Moving Toward Transparency and Disclosure in the Energy Performance of Green Buildings

Adam Hinge, Sustainable Energy Partnerships
Donald Winston, The Durst Organization
Byron Stigge, Buro Happold

ABSTRACT

Some new high performance, green buildings are cited in the literature as what is needed in the future to achieve carbon reduction targets in the buildings sector. Growing anecdotal information suggests that some of these buildings, while built with the latest technologies, are in fact operating at a higher energy intensity than predicted. In one of the more public examples, the new Seattle City Hall, which had received LEED Gold Certification, has been shown to use more energy per square foot than the "less efficient" building that it replaced. In many cases, there are valid reasons for the higher energy intensity, perhaps due to more outside air ventilation or innovative water recycling systems. Additionally, technologies in these buildings, and the interaction of these newer technologies, can be quite complex, and may be challenging to operate as designed and modeled.

A variety of efforts are presently underway to accurately disclose the measured energy performance of the high performance building stock. The EPA ENERGY STAR® Program, LEED for Existing Buildings, and a number of other efforts are based on actual energy performance, instead of modeled or simulated energy use. This paper reports on a number of efforts that are underway, particularly in Germany, the United Kingdom and some regions of the US, to better understand why some of these buildings are operating on a more efficient level, and for others why the performance has been different than expected.

Introduction

In the past several years there has been a dramatic rise in the interest in "Green Buildings". Green buildings are perceived as being better places to live and work, and to have higher asset value due to their lower operating costs and lessened impact on the environment. The US Green Buildings Council (USGBC), the "leading nonprofit coalition for advancing buildings that are environmentally responsible, profitable and healthy places to live and work" has reported amazing growth over the past several years. The USGBC has nearly 6,000 members, more than five times the number in 2001, and reports that the annual US market in green building products and services has grown to $7 billion, representing 37% growth over the prior year (USGBC 2006).

A challenge in understanding the performance of green buildings is that there is a delicate interaction and balance between several of the goals in some green buildings. If energy conservation is the only goal in the building, that priority may preclude other environmental attributes that are important, but can result in higher energy usage. For example, extra outdoor air ventilation generally requires additional fan energy to move the air, as well as energy use for conditioning that outdoor air. Similarly, the fans/pumps used for water reclamation and recycling require more electricity consuming equipment than is typical in most buildings.

Many high performance buildings are designed with state of the art efficient and complex equipment, particularly controls, which can be very difficult to operate in an optimal way. While these systems may be the best from a design perspective, based on the assumed operating profile, the realities of commercial operation are often not adequately considered in establishing design intent. Complex building systems (in any building, not just green or high performance buildings) often require improvements and iterative adjustments over multiple seasons to ultimately operate as designed. Given these realities, and the fact that sophisticated systems can be a real challenge to run in the optimized way, actual energy performance is often quite different from predicted performance, particularly for the first years of operation. The issue of predicted energy performance differing from actual is not unique to green buildings; the challenges of accurately modeling and predicting building energy use apply to all buildings, though the same scrutiny about performance is usually not applied to the general building stock.

In the interest of publicizing the benefits of green buildings many statements can be found on predicted energy performance. Actual performance measurements are much less widely published. This may be simply because all green buildings are required to calculate predicted energy savings while obtaining actual consumption figures can be difficult, expensive and not required. But a number of efforts are currently underway to more widely publish systematic reviews of actual energy performance, including those reported on in this paper.

There are a variety of issues with current practices for disclosure of building energy performance. Protocols for determining predicted energy performance by energy modeling are challenging and often more meant to determine relative performance than to determine actual energy use. Knowledge and intentions are usually not shared between building operators and building designers either during the design process or during the first years of occupancy. For example, an understanding of the potentially conflicting goals of indoor environmental quality, occupant comfort, system redundancy and energy savings needs to be explained and reconciled. It is a real challenge to communicate these complex issues in a media “sound-bite”, so there is great potential for confusion.

This paper arose from author experiences in trying to get “lessons learned in operating high performance buildings” into the professional literature to speed up solving the operational challenges that arise from more complex systems and controls, and experiencing challenges in having owners share those experiences publicly. As such, there are growing perceptions of problems due to the lack of transparency about operating experiences, but little data to have real discussion about how green buildings actually perform and work in practice.

This has exposed the need for leadership from industry/market leaders to share lessons learned and problems.

Issues/Dilemma

Disclosing energy performance and properly characterizing the benefits of improved performance is complicated by a range of factors. For this paper, we have broken these factors down into three categories: defining and measuring energy performance, expected versus actual energy performance, and managing expectations.

Defining and Measuring "Energy Performance"

Energy performance of buildings means many different things depending on one's perspective. A wide variety of building energy performance definitions and metrics exist, and in some cases a building performing well to one measure may not appear as good under different metrics (a good discussion of the various definitions of building performance appears in MacDonald 2000).

Energy intensity, or energy use per unit of floor area, is a common measure of building energy performance, but must be balanced against other performance criteria. The US Environmental Protection Agency's (EPA's) ENERGY STAR building program, with its Portfolio Manager rating system, measures and compares building energy performance through an adjusted energy intensity. A building with no lights, air-conditioning or ventilation will have extremely low energy intensity, yet not adequately serve the needs of building occupants. The primary function of a building is to deliver a satisfactory environment to the occupants, and all other goals should serve that function.

Building energy efficiency is often measured as a percent below a threshold, usually an energy code or standard. While this is the most common measure used for new building energy performance, a building that has been designed to perform at a significant reduction below the energy code may not compare well to some similar buildings when performance is measured by energy intensity.

Expected vs. Actual Energy Performance

There are a variety of reasons why actual energy use might be higher than predicted during design. Quite often new buildings have higher performance standards for lighting levels, temperature control, ventilation rates, and redundancy that require more energy. At the time of design and modeling of predicted energy performance, optimal control strategies and schedules are often assumed. Daylighting strategies might assume that artificial lighting is dimmed or turned off, while those control systems often are not utilized as intended.

A major issue in comparing simulated to actual performance (in green buildings as well as the more general building stock) is challenges in correctly modeling building energy performance. The potential inaccuracies of energy modeling are well known, yet seem to persist. Most energy modeling tools are very good at modeling standard HVAC systems, but struggle to model advanced green building systems such as: natural ventilation, atria, displacement ventilation, chilled beams, double facades, and more.

Calculating a building's predicted energy performance below a code threshold historically has only included "regulated energy use", which is only part of the total energy bill. Most codes and rating schemes (including LEED) exclude "process energy", defined in ASHRAE Standard 90.1-1999 as "energy consumed in support of a manufacturing, industrial, or commercial process other than conditioning spaces and maintaining comfort and amenities for the occupants of a building." The published energy savings for many high performance buildings compares the things over which the design team has control such as envelope insulation value, percentage glazing, solar shading, chiller and boiler efficiency, fan and pump motor efficiency, installed lighting power density and system selections. This excludes some of the biggest end uses in new buildings such as server rooms, lab equipment, cooking or restaurant equipment, security systems, building control systems, fire safety systems, computers, printers, copiers and some plug loads. And many of these excluded loads operate 24 hours a day, 7 days a week. So while an energy savings calculation will state significant energy savings, the real energy use of a new building may be much higher. Such intricacies can be hard to explain concisely in press releases or to an audience unfamiliar with energy use in buildings.

Managing Expectations

A major challenge with any rapidly growing industry or practice is the potential to raise expectations beyond what can be realistically attained. In the case of green buildings and the actual operating performance, the potential savings are being "oversold" in some cases. There have recently been a number of reviews in the press about similar issues with hybrid vehicles and their fuel savings performance. Hybrid vehicles, like high performance buildings, are very efficient, but cannot meet expectations that get overblown. In the case of hybrid vehicle performance, questions about actual performance have led to a recent change in the testing process for how the fuel efficiency ratings are calculated and reported.

A recent high profile example of actual performance not meeting certain expectations is the new Seattle City Hall, which received a gold LEED rating from the USGBC. A front page headline in the Seattle Post-Intelligencer stated "Seattle's New City Hall is an Energy Hog; Higher Utility Bills Take the Glow off Its "Green" Designation" (Seattle Post-Intelligencer 2005). The article pointed out that the energy consumption of the new City Hall was higher than the old City Hall, which many stakeholders thought had been inefficient. While there are many valid reasons for the higher energy use, some of which were clarified in a press release by the City of Seattle when announcing the LEED Certification, the news article stated "City Council members last week reacted to the energy consumption news with shock, then shook their heads in disbelief." Press coverage of this sort points out the need to better manage expectations to avoid similar incidents in the future.

Because of reports like the Seattle City Hall news story, and perception concerns about potential misuse of the information, there has been reluctance on the part of many owners and managers of higher profile green buildings to release actual energy performance and share data on operational experience.

Research Currently Underway

In the past few years there has been a large move in the US toward understanding and sharing operational performance and experience with high performance buildings. This follows earlier activity in Europe in recent years that provides some good experience from which US efforts are benefiting.

The oldest and most significant review of building operating experience and occupant satisfaction has been the United Kingdom PROBE ("Post-Occupancy Review of Buildings and their Engineering") project initiated in the 1990s by the Chartered Institute of Building Services Engineers (CIBSE, the UK equivalent of ASHRAE). PROBE had several rounds of review of operational issues of both high performance and standard design buildings. A variety of reports were issued on the project, with one 1999 article beginning "Over the last five years the PROBE research team has uncovered the stark truths of how buildings really perform. Successes and failures have been reported in equal measure, providing clients, designers and end users with valuable, real world information." (Building Services Journal 1999).

As the green/high performance buildings market has grown in Europe, other relevant projects have been conducted. There has been an increase in activity in recent years, both due to the growth in interest in green buildings, as well as the approaching deadlines of the European Union "Directive on the Energy Performance of Buildings" which requires a number of new building performance regulations and reporting requirements in European member states.

A detailed review of seven Dutch high performance buildings, including end-use monitoring of energy, showed that in some cases the actual energy consumption for the traditional, more easily predicted end-uses such as lighting, heating, cooling and ventilation correlated reasonably well to the predictions, but that the office equipment and other uses (including kitchens and elevators; many of the "non-regulated" loads in energy modeling parlance) were quite significant and had not been accounted for. In other cases, even the traditional energy use was much higher than modeled, and the "design" energy use was very different from what had been expected (Hendricksen & Geelen 2004).

A number of projects currently underway in Germany are examining actual performance of "innovative" buildings. The "EVA – Evaluation of Energy Concepts for Office Buildings" project, conducted by the Technical University at Braunschweig, has detailed monitoring to evaluate the energy efficiency and user comfort of 19 new office buildings in Germany. Results from the project show that overall energy performance for the innovative buildings is similar to typical buildings, though there is a wide spread of performance among the buildings. A key finding of the work is that the analysis suggests "…that the performance might be significantly improved by means of operational changes." (Plesser et al 2006).

In the US, the Department of Energy, and National Renewable Energy Laboratory (DOE/NREL) have widely published lessons learned from six high-performance buildings that have been heavily monitored and analyzed. Detailed information about these six buildings has been presented in a variety of fora (see for example, Torcellini et al 2004). The operating results of these six buildings shows quite low energy usage, and reasonable correlation with simulated results, though it is uncertain how widely these results can be extrapolated to the remaining 74 buildings that are highlighted in the DOE/NREL High Performance Buildings database (www.highperformancebuildings.gov).

Two new efforts have begun in the past year in the US: a research project managed by the USGBC, with funding support from the EPA, to study the correlation between design intent and actual operations, compare performance with the broader building market, and determine needs for future research. Additionally, a review of the energy performance of Federal Buildings which have received LEED Certification is being conducted by Lawrence Berkeley National Laboratory. Both of these efforts are feeding into the USGBC's newly formed Research Committee which is attempting to compile more data on operating experience. The results of these reviews are presented in Diamond et. al. 2006. Additionally, a more detailed review of 11 LEED buildings in the Pacific Northwest has been performed by the Cascadia Region Green Building Council (Turner 2006).

Recently a number of higher profile projects in the Northeast have begun to dig more deeply into operating experience with the goal of sharing lessons learned. One of these is highlighted below.

Four Times Square/Durst Portfolio in New York City

An early, very high profile building that is often cited as starting the green building movement is the Four Times Square/ Condé Nast building in New York City. The developer of that building, the Durst Organization, is now in the construction phase of their next showcase green project, the Bank of America Tower at One Bryant Park (located on the same block as Four Times Square).

The Durst Organization has been widely lauded in New York and national real estate markets for their leadership. Since 2000, Durst has reported the energy performance of many of their buildings through the EPA ENERGY STAR rating system. With the growing interest in measured performance of green buildings, as well as increased interest from tenants about relative energy use/costs with energy prices rising dramatically over the past year, Durst has undertaken a review of the energy use at Four Times Square in comparison with other buildings in their portfolio in New York City, as well as the broader population of peer buildings in New York.

Table 1 below shows how the Four Times Square source and site energy use intensity, in kBTU/square foot per year, compare with other Durst buildings, and with what the ENERGY STAR Portfolio Manager calculates to be the “Annual Site Energy Intensity for an average rated building (50th percentile)” with the use characteristics of Four Times Square. The Durst office portfolio consists of eight Class A, high-rise office buildings in midtown Manhattan, comprising almost six million square feet. The Durst Organization is presently in the process of refining the energy performance benchmarking to identify cost and energy savings opportunities for the base buildings and tenants, and better understand relative performance compared to other New York City buildings.

Table 1. Comparison of Four Times Square Energy Performance to Benchmarks

	kBTU/sf	
	Source	Site
Four Times Square	244	120
Best Durst Building	213	76
Durst "Fleet Average"	239	107
50th Percentile Class A (Energy Star)	366	180

The table demonstrates that Four Times Square is significantly more energy efficient than the typical New York City office building, but that it is not the lowest in energy intensity among the Durst portfolio. The reasons for the higher energy use of Four Times Square relative to other Durst buildings include:

- Significantly higher amounts of outside air (twice the prior New York City industry standard) are delivered to the tenant floors by a dedicated outside air system. This additional outside air requires additional fan and chiller energy use to deliver and condition the air. In addition, the outside air is filtered to a higher level (85%) than older buildings, and the additional filter resistance adds to fan energy consumption.
- The building is located in the “Times Square Redevelopment District”, and as such is required to have a specified amount of exterior signage and lighting as the minimum. This lighting consumes substantial additional energy.

- The principal tenants of the building are a publishing house and a law firm. Both tenants have significant after hours operations, often until 1 AM. The building is available for tenants 24 hours/ 7 days per week.
- There is a broadcast antenna atop the building, with transmitter facilities for radio and television stations. Some of these facilities operate 24 hours/ 7 days, and require continuous operation of the building cooling plant.
- There are 2 corporate cafeterias, with commercial kitchen facilities that use significant amounts of "process" energy.

In addition to the above noted reasons, there were some significant infiltration issues with the building envelope for several years after occupancy. This required substantially greater energy use for heating and freeze protection.

Finally, direct gas fired absorption chillers were selected by the design team primarily due to the perception of absorbers as "green" chilling systems, for their lack of impact on the electrical grid, as well as for the favorable operating costs and lack of harmful refrigerants. Absorbers are not, however, the most efficient choice with respect to overall net site or source energy use. If the building had been built with electric chilling, the site energy intensity would be substantially lower.

Discussion

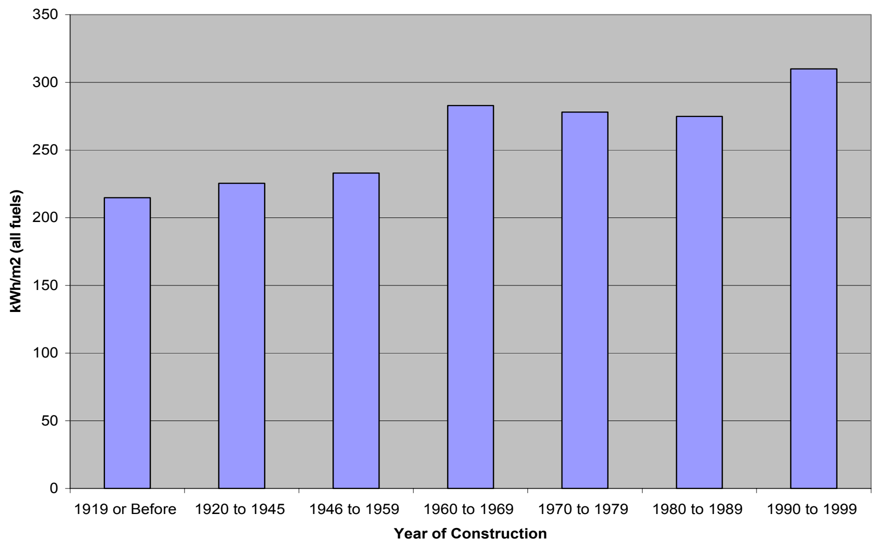
Despite the dramatic growth in the use of more energy efficient technologies and systems, newer buildings are generally more energy intensive than older buildings that are being replaced. Recent data from the Commercial Buildings Energy Consumption Survey ("CBECS") shows that energy intensity (measured in energy use per unit of floor area per annum) by year of construction of the US building stock peaked in the 1990s and newer buildings are now becoming less energy intensive than those constructed in the 1980s and 1990s as shown in Figure 1 (detailed energy intensity data are not yet published for buildings constructed after 1999). However, in comparing energy usage of new high performance buildings it is important to manage unrealistic expectations of lower energy intensity when compared with some older buildings with simple energy using systems.

With all of the current research underway, the industry is moving in the right direction, but there is a need for more disclosure so that important lessons are not missed for current generation of buildings being constructed. Information from Europe suggests that there are substantial opportunities for energy savings from operational changes with some of the more "innovative" technologies and systems in high performance buildings. The sooner that lessons learned from operating experience with these technologies and systems can be shared, the better the overall performance results for this new generation of buildings will be. The experience in the UK with the PROBE project demonstrated that much can be gained from better "post occupancy evaluation", and there seems to be a lot of work beginning in this field here in the US.

The green building movement has recognized that in order to affect a wide market transformation toward more advanced buildings, there is a need to "green" the very large existing building stock in addition to changing practices in new construction. The USGBC's "LEED-EB" (LEED for Existing Buildings) rating system was introduced in a pilot version in January 2002, and then LEED-EB version 2.0 was finalized in October 2004. For most areas of

LEED-EB, including energy performance the rating credits are based on actual performance (energy bills), not models or simulation. This is a great inducement to demonstrating optimal performance, however, it also sets a higher bar and growth in LEED-EB certifications has not been rapid since the first certified buildings were announced in 2004.

Figure 1. US Commercial Building Energy Intensity by Year of Construction



Source: EIA 2002

A major cause for discrepancy between design predictions and actual performance is the divide between building operators and building designers. Only the rarest of projects will include operating personnel in design development phase. "Optimum" design often fails to take into account realities of commercial operation, including elements such as standard practices, labor costs, union jurisdiction, or the final operating program of the building. Design intent must be carefully vetted with the owner's operating personnel to ensure that the design takes into account the intended method of operation.

In addition, this communication loop must be closed at the end of the commissioning process, when the design intent must be shared with the operating personnel in order for them to ensure that the building operates as close to the design intent as possible. Bringing designers back on board after occupancy to review and comment on operations happens even less frequently. This should continue beyond commissioning as even commissioning is not 100% effective. A seasonal or annual review by the original design team can pick up small issues like errors in critical sensors or control elements that greatly impact energy performance.

In the commissioning of Four Times Square, discharge air temperature sensors were found to be reading up to 4 deg F higher than the actual temperature. This resulted in significant excess cooling plant energy use. Generally, only a small sample of sensing elements is validated, leading to inaccurate control. Further, in actual practice, many control loops are unstable as installed. Careful testing and monitoring of system performance under actual load is essential to identify and correct instabilities inherent in the systems as installed. Most complex buildings can easily take three years (or three seasonal cycles) to bring up to optimal operation as designed.

Unfortunately clients are hesitant to pay designers to return after occupancy and designers are on the next urgent project deadlines.

Another challenge in understanding the performance of green buildings is that there is a delicate balance between energy use and indoor environmental quality. As noted earlier, the primary function of buildings is to provide healthy and safe places in which to live and work. Clients require energy efficiency, improved environment, and innovative design, but struggle to balance the trade-offs between them. Reducing the performance expectations for lighting levels, temperature control, daylight, ventilation rates, and redundancy will reduce energy consumption, but those expected performance levels are rarely negotiable. These concerns often exclude the use of passive systems such as natural ventilation or optimal thermal mass. Operable windows are generally not considered in the design of new buildings because of performance requirements of acoustics, humidity control and air filtration, even if the operational and first cost hurdles can be overcome. There has been a trend over a number of years of increasing the glazing area of buildings due to both client requirements and architectural preference. Yet energy reductions are still expected even with greater heating and cooling loads than ever before. In the best green projects clients, architects and engineers share the risk, reward and responsibility of energy efficient innovation.

A common solution to optimize the inherently contradictory goals of improved indoor environment and reduced energy consumption is a complex set of controls and systems to minimize energy use wherever possible. In addition, some designers are tempted to utilize new and often unproven technology and design concepts. The unproven technology and design concepts sometimes fail to deliver on their promised improvements in function and efficiency, and in some cases it has been shown that these concepts and technologies consume more energy initially than the mature technology they replaced.

Lease requirements also constrain designers and incur over-sized, inefficient mechanical systems. For example, even though peak power consumption in most modern office buildings rarely exceeds 3 W/ft^2, tenants regularly demand capacities of 7 or 8 W/ft^2 with the accompanying excessive cooling capacities. This results in systems that operate at 50% or less of design capacity most of the time. Equipment that is selected for best full load efficiencies rarely performs as well at part-load conditions. Equipment selection for a good balance of part- and full-load conditions is essential to ensure that the building meets expectations.

Conclusions

Green buildings certainly have great value and provide many benefits to building owners, occupants, and all other members of the building design and construction marketplace and hopefully, the global environment. There is a need, though, to temper expectations about performance to avoid frustration from clients and potential backlash from certain segments of this large marketplace. Because interest in green buildings is growing, at least in part based on expectations of improved performance and reduced operating costs, it is important (in spite of the potential for pain or embarrassment) for building owners to release data and report on actual performance. This paper points out items that may impact such reporting.

A variety of new reports have stated the energy cost savings benefits of green buildings, and often energy cost savings are cited as offsetting any additional first costs of green buildings. Most of the cited energy benefits, though, are based on predicted, not measured, savings. As more detailed information becomes available about actual performance there will be more confidence within the building design and construction industry about the costs and savings data, and this will allow for more sustainable development of green technologies and practices. Sharing operating results and lessons learned earlier rather than later can avoid repeating potential mistakes as the green buildings movement proceeds.

There is a great deal of activity toward better disclosure of measured building energy performance. The implementation of the pan-European "Directive on the Energy Performance of Buildings" requires disclosure for most public buildings, and different member states are now developing building performance labeling regulations that will help in allowing comparison of energy performance. In California, Governor Schwarzenegger's Green Building Initiative Executive Order requires a plan that all commercial and public buildings be benchmarked. Appropriately, these requirements cover all buildings, not just high performance buildings. These efforts will drive more activity, and the market will eventually require much better disclosure of energy performance.

Additionally, there is a significant amount of important work happening to improve energy performance modeling. The tax credit provisions of the 2005 Energy Policy Act are leading to development of new modeling protocols.

High performance building projects must more consistently build in budgets for post occupancy evaluation, and proper ongoing commissioning of systems. While it is a relatively new concept, performance based professional fees may be one way to see that this happens.

Since most developer decision making is cost based, owner expectations are generally also cost-based. Owners and tenants tend to be satisfied by projects that meet cost expectations, regardless of the actual energy intensity. Accurate measurement of the appropriate metrics and benchmarking of actual building operations, combined with transparency and disclosure will help the industry to manage expectations so as to achieve the environmental as well as the financial goals, and communicate these achievements appropriately.

A lot of excellent research work is currently underway, and it is expected that the level of transparency about performance will grow as the green building industry moves more toward maturity.

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