth easily understood criteria and goals for every aspect of the project, and is easy to use from the very beginning of the project. The following are tips on using the rating guide:

- Commit to use it from the beginning of the project.
- Review the status at every project meeting and update the evaluation.
- Be systematic in pursing each LEED credit.
- Don't look for individual credits in isolation, but look for opportunities for synergies.
- Appoint someone to be the keeper of the LEED checklist.
- Go beyond LEED wherever possible.

LEED should be viewed as *a floor and not a ceiling.* The potential trap of LEED is that you become satisfied by reaching a certain point when going beyond the threshold may be easy to do. LEED is just a step along a path that will eventually take us to buildings that are truly sustainable. Even the very best "sustainable" buildings, current LEED buildings included, are far from sustainable. Each of these buildings is an extremely important step, however, in that direction.

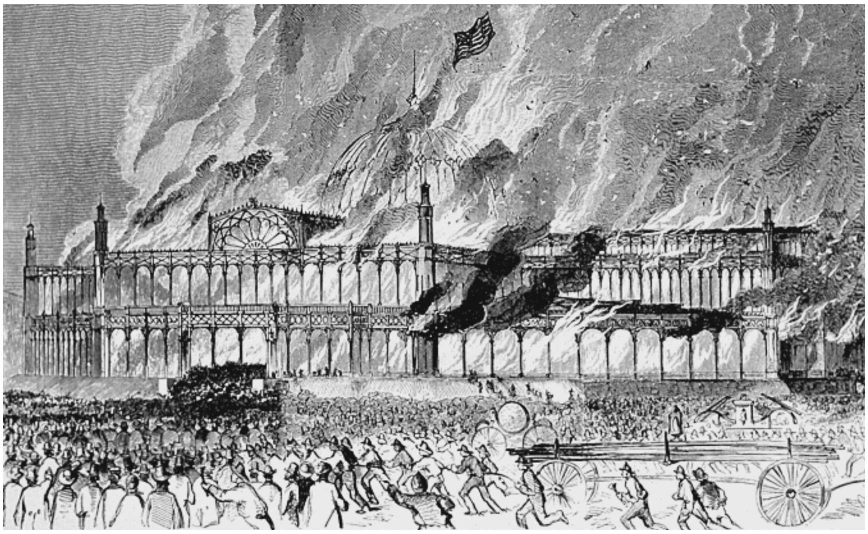
Finally, don't set an arbitrary goal of reaching a certain level. If you aim at a certain level and are satisfied when you reach that point, you may very well be missing important opportunities. Go as far as you can with the budget and program that you have and see where that takes you.

LIFE SAFETY ANALOGY

Until the nineteenth century, we generally built buildings, communities, and cities without the help of building codes, life safety codes, zoning regulations, or any of the myriad of other restrictions that guide us today. As the industrial revolution spread in Europe and North America, the nature of buildings began to change, the use of buildings began to change, and the kinds of buildings necessary to accommodate new industrial processes began to change as well. These changes quickly led to a series of building disasters of an unprecedented order—fires, structural failures, decayed neighborhoods, and pollution of all kinds. Much of the history of building in the nineteenth century is one of trial and error as people struggled to understand these problems and arrive at solutions. It took about a hundred years to arrive at a generally accepted set of rules to deal with basic issues of safety and fire protection in modern buildings. Those rules are the basis for today's collection of building and safety codes.

Today, we follow the much-improved version of those rules, but we do so in an almost automatic way. It is second nature to us because society agrees on the necessity for safe buildings and communities. Designers, builders, owners, and operators know instinctively the "right" way to approach things. There is no debate about the goals of having safe buildings; rather, there is a constant upward cycle of improvement in the safety performance of our buildings.

We now must move forward by focusing on environmental and health issues, on moving toward sustainable design in the twenty-first century, just as our nineteenth-century predecessors focused on life safety. We are only now beginning to see the challenges we face as we attempt to create buildings and communities that will sustain us. We are just beginning to understand cause and effect as well as the urgency of the environmental and health challenges that confront us. And we are just starting to look for the solutions. Like our predecessors did with life safety issues, we need to be self-conscious, careful, and deliberate about this effort. Unlike them, we don't have a hundred years to figure this out.



Today, the Crystal Palace outside London is known as one of the icons of modern architecture because of the exhibition center's early use of metal and glass for the exterior walls. At the time it was built—the mid-nineteenth century—however, it was known as one of the first fireproof buildings, as iron and glass do not burn. They forgot, of course, that the wood exhibits inside would burn. The building was destroyed by fire shortly after it opened.

Postoccupancy Evaluation

Since the first edition of this guide, many more of HOK's projects have been completed and occupied for several years. These include some of our earlier efforts to focus comprehensively on sustainable design project integration. This has allowed us, in the new edition, to address a real need in the evolving sustainable building design world: to engage in a postoccupancy evaluation process to see how some of our completed works have performed and to share lessons learned in order to improve the performance of future sustainable buildings. We partnered with Architectural Energy Corporation in Boulder and the Center for the Built Environment (CBE) at University of California at Berkeley in this process to provide expert resources in gathering and analyzing data.

This chapter summarizes recommendations on a postoccupancy evaluation process and the common findings from our own process.

METHODOLOGY

DID YOU KNOW . . . ?

The world has some 28 billion acres of productive land and ocean to meet the needs of 6.3 billion people—an average of 4.4 acres per person. Since the mid-eighties, people have been consuming natural resources faster than nature can renew them, creating a global deficit that is impacting the health, vitality, and long-term productivity of natural systems. Current rates of consumption exceed natural production by 20%, with Americans requiring 23.5 acres per person.

—2004 Living Planet Report, World Wildlife Foundation.

Because of the broad number of issues addressed in sustainable design—such as site ecosystems, impact on building occupants, building systems, and sustainable materials performance—assessing sustainable building performance is a complex undertaking. In order to cover a range of topics, qualitative and quantitative methods to collect and analyze performance are needed. A three-step process is recommended to gather this information:

Building Systems Performance

Comparing models developed during the design process—such as energy, water, and daylight—against actual performance data gives needed information on building performance. Using readily available data such as utility bills and maintenance records will minimize client effort and time involved. The goal should be to collect a minimum of one year's key performance data on energy, water, waste, and maintenance information. The table on page 31 summarizes the type of information that optimally should be collected.

The amount of time and resources available will dictate how extensive an analysis of this data can take place. A true "apples to apples" comparison between predicted and actual building energy performance requires extensive monitoring—of the building and building energy systems, occupants, and climate—and analysis of the collected data relative to design assumptions made versus actual operating conditions found. Weather normalization should ideally be done to eliminate the influences created by differences between energy model weather assumptions and historical weather during the occupied period. Another, less intensive approach is to take a "snapshot" based on utility and occupancy data and compare that to the original models. This approach results in a more anecdotal assessment of the building's systems performance and some lessons learned. This latter method is the one we used to evaluate the case studies in this edition.

Building Performance Metrics

Building performance metrics measure the impact of building operations. Most of these data will be collected monthly and summarized into annual performance data (units shown are for annual summary). The following table offers basic information about each of the building performance metrics. This list was adapted from the metrics developed by the U.S. Federal Energy Management Program.

Energy

Metric	Collection Units	Data Source(s)
Total building energy use	$\frac{Btu}{month}$ $\frac{\$}{month}$ $\frac{kWh_{delivered}}{month}$	Utility bill, or metering
Source energy	$\frac{kWh_{source}}{month}$ kg_{co_2} kWh_{source}	
Peak electrical demand	kW	Monthly electricity bill
Total building energy generation: Electricity	$\frac{kWh_{delivered}}{month}$	Utility bill, or metering

Water

Metric	Collection Units	Data Source(s)
Total building potable water use	$\frac{gal}{month}$ $\frac{\$}{month}$	Water bill and sewage bill
Indoor potable water use (if available)	$\frac{gal}{month}$ $\frac{\$}{month}$	Meter
Outdoor potable water use (if available)	$\frac{gal}{month}$ $\frac{\$}{month}$	Meter
Total storm sewer output (if available)	$\frac{gal}{day}$ $\frac{\$}{month}$	Meter

Maintenance and Operations

Metric	Collection Units	Data Source(s)
Building maintenance	$ *hrs* *# requests by type* *# preventative maintenance*	Service requests, work orders, actual costs of time and materials, and interviews with facility managers
Grounds maintenance	$ *hrs* *# requests* *kg of hazardous chemicals used*	Service requests, work orders, budgets, and interviews with grounds managers

Waste Generation

Metric	Collection Units	Data Source(s)
Churn cost	$\frac{\$}{churn}$ $\frac{moves_{box}}{occupant \bullet year}$ $\frac{moves_{furniture}}{occupant \bullet year}$ $\frac{moves_{construction}}{occupant \bullet year}$	Bills or other measurement as needed
Hazardous waste	$\frac{gal}{year}$ $\frac{kg}{year}$ $\frac{\$}{year}$	Hazardous waste disposal manifest
Recycled materials	$\frac{ft^3}{month}$ $\frac{ton}{month}$ $\frac{\$}{month}$	Recycling contract or other (can also be described as percentage as total trash removed)

Occupant Satisfaction

Valuable insights into the soft "people" aspect of sustainable design can be gained through evaluation of occupant satisfaction surveys. Through collaboration with research partners like the Center for Built Environment (CBE) at the University of California at Berkeley, quantitative methods are available to interpret the indoor environmental characteristics of the buildings. CBE has developed an online survey administered by e-mail that is becoming a standard tool in North America for assessing occupant indoor environmental quality (IEQ) information. As described on the CBE Web site (www.cbesurvey.org), the survey helps to "take the pulse" of operating buildings from the perspective of the building users: assessing which aspects of the interior environment they find satisfactory or unsatisfactory. Occupants have the opportunity to indicate the exact nature of a problem when they express dissatisfaction with any topic. Basic demographic information and design characteristics of each building are collected for trend analysis. Members of CBE have access to their larger database of findings in order to compare their specific results with normative data. See a further description of the CBE survey in the Process Guidance chapter.

Personal Interview

An interview and facility walk-through with key members of the client's team to get personal feedback of what's working and not working in the facility is a critical component of a postoccupancy evaluation. This typically includes the facility manager, some staff, and representative users on the client side, as well as members of the original design team and, potentially, an individual not directly involved in the original design who can give an independent perspective on the findings. The interview solicits feedback on all sustainable design strategies, materials, and systems relating to the building and site to discuss how they are working against original design intent. The interview may also include review of the findings from the occupant survey and the building performance metrics for additional valuable owner input.

FINDINGS

Although the results from our postoccupancy process were dependent on the specifics of the design solution, there are some interesting findings that cross projects based on their common, sustainable attributes:

Energy & Atmosphere

Energy Analysis

Energy usage: A trend existed across all case studies that the actual energy usage exceeded the original energy model. Interestingly, the peak electrical demand generally was well below the energy model for predicted peak electrical demand.

The reasons for this difference varied by project but fell into several clear categories:

- Changes in use. In many cases, changes were made to the facility that had significant impacts on the building systems' performance. This ranged from number of occupants and hours of operation to changes in function.
- Energy model differences. What got modeled during design did not always reflect final changes made during the value engineering and construction process.
- Commissioning. Increases in energy usage were greatest in those projects where no or limited commissioning took place.
- MEP approach. Increases in energy usage were greater where there was a disconnection between the MEP engineer and the sustainable engineering consultant. This was especially true when HVAC was through design-build contractors.

DID YOU KNOW . . . ?

If every household in the United States replaced one 100-watt incandescent light bulb with an ENERGY STAR qualified compact fluorescent light bulb (CFL), it would prevent enough pollution to equal the removal of one million cars from the road, while providing savings of $30 in energy costs over the life of each CFL bulb.

—EPA Energy Star, Green Lights Program, see http://www.energystar.gov/index.cfm?c=cfls.pr_cfls

Occupancy Sensors

Although generally well received, a common complaint in the CBE survey with occupancy sensors was that they turned off electric lighting even when the space was occupied.

Indoor Environmental Quality

Open Office Environment

Data indicated high satisfaction rates with ease of interaction with coworkers in open office workspaces; dissatisfaction with visual and acoustic privacy was higher than in enclosed office settings. Some respondents reported that the open design negatively impacted their ability to be productive.

Daylight

Occupants reported high satisfaction with the amount of daylight in their workspace, which was an important feature in all of the buildings. They expressed satisfaction with daylight sensors, though some indicated problems with electric lighting not dimming or turning off.

Air Quality

Satisfaction with air quality was higher than the CBE average for all projects.

Thermal Comfort

The thermal comfort results varied a great deal across the surveys but showed a definite link between projects where decisions were driven by low first-cost budgets and those where occupant comfort was a concern.

Conclusion

Performing a postoccupancy evaluation is not an overwhelming task, and it is enormously beneficial for all parties involved—the design team, client, and users. Even when a project has been completed for many years, possible remedies to ongoing problems that could improve performance can sometimes be identified. Lessons learned from the evaluation can be incorporated into subsequent work and shared with others.

Another reason for incorporating postoccupancy process as standard practice is to avert false conclusions. Some problems—for example, glare on computer screens or installation problems with new materials—could be unfairly linked to "sustainable" design strategies, when the actual cause may be more general in nature. Studying how well sustainable strategies are working and learning from these findings will help accelerate integration of sustainability into standard design and construction practice.

Postoccupancy evaluation information is included in the following case studies in this book:

- JohnsonDiversey Global Headquarters
- Missouri Historical Society Museum Expansion
- National Wildlife Federation Headquarters Office Building
- San Mateo County Forensics Laboratory and Coroner's Office
- University of Wisconsin Green Bay Mary Ann Cofrin Hall
- Whitehead Biomedical Research Building, Emory University
- World Resources Institute Headquarters Office Interiors