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FEATURE

Postoccupancy Evaluations for Green Buildings

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Despite the recent growth in the use of more-energy-efficient technologies and more-sustainable building practices, postoccupancy evaluations are still often neglected in the construction process. A postoccupancy evaluation can show whether a building is performing up to expectations after occupants move into it. Those evaluations that have been conducted have revealed that some green buildings are performing far worse than the initial design models predicted.[1] One such building, the new Seattle City Hall—which attained a Leadership in Energy and Environmental Design (LEED) Gold Certification from the U.S. Green Building Council (USGBC)—is actually using more energy per square foot than the city hall it replaced (see **Figure 1**).[2] Though there might be a legitimate explanation for the increased energy usage in the new building, a postoccupancy evaluation can detect performance deficiencies in building systems so that building operators can take proper action to resolve them.

Postoccupancy evaluations are valuable because they are a comprehensive method of determining whether a building is performing as promised and whether occupants are using the building correctly. Designers are held accountable for the successful operation of high-performance systems that building owners have likely paid a premium for. Though there is no industrywide standard for postoccupancy evaluations, they often involve collecting energy usage data and occupant satisfaction feedback as well as inspecting and maintaining the building systems after occupation.[3] This diagnosis typically is followed by a tune-up of poorly performing building systems or training for facility managers or occupants who may be operating systems inefficiently. Without a postoccupancy evaluation, energy managers may be in for a rude awakening when they encounter high energy bills and occupant complaints.

To ensure that a postoccupancy evaluation is conducted, it is essential that all new building construction projects have

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a central coordinator to oversee the design and building process from inception to after occupation. The project coordinator may be held accountable for how equipment is installed and how well all the systems work, in addition to monitoring end uses once the building is occupied. Planning ahead and budgeting for postoccupancy evaluations early in the design process will help guarantee their implementation.

Closing the Gap

Oftentimes the projected (modeled) performance of a green building is touted as the actual building performance, when in reality the two performances may be very different. Verifying that green buildings have met their design specifications and goals can help close the gap that currently exists in green building design.[4] In 2005 the High-Performance Buildings Group at the National Renewable Energy Laboratory (NREL) conducted a study focusing on the actual performance of six newly constructed high-performance buildings (see "Improving the Energy Performance of Green Buildings," *E SOURCE Report, ER-05-11*). The NREL study found that the six buildings evaluated were saving energy; however they were not saving as much energy as expected (see **Table 1**).[5] The problems were due mainly to the use of unfamiliar technologies, unpredictability of occupant behavior, and lack of operator training. Had there been a postoccupancy evaluation, these problems might have been resolved earlier.

Use of unfamiliar technologies. High-performance buildings often utilize high-performance technologies that are unfamiliar to the building team and building operator. These technologies help fulfill the green building requirements, but since designers and building operators have little experience using them, they can cause unexpected problems. For example, NREL found that underperforming design features in the buildings included photovoltaic (PV) and daylighting systems.

Building-integrated PV systems are still new and unfamiliar to many building design teams. They can be effective at decreasing the use of grid electricity during peak demand periods, but because of installation design flaws or improper maintenance, they often perform below the expectations of the designer. One common problem with PV systems is the inadequate selection, sizing, and programming of the inverter. One such problem occurred at BigHorn Home Improvement Center in Silverthorne, Colorado, where NREL found that the PV system was generating only 46 percent of its expected output owing to poor inverter selection.

Figure 1: The Seattle City Hall earned LEED certification but performs poorly

The new Seattle City Hall has a green exterior—the green roof shown here reduces rainwater runoff and helps insulate the building—and earned Leadership in Energy and Environmental Design (LEED) Gold Certification from the U.S. Green Building Council. But a postoccupancy evaluation showed surprising results: The new building is using more energy per square foot than the old "less-efficient" one.

Courtesy: The Greenroof Projects Database [2]

Utilizing daylight to replace artificial light can also provide significant energy savings and peak power reductions, but poor management of direct light and poor lighting controls can decrease energy savings as well as occupant comfort. For example, designing a building with big windows provides daylight but can also generate glare and increase the cooling load. Control problems usually occur because control systems do not respond properly when lighting levels change. For example, lighting sensors sometimes fail to dim lights when there is sufficient daylight because of poor placement of the sensor. Without postoccupancy evaluations, these problems may go unnoticed.

Unpredictability of occupant behavior. Variations in human behavior can affect the actual building performance compared to the modeled building performance. In some cases, design teams fail to accurately predict energy consumption because of a lack of understanding of working conditions. For example, occupants may need to have more than one computer at their desk, desire more lighting than expected, or place space heaters by their work station. Unexpected occupant changes such as these increase the energy usage in the building. Postoccupancy evaluations help designers account for additional energy use caused by occupant behavior.

Lack of operator training. The efficiency of building systems often relies on the skills of the building operator. A 2003 study by the California Energy Commission's Public Interest Energy Research program found that many building systems do not perform as efficiently as expected due to lack of building operator training.[6] Postoccupancy evaluations may be a good time for training operators and creating an operating manual to leave in the building.

Table 1: Monitoring revealed that five green buildings were less efficient than expected

The results of building monitoring showed the discrepancies between predicted energy cost savings and actual energy cost savings in five high-performance buildings that were evaluated by the National Renewable Energy Laboratory's High-Performance Buildings Group. All the buildings yielded lower energy cost savings than the models had predicted.

	Energy cost savings (%)	
Building	Predicted	Measured
Zion National Park Visitor Center	80	67
NREL's Thermal Test Facility	70	63
Pennsylvania Department of Environmental Protection's Cambria Office Building	66	44
BigHorn Home Improvement Center	60	53
Adam Joseph Lewis Center for Environmental Studies, Oberlin College[a]	100	79

Note: a. Site energy savings, not energy cost savings.

Source: E SOURCE, data from NREL [5]

Conducting a Postoccupancy Evaluation

Although there are no set standards for conducting postoccupancy evaluations, a number of studies have outlined the important steps to take when performing such an evaluation. The two main steps are monitoring and analyzing energy usage and surveying the building occupants about their perceptions of comfort.

Monitoring the building. The purpose of monitoring the building energy usage is to find out whether or not a building is providing the predicted energy-efficiency benefits. Monitoring should ideally be performed by independent analysts who conduct site visits and field observations and compare monthly energy bills to expected building-performance models.

The energy performance of a green building can be calculated in four ways. First, comparing actual energy performance with the design performance shows whether the building performance is consistent with the original modeled expectations. Second, actual energy performance compared to baseline building energy codes shows a

Monitoring should ideally be performed by independent analysts who conduct site visits and field observations and compare monthly energy bills to expected building-performance models.

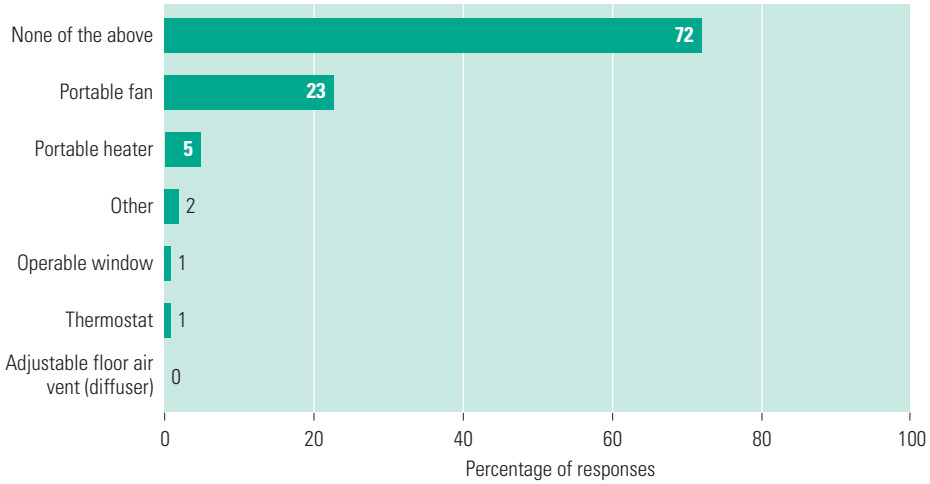
savings estimate relative to similar new buildings constructed without energy-efficiency features. Third, actual performance compared with the average energy performance for commercial buildings shows savings compared to a typical building benchmark that includes existing buildings.[7] The Energy Star Target Finder on the U.S. Environmental Protection Agency (EPA) Energy Star web site (www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder) can help you find average energy performances of buildings in order to make this comparison.[8] Fourth, if a company owns other buildings, the actual performance of the new building can be compared to the performance of other buildings owned by that company. Making all four comparisons will give the energy manager a well-rounded idea of how the building performs.

Surveying the occupants. Occupant surveys can reveal perceptions of building comfort and functionality by inquiring about general building satisfaction, indoor air quality, thermal comfort, lighting, and acoustics.[9] The survey asks occupants to respond to questions regarding their opinions about the building environment. A commonly used survey, the census survey, asks the occupant to rate each building feature on a five-point scale ranging from "very satisfied" to "very dissatisfied." A response rate of 50 percent is the usual target for census surveys. One web-based occupant survey was developed by the Center for the Built Environment (CBE) at the University of California at Berkeley (see **Figure 2**).[10] Using the CBE survey (www.cbe.berkeley.edu/research/survey.htm) will expedite data collection and analysis because it automatically generates an analytical report that allows energy managers to quickly identify the causes for complaints in buildings.

It is useful to analyze the results with respect to the occupant's location in the building in order to identify problems related to specific areas within a building. For example, some employees might complain

Figure 2: Surveying the occupants allows building operators to identify building performance problems

The Center for the Built Environment (CBE) offers a web-based occupant survey that questions the occupants regarding the indoor building environment, such as thermal comfort. As soon as the surveys are completed, the survey automatically generates a report that allows the building operator to identify problems with the building's performance. Here, occupants are responding to the question "Which of the following do you personally control in your workspace?"



Note: N = 150

Courtesy: The Regents of the University of California [10]

about glare, and others might think light levels in their areas are too low. Feedback will help the facility managers make improvements to the building's performance and may increase employee productivity and satisfaction. It is also helpful to compare the results from the same survey in other buildings owned by the same company and to create a benchmark database with results from these surveys.

Making the Commitment

Successful postoccupancy evaluation programs require commitment to the goal of optimizing building performance to get the most out of green building investments. The following guidelines can help make the evaluation process ultimately successful.

- *Budget for postoccupancy evaluations early in the design process.* Too often postoccupancy evaluations and tune-ups don't happen because the teams have run out of money by the end of the project. Setting aside funding for these two functions in the beginning will make it much more likely that they will get done.

- *Appoint a central coordinator to a building project.* So many issues—large and small—can slip through the cracks on a building project. We don't see any way to overcome that chronic problem without designating a coordinator to oversee the project from inception to occupation, including monitoring of actual building performance after occupancy. Everyone else on the project team is too busy and too focused on their own trades and skills to provide this critical project management.

- *Limit the scope of the evaluation.* It may not be possible, due to time or budget constraints, to evaluate all building systems. If this is the case, limit the scope of the evaluation to focus on the most-energy-intensive systems that will provide the most return for your investment.

- *Publish findings and benchmarking.* A postoccupancy evaluation program can benefit from having a large number of buildings publish their monitored performance results so that benchmarking can occur.

Whether the purpose for green building design is to reduce energy costs, improve the indoor environment, reduce the environmental footprint of the building, or a combination of those three, it is likely that buildings designed with these goals will continue to occupy a growing share of the market for the foreseeable future. However, there is still much to be learned regarding the design and performance of these buildings and many costly surprises that can occur once they have been occupied. Addressing performance problems that are revealed by postoccupancy evaluations helps to ensure that high-performance buildings provide the promised return on investment.

For reports on actual postoccupancy evaluations, refer to the report "LEED Building Performance in the Cascadia Region: A Post Occupancy Evaluation" (www.cascadiagbc.org/pdfs/CascadiaPOE_1_2.pdf) and the report "Post-Occupancy Evaluation of UK Library Building Projects: Some Examples of Current Activity" (http://webdoc.gwdg.de/edoc/aw/liber/lq-1-02/lq-1-02_026-045.pdf).[11]

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Notes

1 Adam Hinge et al., "Moving Toward Transparency and Disclosure in the Energy Performance of Green Buildings," *ACEEE Summer Study on Energy Efficiency in Buildings* (2006).

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