The HOK Guidebook to Sustainable Design
SECOND EDITION

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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.

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.
• **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.

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 V/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, 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.

**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 some-
what distinct from other project goals so that they receive the attention
they deserve. In years to come we can expect that project goals and sus-
tainable 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 opportuni-

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 solu-
tions that reduce cost and environmental impacts come about by chal-
lenging 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.

• 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 day-
  light the building such that no electric lighting was required for general ambi-
  ent 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.
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.

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.
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 detailed 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 parameters 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, lighting 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.
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.

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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.

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.


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.
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 the 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

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.

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<tr>
<td>Total building energy use</td>
<td>Btu/month</td>
<td>Utility bill, or metering</td>
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<td>Source energy</td>
<td>kWh_{source}/month</td>
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<td>Peak electrical demand</td>
<td>kW/month</td>
<td>Monthly electricity bill</td>
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<td>Total building energy generation: Electricity</td>
<td>kWh_{delivered}/month</td>
<td>Utility bill, or metering</td>
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<th>Water</th>
<th>Collection Units</th>
<th>Data Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total building potable water use</td>
<td>gal/month</td>
<td>Water bill and sewage bill</td>
</tr>
<tr>
<td>Indoor potable water use (if available)</td>
<td>gal/month</td>
<td>Meter</td>
</tr>
<tr>
<td>Outdoor potable water use (if available)</td>
<td>gal/month</td>
<td>Meter</td>
</tr>
<tr>
<td>Total storm sewer output (if available)</td>
<td>gal/day</td>
<td>Meter</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintenance and Operations</th>
<th>Collection Units</th>
<th>Data Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Building maintenance</td>
<td>$/hr</td>
<td>Service requests, work orders, actual costs of time and materials, and interviews with facility managers</td>
</tr>
<tr>
<td>Grounds maintenance</td>
<td>$/hr</td>
<td>Service requests, work orders, budgets, and interviews with grounds managers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Waste Generation</th>
<th>Collection Units</th>
<th>Data Source(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Churn cost</td>
<td>$/churn</td>
<td>Bills or other measurement as needed</td>
</tr>
<tr>
<td>Moves</td>
<td>moves_{max}/occupant \cdot year</td>
<td></td>
</tr>
<tr>
<td>Moves, furniture</td>
<td>moves_{furniture}/occupant \cdot year</td>
<td></td>
</tr>
<tr>
<td>Moves, construction</td>
<td>moves_{construction}/occupant \cdot year</td>
<td></td>
</tr>
<tr>
<td>Hazardous waste</td>
<td>gal/year</td>
<td>Hazardous waste disposal manifest</td>
</tr>
<tr>
<td>Recycled materials</td>
<td>ft^3/month</td>
<td>Recycling contract or other (can also be described as percentage as total trash removed)</td>
</tr>
</tbody>
</table>

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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.

**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.

**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.

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.

**Conclusion**
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 Coffrin Hall
- Whitehead Biomedical Research Building, Emory University
- World Resources Institute Headquarters Office Interiors