Performance by Design

An Energy Analysis of AIA/COTE Top Ten Projects

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Cover Images (left to right) are:
The Terry Thomas, Seattle, WA;
Weber Thompson; photo by Gabe Hanson
Chartwell School, Seaside, CA;
EHDD Architecture; photo by Michael David Rose
World Headquarters for the International Fund for Animal Welfare, Yarmouthport, MA
DesignLAB Architects; photo by Peter Vanderwarker

ABSTRACT

This study investigates the energy performance of buildings recognized by the Top Ten Green Projects award from the American Institute of Architects Committee on the Environment (COTE). Actual energy use data was gathered for 28 projects for all fuel types. This energy use data is then compared to the energy use of a typical building of a similar type using Portfolio Manager, either by calculating an ENERGY STAR rating or by comparing the energy use to a national average for a similar building type. The researcher develops a methodology to further study buildings as cases, including a set of interview questions to identify important points in the design and delivery of a building that may affect its actual energy use. From the list of buildings with ENERGY STAR ratings, three were selected for the case study phase. The researcher then conducted a series of phone interviews, revealing crucial aspects of each design process.

INTRODUCTION

This research project began with two questions: how well are the Top Ten projects performing, and why? While there are many aspects of building performance, this study focuses specifically on operational energy use. This is an urgent current concern in part because of the link between energy use and greenhouse gas emissions, but energy use also has significant implications on a variety of other issues, such as air quality, depletion of natural resources, and national security. In each of these issues, the critical concern is largely how much fossil fuel is being consumed to deliver energy to buildings. A large portion of this energy is lost in the conversion, transmission, and distribution of this energy as electricity. The practice of reporting only energy consumed at the site thus vastly underestimates the amount of primary energy used. This study addresses this issue by using source energy as a metric, thus accounting for the primary energy a building requires to operate. These data and calculations allow three comparisons to be made:

- ENERGY STAR rating: a metric that compares a building with a similar, “typical” building based on the national building stock
- Source energy: actual weather-normalized source energy intensity compared with national average source energy intensity for similar building types nationally
- Site energy: actual site energy intensity compared with predicted, or modeled, site energy intensity

Other studies have attempted to use similar comparisons to draw statistically significant conclusions for a set of buildings. These include an initial analysis of buildings certified under the United States Green Building Council's Leadership in Energy and Environmental Design (LEED) program (Diamond 2006), a study of buildings in the Pacific Northwest (Turner 2006), and a study characterizing the energy use of LEED buildings nationally (Turner & Frankel 2008). Subsequently, a more recent paper questions the methodology of the Turner & Frankel study, and finds a much smaller improvement for LEED buildings compared with the national building stock (Scofield 2009). One of the undisputed findings of the Turner & Frankel study was that the range of performance was dramatic: while there were many LEED buildings in the highest 20% of performers according to ENERGY STAR ratings, several LEED buildings were among the worst 20%.

This study differs from the previous studies. Rather than attempting to summarize the performance of the Top Ten projects as a whole, the goal is to develop a methodology to investigate why the lowest rated buildings performed poorly, and why the highest performed well. Such information may be useful in identifying ways to improve the actual energy performance of buildings.

This study uses an initial comparative analysis of energy use as a base point for developing exploratory project team interviews that focus on the process of design and delivery of the building. The experiences of individuals provide lessons learned for buildings that performed well and also for those that performed poorly. The scope of the questions addresses as many potential factors as possible in determining building energy performance, while recognizing the limitation of the timeframe of this project. To determine whether specific factors are actually contributing to energy expenditure or savings, a detailed on-site evaluation of energy end uses would need to be performed.

DEFINITIONS

Energy

The capacity for a physical system to do work, often measured in kilowatt-hours (kWh), thousand British thermal units (kBtu), or Therms. Energy may exist in a variety of forms, including the potential energy of water behind a dam, the electro-magnetic energy of sunlight, the chemical energy of hydrocarbons in oil, the kinetic energy of wind, the nuclear energy of decaying isotopes, the electrical energy traveling through wires, and the heat energy in steam. Energy may be converted between different forms, but the converted energy will always be less than the initial energy after accounting for losses in the conversion.

Site energy

The energy used on site as recorded in utility bills. This includes primary energy associated with burning fuel directly (such as using natural gas for heating) and secondary energy that was converted from a primary source off site (such as electricity that was generated by burning coal).[1]

Source energy

The energy use accounted for exclusively in terms of the primary energy required to deliver the energy used at a site. For instance, in 2008, a unit of electricity delivered on site required more than three times as much primary energy (i.e., source energy) due primarily to losses in the process of converting primary source energy to electricity (Figure 1).[2]

Net Zero Source Energy

A method of defining a zero energy building (ZEB) that takes into account the primary energy use of a building (Torcellini 2006). A building may be considered a net zero source energy building if the renewable energy produced on site is greater than or equal to the source energy used by the building.

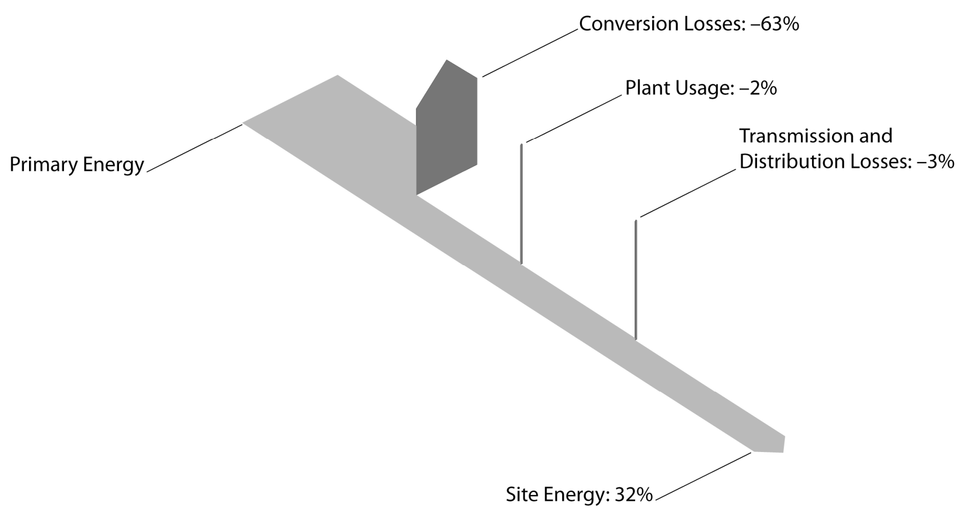

Figure 1. Energy losses due to the conversion from primary energy to the site energy point of delivery, averaged for all fuel inputs for the United States in 2008. Percents refer to primary energy as 100%.[3]

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[1] Understanding Source and Site Energy. 19 August 2009. <http://www.ENERGY STAR.gov/index.cfm?c=evaluate_performance.bus_benchmark_comm_bldgs>

[2] Methodology for Incorporating Source Energy Use, December 2007. 19 August 2009. <http://www.ENERGY STAR.gov/ia/business/evaluate_performance/site_source.pdf>

[3] Electricity Flow 2008. 19 August 2009. <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec8_3.pdf>

ENERGY STAR

A voluntary labeling program for appliances, office equipment, lighting, home electronics and commercial and industrial buildings. ENERGY STAR is jointly administered by the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy. ENERGY STAR measures efficiency by comparing the actual *source* energy use of a building with its predicted source energy use based on analysis of buildings in a 2003 national database. The predicted source energy use accounts for factors such as occupancy patterns and climate. An ENERGY STAR rating is then a percentile ranking of a building's efficiency relative to buildings in the same national database: a rating of 75 (the minimum score for ENERGY STAR label eligibility) is the same as saying that building is performing more efficiently than 75% of its peers (see the BENCHMARKING section for further discussion). Only specific building types are eligible for ENERGY STAR ratings. Presently, these space types include office, retail, warehouse, and dormitory.[4]

Portfolio Manager

An online tool maintained by the EPA for calculating ENERGY STAR ratings and tracking energy and water consumption for one or more existing buildings.[5] The user enters basic building information including address, space use type, floor area, and monthly utility bill data for a year. The tool then calculates metrics such as potential ENERGY STAR rating and weather-normalized source energy use intensity (EUI) comparison to typical buildings of that type.

DATA COLLECTION

Among the AIA-COTE Top Ten Green Buildings, project types that were potentially eligible for an ENERGY STAR rating (ie, mostly offices, retail, warehouse and dormitory uses) were the top priority for data collection. In addition, firms who had personal contacts with COTE committee members were contacted first in order to ensure a high response rate. Data was collected primarily through initial email requests by COTE members and subsequent detailed requests by the author. A "cold" email was also sent by the author to firms with no personal contacts of committee members. The process of collecting data and communicating regarding case studies involved a total of about 670 emails sent and received. Table 1 documents the data collection efforts.

[4] Other space use types may be found at:
<http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager>.

[5] For calculating ENERGY STAR ratings for projects in the design process, the EPA maintains the *Target Finder* tool:
<http://www.energystar.gov/index.cfm?c=new_bldg_design.bus_target_finder>

Table 1: Data Collection Statistics

Number of projects in Top Ten database	134
Projects where contact attempt was made	110
Projects where contact was made	66
Projects with actual energy use data collected	28
Projects with an estimated ENERGY STAR rating	13
Projects with follow-up interviews	3

The data collected includes building address, zip code, actual energy use for all fuel types, gross floor area, and space use types. Utility bill information was gathered for any year in which it was available, and data from the most recent year available are used in the study. The researcher created a database to organize the data collected. In some cases, the researcher asked follow up questions and used judgment to ensure that floor areas were accurate and matched the spaces serviced by utilities and that space types were accurately categorized in Portfolio Manager. For each space use type that was eligible for an ENERGY STAR rating, operational data were collected; for offices, for instance, this included number of workers, hours of operation, number of PCs, percent of floor area cooled, and percent of floor area heated. Once the data were collected and entered in the database and in Portfolio Manager, a summary sheet of energy use data was emailed to the primary contact for checking.

BENCHMARKING

ENERGY STAR

This project uses the ENERGY STAR methodology for comparing the energy use of buildings. This metric makes a statistically rigorous comparison to the Commercial Building Energy Consumption Survey (CBECS), a nation-wide survey of energy use in commercial buildings, conducted by the Department of Energy's Energy Information Administration.[6] Once a user enters building operation data in Portfolio Manager, it computes the typical (median) source energy use intensity for a building of a similar type. This is the "National Average Source Energy Use Intensity (EUI)". Portfolio Manager then calculates an estimate of the building's actual source energy use intensity by converting the utility meter data to an estimate of source energy use: it multiplies electrical energy by a factor of 3.34 to account for energy loss in the conversion of primary energy and its transmission and distribution to the point of use, and it multiplies natural gas by a factor of 1.047 to account for losses in the delivery process.[7] This source

[6] The survey included a representative sample of the building stock: see <http://www.eia.doe.gov/emeu/cbecs/>

[7] These factors are national averages, so they do not take into account regional or local differences. Also, while these factors make electricity seem vastly less efficient, it is important to consider the use of a unit of each kind of energy. For instance, the conversion of electricity to heat is nearly 100% efficient, while the conversion of natural gas to heat results in energy losses due to combustion inefficiencies.

energy use intensity is normalized to account for weather conditions, arriving at the weather-normalized source energy use intensity. Finally, Portfolio Manager computes the ENERGY STAR rating by comparing the efficiency ratio (actual weather-normalized source energy use intensity divided by typical source energy use intensity) with the national building stock. Thus, a building with an ENERGY STAR rating of 75 has an efficiency ratio that is better than 75% of typical buildings.[8]

The results of the ENERGY STAR rated Top Ten projects analyzed in this study are displayed in Figure 2. The base graphic shows the national building stock and the distribution of LEED projects as published in the New Buildings Institute Study (Turner & Frankel 2008). This result shows that indeed, there are Top Ten projects that have a very high level of energy performance. Note that this is not necessarily a statement about Top Ten projects in general, however, since the sample was self-selecting. For a general statement of performance for this group of buildings, a representative sample would need to be formed. Figure 3 displays the weather-normalized source energy intensities compared to ENERGY STAR ratings. The consistent downward-sloping trend demonstrates the strong correlation between decreased source energy use and higher ENERGY STAR ratings, while the IRS Kansas City Service Center's ENERGY STAR rating of 84 is an outlier because of its especially intensive use as a 24-hour facility.

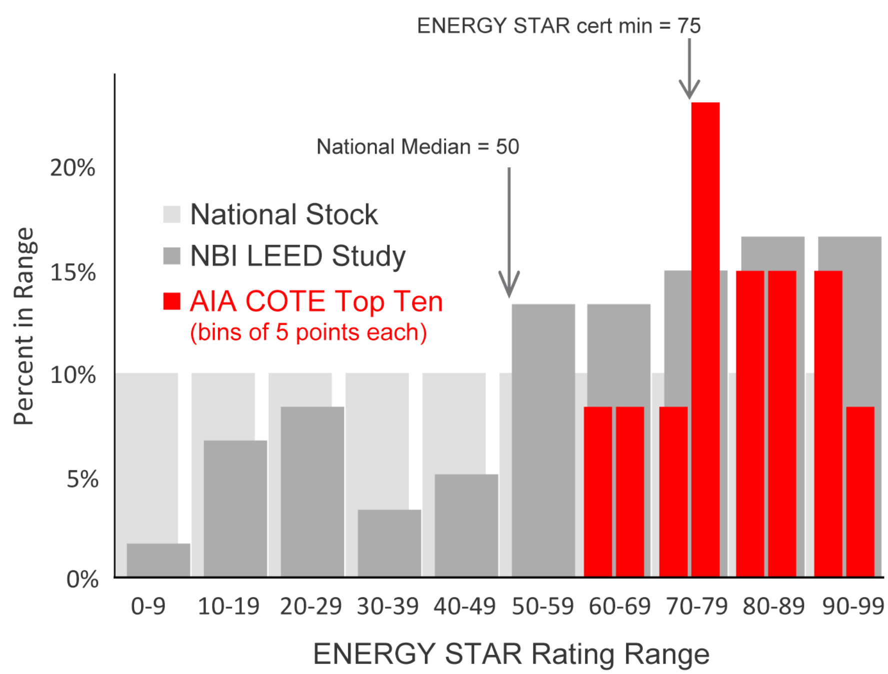

Figure 2. COTE Top Ten ENERGY STAR ratings compared with national stock and the New Buildings Institute LEED study. Source for underlying graph: (Turner & Frankel 2008).

[8] Portfolio Manager Overview: Technical Descriptions for Models Used in the Rating System. 19 August 2009. <http://www.ENERGY STAR.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager_model_tech_desc>.

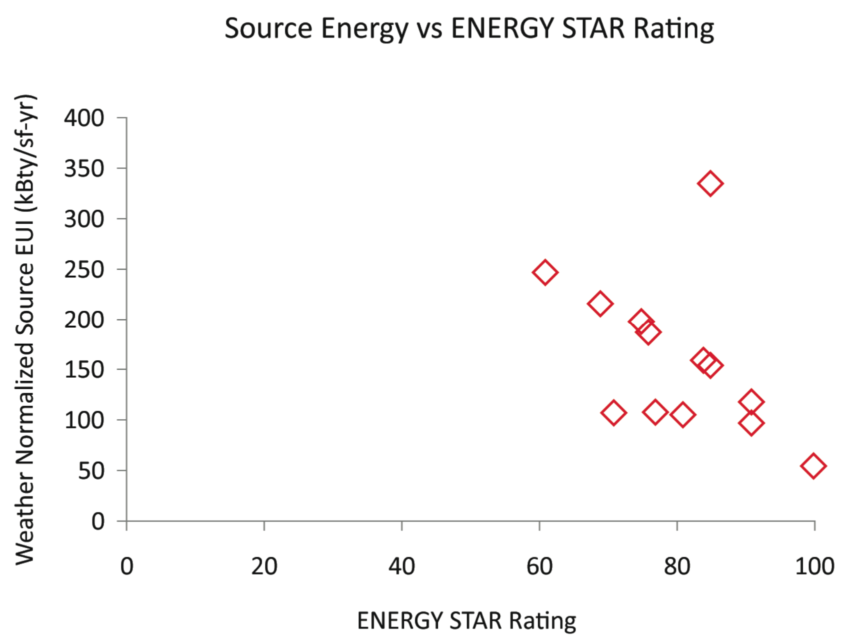

Figure 3. COTE Top Ten Projects with ENERGY STAR Ratings compared with the weather-normalized source energy use intensity (kBtu/sf-yr)

Actual vs National Average

In order to encompass more projects than just those types eligible for an ENERGY STAR rating, the researcher uses Portfolio Manager to compare the Top Ten projects to the entire CBECS database. Only a subset of specific types in this database is used to calculate ENERGY STAR ratings, so a national average comparison allows more building types to be compared. While these comparisons are less accurate since they ignore important variables such as climate and use patterns, they at least provide a rough approximation of comparative energy use. For five of the 29 projects, the building type does not correlate sufficiently with any CBECS building type, and so no comparison is made.

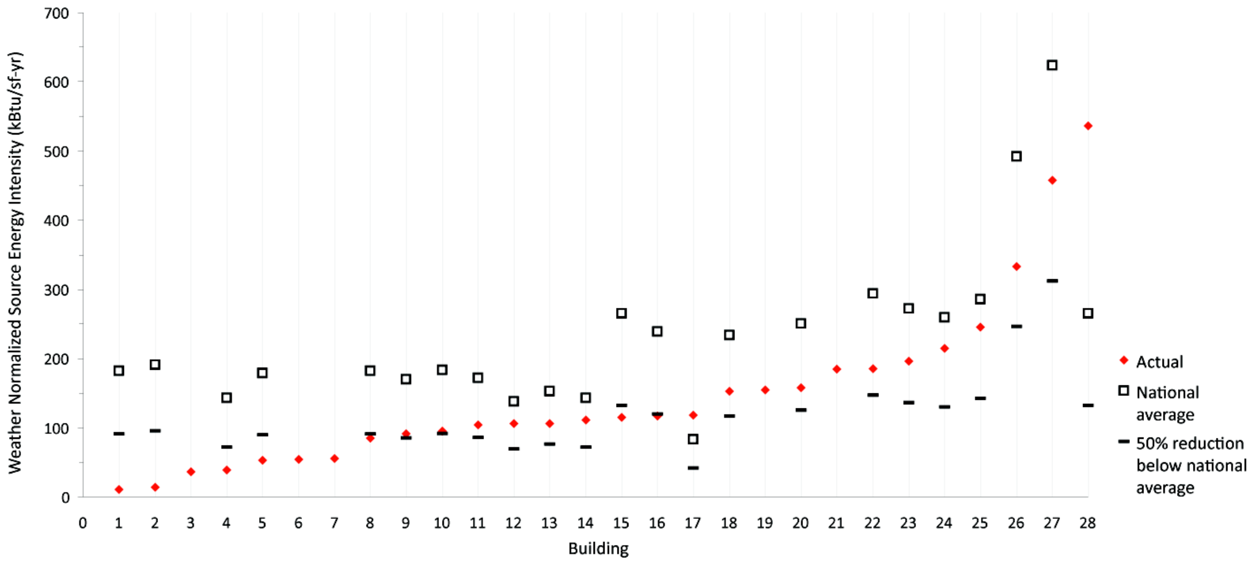

Figure 4. Weather-normalized source energy intensity: actual measured data compared with national average energy use for the given project type. The 50% reduction goal reflects the Architecture 2030 Challenge requiring all current buildings to reduce carbon by 50%, assuming that the reduction is accomplished by reducing energy use by half.[9]

Three projects contain records of electricity sales to the grid. Calculating the net energy use for site energy is fairly straightforward: energy produced at the site directly offsets energy consumed on the site. However, when considering source energy, the analysis must take into account the losses associated with the transmission and distribution of the electricity sold. For this reason, the electricity sold to the grid is discounted to reflect these losses.[10]

Figure 4 shows that of the 23 Top Ten projects where the building can be compared to a national average, 21 performed better than average. These include the 13 projects that are analyzed by ENERGY STAR rating. Indeed, there are Top Ten winners that performed very well relative to the overall building stock and relative to the LEED buildings from the New Buildings Institute study (Figure 2). However, the performance of these Top Ten buildings compares less favorably to the current Architecture 2030 goal of 50% reduction in carbon emissions, where only about a third of the buildings demonstrated a source energy use equal to or less than a 50% reduction below the national average energy use. Looking further ahead to the Architecture 2030 goal of zero carbon buildings by 2030, no building in this study has reached that point since no building reached net zero source energy.[11] For the projects that are

[9] See http://www.architecture2030.org/.

[10] The amount that could be credited against the purchased source energy was the source energy equivalent of the electricity sold multiplied by a transmission and distribution loss factor of 7.4% (determined by referencing <http://www.eia.doe.gov/emeu/aer/pdf/pages/sec8_3.pdf> and the ENERGY STAR source energy methodology): source energy credit = (energy sold)*3.34*(1-0.074).

[11] see http://www.architecture2030.org/

performing worse than average, see the Anonymous Sources section (page 14), which contains some potential reasons why these buildings performed poorly.

Actual vs Predicted

Site energy is used for the comparison between actual energy use and predicted energy use since the simulation data in the Top Ten buildings database are given in terms of site energy. For each building that references a simulated energy model, the predicted energy use is reported (Figure 5). The same data are presented in Figure 6 to compare actual and measured energy use directly and to compare the results from this study to the results from the NBI study (Turner & Frankel 2008); while the result seems similarly scattered when compared with the NBI study, about a third of the Top Ten projects used significantly more energy than predicted. Again, see the Anonymous Sources section for potential reasons why these projects used more energy than predicted.

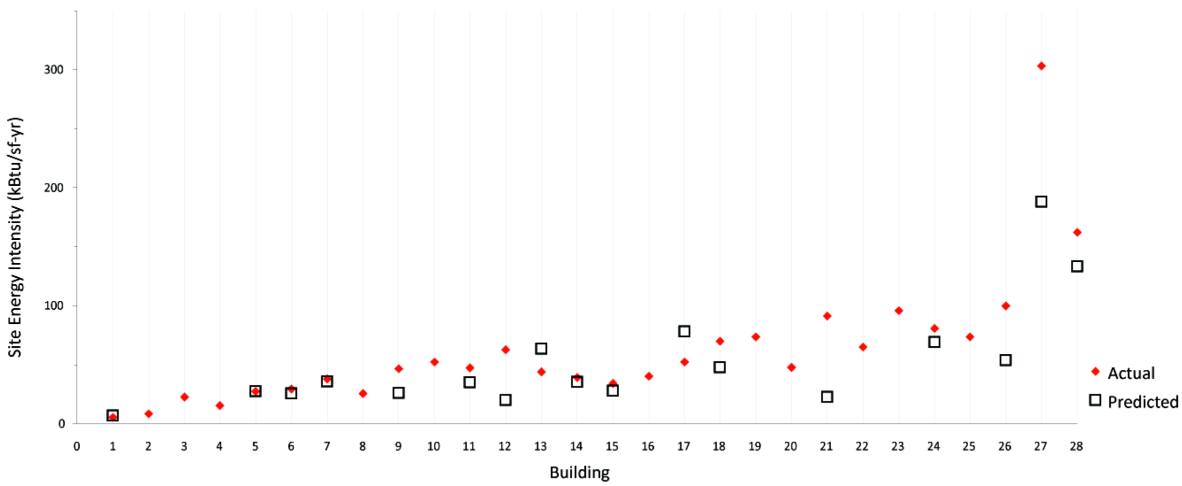

Figure 5. Site energy intensity: actual site energy use intensity compared with simulated site energy use intensity.

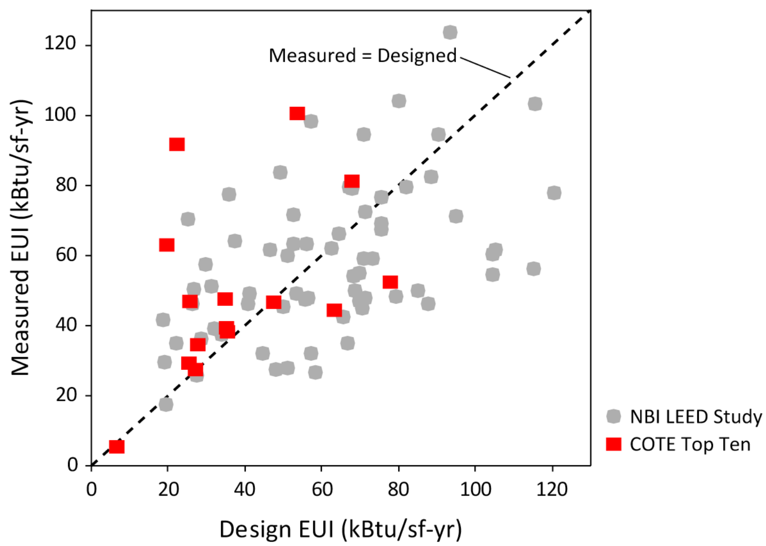

Figure 6. Design site energy intensity compared with measured site energy intensity. Source for base of graph: Turner & Frankel, 2008.

CASE STUDY SELECTION

For the case study phase of the project, the researcher chooses to focus on buildings for which the ENERGY STAR rating is calculated, so that the comments of project team members are associated with the most accurate metric for building energy performance. At the time of the selection of case studies, ENERGY STAR data was available for eight projects, reported with corresponding ENERGY STAR ratings: Chartwell School (100), McLean Environmental Living and Learning Center (91), The Terry Thomas (85), IRS Kansas City Service Center (84), Chesapeake Bay Foundation Headquarters (84), National Wildlife Federation Headquarters (76), Herman Miller Marketplace (75), and International Fund for Animal Welfare Headquarters (69).

Detailed case studies already exist in the literature for Chartwell, McLean, and Chesapeake Bay Foundation (see below for further discussion of these). Rather than duplicate efforts with prior case studies, the researcher chose to summarize what is reported in the literature for those three buildings, and focuses attention on The Terry Thomas, IRS, and IFAW. The National Wildlife Federation and the Herman Miller Marketplace were not selected since contact had not been made with their respective design teams. For this reason, these projects were given a lower priority.

INTERVIEW PROTOCOL

The researcher developed a set of questions to focus the interview around issues in the design and delivery process most relevant to the building's energy performance. In order to prepare for the conversational nature of the interview, these questions were grouped under four essential categories:

- How were the goals for the project established and the team formed?

- How did the team develop the low-energy strategy for the design?
- What economic factors influenced decisions affecting the energy use of the building?
- How did the delivery and occupancy of the building affect its energy use?

Within each of these categories, a set of more specific questions was prepared as specific prompts for the interviewer to use when appropriate. This interview organization allowed the interview to feel structured but also flexible to allow adjustments as the pace and the direction of the conversation warranted. See the Appendix for the complete set of interview questions.

The architect was contacted first, and a 30-minute (sometimes longer) telephone interview was scheduled. With the subject's permission, the first interview was recorded using an in-line telephone recording device. However, the audio quality of the recording was insufficient for transcription purposes, so subsequent interviews were documented using handwritten notes alone. This is a significant reason why the interviews are presented as narratives written in the third person rather than as quotations in the first person.

Upon the completion of an interview, the narrative was sent to the subject for review and comment.

NARRATIVES

For detailed narratives of the case study interviews, refer to the Appendix. The following are highlights of the interviews from each project. Within these specific highlights are lessons learned that can hopefully be generalized to other projects.

The Terry Thomas (Building 18)

Completed in June 2008, this office building occupies a corner lot in the South Lake Union District of Seattle. Its ENERGY STAR score of 85 likely underestimates the building's energy performance since the first four months of data show significantly more energy use than the subsequent months, and this corresponds with reports that the building systems were in the process of being commissioned at that point.

Gabe Hansen, Weber Thompson (Architect)

- Primary goals of the project were related to occupant well-being. A desire for an aesthetic of efficiency and utility also informed the project.
- A pre-design charette provided an opportunity for multiple strategies to be proposed and evaluated, giving the design team a set of ideas to begin design work.
- Low energy strategies often played a role synergistically with other considerations in the building: for instance, the strategies for daylighting, natural ventilation, and a sense of communal space are inseparable.

- The building demonstrates the importance of the designer in gathering a disparate set of potential strategies, interests, and concerns, and providing a synthesis that can later be refined and tuned by expertise within the design team. Since the low-energy design strategies relate to multiple aspects of the project (eg, the atrium relates to light, air, and spatial qualities), the argument for these strategies becomes stronger than arguing for an added low-energy "feature" that might have only one use.
- Computer simulation was used to ensure the minimal level of occupant comfort, allowing the designers to provide comfort in an efficient manner, reducing the operational energy use and costs as well as minimizing the first costs and embodied energy.
- The triple net lease[12] agreement provided the financial incentive to reduce operational energy use.

Internal Revenue Service Kansas City Service Center (Building 26)

Constructed in 2006, this 1,140,000 sf building contains offices and a warehouse. Its use as a 24-hour facility explains how its relatively high weather-normalized source energy intensity of 333 kBtu/sf translates to an ENERGY STAR rating of 84. The following are highlights from interviews with Craig Scranton and Bill Edwards, representatives of the architect and general contractor, respectively.

Craig Scranton, BNIM (Architect)

- This was a design-build, developer-led project – the architect helped form the team early on with the choice of MEP and contractor.
- Energy performance targets were written into the lease – although some targets were not aggressive (eg, 50 fc light levels on desks).
- The design process relied upon the architect's intuition about energy issues, and modeling was used to verify performance.
- Under floor air distribution (UFAD) was designed to provide means to turn zones on and off depending on occupancy patterns.
- The decision to go with electric rather than more efficient gas related to utility rate structure that favored all-electric facilities. Cost analysis showed that natural gas would not be cost effective.

Bill Edwards, JE Dunn (General Contractor)

- The terms of the lease include performance requirements not only for first costs but also operational costs.

[12] a *triple net lease* is an agreement where the tenant pays expenses that would otherwise be paid by the landlord, such as utility bills

- A detailed energy model was used to identify or verify a variety of strategies for low-energy performance, and to assist in decision-making.
- Teamwork was emphasized not only in the establishment of an integrated team, but also in the physical arrangement of shared workspace.

World Headquarters for the International Fund for Animal Welfare (Building 24)

Completed in 2008, this is the headquarters for a non-profit corporation, located in Yarmouthport, MA. It contains offices and a data center in 55,200 sf. In its first year of operation, its weather-normalized source energy intensity of 215 kBtu/sf translates to an ENERGY STAR rating of 69.

Sam Batchelor, designLAB (architect)

- Habitat protection and restoration were primary goals of the project, in keeping with the mission of the client; energy performance was not a primary goal.
- The contractor, involved in a CM (Construction Manager) at-risk arrangement, was involved from the start.[13] A series of mock-ups allowed the architect and contractor to test assemblies before construction. This had consequences for energy use: the effectiveness of a daylighting mechanism was demonstrated, allowing for a reduction in electric lighting.
- Despite not having energy performance as a top goal for the project, the design team delivered a building that is potentially 6 points away from being an ENERGY STAR rated building. The building's exceptional performance is in aspects other than energy use, in particular in its preservation and restoration of habitat on site and off site, an aspect that had been given priority in the project due to the mission of the client.
- LEED points helped to keep at least one energy efficiency measure in the project since the loss of LEED points outweighed the added cost of a highly efficient HVAC system.

BUILDING UPON EXISTING CASE STUDIES

Chartwell School (Building 5)

Alison Kwok's interviews with project team members provide an opportunity to extract information directly for this study (Kwok 2009). In particular, the interview completed with architect Scott Shell provides some relevant insights:

- The sustainability goals of the project, including achieving LEED platinum, were largely driven by the client, but then pushed forward by the design team. The goal of net zero energy was deemed feasible, and so the secondary goals of achieving comfort and a

[13] The CM at-risk arrangement meant that the construction manager agreed to limit the project cost to a Guaranteed Maximum Price.

pleasant learning environment through daylighting and natural ventilation became the focus.

- The daylighting goals were emphasized in project conversations, and a daylighting consultant provided input on the project, including the performing of several daylight simulations to consider design alternatives.
- An economic analysis was performed very early in the process to determine the cost of using photovoltaics to reach net zero energy; since the cost of the panels was relatively small compared to the total cost of the project, it allowed the net zero energy goal to be taken more seriously.
- The actual energy use was "way off" from what was predicted, a point which was not elaborated upon in the report.[14]
- Daylighting was affected during construction because of the installation of skylights using a "curb" that encroached on the clear skylight well. The contractor had little experience with sustainable design and overall did good workmanship, but the lack of experience likely contributed to this critical error.

McLean Environmental Living and Learning Center (ELLC) (Building 10)

Completed in 1998, the ELLC is a 40,000 sf dormitory for students at Northland College in Ashland, Wisconsin. The following are points summarized from a study of the design process completed by the Energy Center of Wisconsin in 2000 (Bensch 2000).

- The project was described as a green building delivered through a conventional building process.
- Miscommunications were reported that delayed the project – the major reasons given for this were the physical distance between the design team members and the short duration of some team members' involvement in the project.
- Energy efficiency measures provided much more significant economic benefit than renewable energy generation. These measures included improved insulation, reduced lighting power, and efficient building systems (including heat recovery, efficient boilers, and occupancy sensors).
- Analysis was performed to determine the marginal cost for "green features", which were estimated to cost about 5% of the final design and construction cost, although some had the impression the marginal cost was much higher, perhaps due to initial under-budgeting.

[14] However, Alison Kwok adds, 'Scott Shell and Taylor Engineering have continued to collaborate to find the causes of the increased energy use from the simulated results.' (personal communication with Alison Kwok).

- The commissioning process was not well integrated, making it difficult for the commissioning team to both diagnose problems and cause problems they did find to be fixed adequately.
- According to a handful of student interviews, the building is a desirable place to live, mostly due to the building's relative newness and improved amenities.

Philip Merrill Environmental Center (Building 20)

This 31,000 sf office building serves as the headquarters for the Chesapeake Bay Foundation. It is located in Annapolis, MD, and was completed in 2000. In 2005, the National Renewable Energy Laboratory (NREL) completed study of the actual energy use of the building (Griffith 2005).

- This report contained references to the goals and design process, documenting the use of an energy model in an early phase, mention of input from engineers, and a peer-review of the concept design. However, the lack of a more detailed description did not allow extraction of information directly relevant for this study. A next step would be to follow up with more process-related questions for the design team. For instance, it could be interesting to describe the exchange of ideas that occurred during the "peer review" and energy modeling process.

Anonymous Sources

Finally, information was obtained from multiple anonymous sources that helps explain the performance of projects that used more energy than typical buildings based on national averages, or more than was predicted using a simulation. In order to publish these lessons that will likely have applicability beyond the specific projects mentioned, they are gathered here, without being associated with specific buildings. The highlights are:

- Timers for several pumps were disabled, causing pumps to run continuously rather than intermittently.
- The HVAC system did not meet its goals due to an open plan, allowing pressure imbalances to exist between zones.
- Automated shades did not function properly. Since the automatic system was not controlling heat gain and glare, the it was switched to manual operation.
- Occupancy sensors were disabled in public restrooms because visitors kept breaking them.
- There were numerous HVAC control problems, such as improper functioning of water-side economizer and cooling tower fan operation.
- An increasing or high frequency of uses that are not accounted for in Portfolio Manager

CONCLUSION

Lessons Learned: Building Design and Delivery

Low-energy performance as a design goal

The development of goals and the advocating for goals is a significant consideration that may, in some cases, trump the effectiveness of an integrated team. In the case of the IFAW, its above average energy performance seems to have been motivated by responsible design principles and LEED, with some benefit being generated by the integration of the contractor in the process of developing mock-ups. It seems that the exceptional performance of that building is in its preservation and restoration of wildlife habitat, reflecting the project's top goals. In the Terry Thomas, since the architect was planning on being a tenant and since a triple net lease was negotiated, there was motivation for the architect to design a highly efficient building. Thus, when a contractor was unfamiliar with the construction process for the sunshades, the persistence of the architect became important: it took multiple rounds of communication to reach an appropriate price for the shades. While the contractor was not closely integrated early on in this aspect of the design process, the persistence of the architect in achieving a goal proved decisive. In the IRS Kansas City Service Center, the performance goals of the project were established very early in the design process through the negotiation of the lease. Whether these goals were as aggressive as they could have been seems to be an open question, but the establishment of specific performance goals that were tied to the targets of project cost eliminated the need for value engineering later in the design process as long as the design met the performance goals. These projects not only underscore the importance of establishing goals for performance, but they also show a variety of sources of motivation for energy performance.

Communication through mock-ups

Mock-ups were used in both the IFAW and IRS Kansas City Service Center. In each of these cases, there was some impact related to energy performance. At IFAW, electric lighting was reduced when a system of daylight reflection was verified. In order to reduce solar loads at IRS, a glazing modification was assembled as a mock-up to test its assembly and effect on the aesthetics of the design. Lastly, it seems that a mock-up might have been useful in both the Chartwell School and the Terry Thomas projects in order to facilitate communication between the architect and the contractor regarding the design of critical sustainable features. In Chartwell, a mock-up of the skylights would likely have resolved the issue of the added "curb" before it was constructed in the building. In the Terry Thomas, a more reasonable cost for the sunshades would likely have been achieved earlier had a mockup been done to allow the contractor to gain familiarity with the design.

Importance of the role of the designer

The Terry Thomas and the IRS Service Center show that the role of the designer is essential in integrated design. In the Terry Thomas, while team members were available from the start to provide a variety of feasible strategies and to provide expert advice and analysis, it was the role of the designer to weave various interests and strategies together to form a coherent design proposal. This becomes a strategy in itself when the sustainable features become inseparable from the overall architectural proposal from the building; a courtyard is not likely to be lost in value engineering. In the IRS project, while a detailed energy model was completed by the contractor and used to assess and select low-energy strategies, the architect relied upon experience and intuition in incorporating specific strategies in the final design.

Elimination of systems

There were multiple examples of design teams not simply reducing the size of systems, but designing to eliminate them altogether. In the Artists for Humanity EpiCenter project, in Chartwell School, and in the Terry Thomas, for instance, air conditioning was eliminated from the project entirely. A system that doesn’t exist will use zero operational energy and contains no embodied energy. It is no surprise then that Chartwell is the highest scoring building in the study. After a year of typical energy use data, the Terry Thomas will likely be a top performer as well. The challenge for design teams then becomes understanding the climate and life of the building in order to characterize and communicate the effects of eliminating air conditioning. If the daily and yearly behavior of the naturally ventilated building can be described, imagined, and accepted, this will go a long way towards reducing energy use in future projects.

Commissioning of systems and follow-through of the owner and/or facilities manager

In the examples where projects were subject to commissioning, it helped ensure that building systems were working efficiently. On the other hand, some projects suffered as a result of not having systems commissioned carefully. Likewise, it is important for the owner or manager of the building to remain invested in its energy performance over time. In the example of one house, energy use had steadily risen as systems were not maintained over time. When the systems were tuned and adjustments made, the house saw its energy use cut in half. This point underscores the limitation of actual energy use in assessing the sustainable qualities of a design, since the architect has no control over occupant priorities and behavior.

Metering and reporting of data

A study cannot evaluate what was not measured. Several Top Ten projects were not included in the dataset for this study because there were no data available. Reasons for this included no meter was installed, the meter was not maintained, or the owner was not willing to share data. If it is a future goal for the performance of green buildings to be studied more extensively, then it should become standard to monitor energy use in green buildings and for that information to be readily and publicly available.

Lessons Learned: Research Process

When gathering data, it’s important to assess the trustworthiness of the source: the individual must be knowledgeable about the building/facility’s energy use in order to be confident the data reported are specific to the space being described

The interview conversations varied from straightforward answers, to narratives that went beyond the specific scope of questions. In many cases, what seemed initially to be tangents often became opportunities to gain insights into projects. A directed but open-ended interview format would allow these moments of clarity to occur.

The number of questions prepared was too many to ensure that each one would be asked in the course of the interviews. It would probably be better to refine the list further to ensure all questions could be asked in the course of a 30-minute interview, with a set of additional questions that could be asked if time permitted. The categorization of questions into four categories helped in this regard, since they allowed the most essential consideration to dominate.

Suggestions for Future Research

Study the performance of select cases in depth

While this study generated a series of potential influences on energy use in specific buildings, it did not seek to reveal these factors by studying the buildings' design and operating characteristics in detail. To determine how a building is actually using or not using energy, a study must look at the building itself in more detail, using methods such as occupant surveys, end use metering and environmental variable monitoring.

Collect the stories of a wider variety of buildings

Because of limited cooperation from a number of personnel who were contacted, the current study does not contain energy use data from projects that have experienced dramatic changes in use. These would have been interesting stories to include since they, too, represent a portion of the building stock. In future studies, researchers should endeavor to include these kind of projects, since building reuse is an established practice and has some impact on resource consumption.

Extend this study by including embodied energy

None of this analysis considers the embodied energy of buildings. Especially in the discourse on net zero energy buildings, it will be important to consider the implications of a tradeoff such as eliminating building systems compared with offsetting the energy required for the systems using photovoltaic energy. While the two scenarios may be equivalent even on a net zero source energy basis, they have different implications for natural resource consumption and embodied energy.

Energy modeling as design iteration

It seemed that there was a tendency for energy models to be used to verify performance rather than to test alternative designs, and that energy models played different roles for different design team members. Future studies might look at relationships between design and simulated energy use and ask what role energy simulation is playing, and what opportunities might exist to extend its use, or what barriers might exist that prevent its more integrated use. Studies could also look at the degree to which a building must be abstracted in order to produce this kind of analysis.

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APPENDIX – INTERVIEW QUESTIONS[15]

1. How were the goals for the project established and the team formed?

- What were the top goals for the project?
- Was there a specific target for energy performance?
- How was the team established? When were the energy consultant and contractor brought into the project?
- Was risk shared? Did team members take risks, and were there risks that team members were not willing to take?
- Was there a primary proponent of low energy performance?
- At what points were the consultants and contractor at the table during discussions about energy use?

2. How did the team develop the low-energy strategy for the design?

- What do you feel were the most and least effective strategies used to reduce energy demand in the building? Why?
- How were the ideas for the most effective strategies developed? How were they introduced?
- In retrospect, were potentially effective strategies for saving energy considered and not pursued? If yes, why were they not pursued?
- Was energy simulation included in the design process? If so, at what phase(s) of the project was the simulation done?

3. What economic factors influenced decisions affecting the energy use of the builidng?

- At what points were cost estimates or value engineering performed, and what was the impact on low energy features?
- Did LEED play a role in value engineering decisions? How?
- Was life cycle cost considered in the design process? At what points and for what features?

[15] These questions were designed in part to complement work underway by the AIA Integrated Practice Discussion Group 2009. While this Top Ten buildings study focuses on energy use, some questions (especially within the goal setting category) are similar to questions developed by the IPD group in order to provide common points of comparison and support for a collaborative case study research effort.

4. How did the delivery and occupancy of the building affect its energy use?

- Did the building undergo advanced commissioning? Who was the commissioning agent? How was this person chosen?
- Since occupancy, have there been any changes in leadership goals that may have had a significant effect on building energy use?
- Has there been any change in facilities management that may have had a significant effect on building energy use?
- Has there been any unanticipated occupant behavior that may have had a significant effect on building energy use?
- Are you aware of any other circumstances that might be contributing to higher or lower energy use than anticipated?

APPENDIX – INTERVIEW NARRATIVES

GABE HANSON, WEBER THOMPSON
SENIOR PROJECT DESIGNER FOR THE TERRY THOMAS

Conducted August 18, 2009

TEAM AND GOALS

The goals for the project originated from the firm's desire to move out of a previous building which had poor views, little daylight and no operable windows. A partner of the firm had partial ownership of a parcel at Terry and Thomas in the South Lake Union district of Seattle, and reached an agreement with the other owners to develop the parcel for office space that would be the new home for Weber Thompson.

The vision for the new office became the antithesis of the firm's prior home: emphasis would be placed on achieving a high quality workplace that included a strong connection between the interior and the street, a reinforced sense of community, adequate natural ventilation and optimum daylight.

The team was assembled largely based on the reputation of firms. The MEP, Stantec, was brought into the project from the beginning. The firms had not worked together before. The architect also selected Rafn as the contractor based on that firm's prior work with LEED buildings. The Integrated Design Lab – Puget Sound also played a very important consulting role and was incorporated very early in the project.

The project appeared different than others Gabe had been a part of in that custom architectural details such as the glass sunshades were drawn or developed well into construction. The use of a triple net lease seemed to play an important role in that it placed risk and reward in the firm's hands: if the building performed well, they would save later when it came time to pay utility bills.

PROCESS

The collaborative process began before any architectural drawings or sketches had been done. After confirming that the site was capable of supporting the programmatic requirements, the design team held an "eco-charette" in which the owners, representatives from the city, consultants, and architect gathered to develop ideas for the building. Everyone posted potential ideas for the building on note cards on the wall, and then everyone voted for the ideas they thought most and least possible using red and green dots. The architects left the charette with multiple starting points for design even before the first studies had been conducted.

The design team then conducted massing studies. Gabe's thesis project at University of Washington greatly informed his design work on the Terry Thomas. He had made an observation that many elements of office design did not contribute directly to occupant well-being. His focus became a study of the moves that would address the specific needs of the user. His conclusion was that the building's form and components should be thought of through a natural, cultural, and economic filter to create a holistic, place-specific environment that could optimize the internal working conditions.

Key strategies developed as a result. The courtyard became not only a symbolic semi-public gathering space and connection to the exterior, but it also became the mechanism by which natural ventilation and daylighting were made possible. Light and air easily penetrated the building's 38 foot wide floor plates. At the suggestion of the mechanical engineer and the Integrated Design Lab – Puget Sound, the team incorporated automated exterior shading to prevent overheating and improve natural daylighting performance. They also included horizontal glass shades on the east and west facades and blinds at the building's corners that dissipate solar heat gain on the exterior before the internal spaces are affected. The architects and engineers traded designs back and forth until they were satisfied with both the aesthetic and physical performance of the shades.

Computer simulation was used in the design process to both model light and thermal comfort. A daylight simulation within the design process demonstrated that not only was there sufficient light for the space, but that the floor to floor height could be reduced, saving significant dollars in structural steel and foundation costs while still providing sufficient light for the workspaces. Similarly, the mechanical engineer performed a ventilation analysis that demonstrated comfortable temperatures in the building for all but about 18 to 25 hours a year. The owner decided that allowing employees to go home on overheated days would be an acceptable cost, and so did not require additional interventions for the sake of thermal comfort.

Overall, Gabe describes the constant necessity to consider trade-offs. These included, for instance, the need for daylight to reduce lighting loads balanced against the need to limit solar heat gain. One such consideration was how to reinforce a sense of visual connectivity to the external landscape and also create a sense of community. This is exemplified by the internal courtyard which maximizes occupant heath and productivity but with an inherent loss in energy performance due to reduced wall insulation levels.

ECONOMICS

This project was designed during a period of contractor shortages and rising construction costs, so the process of value engineering and cost estimating relentlessly put pressure on the designers to reduce costs. The cost estimating of the glass shades was an interesting part of this process. Since the contractor had not seen a system of glass shades like the ones they were asked to price and was concerned about the installation process, the initial estimates were around $750,000. However, in one round of cost estimating, these shades were given the name "canopy" rather than "sun shades". This apparently semantic change in terminology translated to a more than 50% reduction in cost, because an unknown item had become familiar. The persistence of keeping the shades in the project thus paid off in the end.

Life cycle costs were considered in the decision making process: the sustainable features of the building, which included the operable windows, sun shades and blinds, were estimated to be $300,000 more expensive than a sealed building with full HVAC equipment. Considering the added value of the green features, the team estimated that the payback period would be 25 years due to saved operational costs, and just three years when factoring in productivity gains. This analysis was judged to be an acceptable scenario by the owner.

While the team generally sought LEED certification as a way to verify the sustainability of the project rather than as an end goal in itself, Gabe does remember that occasionally decisions were considered based on a balance between what was best from an economic standpoint, what would earn LEED points, and what would be best for the environment. An example of this is in the decision over a high albedo roof vs. green roof having similar weight under the LEED rating system. In the case of The Terry Thomas, a green roof was desired, but a high albedo roof was ultimately chosen because it provided environmental benefit and reduced the budget so that other essential features such as the external sunshades could be incorporated.

DELIVERY AND OPERATION

The occupancy of the building provided some challenges. Amidst zealous press coverage of the opening of the building, some occupants were beginning to complain that the building was not performing properly. The process of commissioning revealed not only that some of the systems were not working as designed, but also that occupants were not aware of the degree of control they had over the features of the building. The systems were also found to be turning on at times when the building sat unoccupied, and subsequently tuned to operate as designed. After six months of tuning and occupant education, the complaints have largely been eliminated, as verified by a recent occupant survey.

CRAIG SCRANTON, BERKEBILE NELSON IMMENSCHUH MCDOWELL ARCHITECTS PROJECT ARCHITECT FOR THE IRS KANSAS CITY SERVICE CENTER

Conducted August 11, 2009

TEAM AND GOALS

The top goals from the project were in part a result of dissatisfaction with the building that the client had occupied at the time the new building was being designed:

- Improve qualities of space for occupants; include daylit spaces and access to exterior.
- Provide a flexible building that could adjust to seasonal requirements, to make it more energy efficient. Design for the flexibility to turn the building on and off depending on occupancy patterns.
- Reduce water consumption.

It was a difficult building to target because sometimes there might be 3000 people, and other times there might be more than 8000 people.

The GSA was a primary proponent of energy efficiency

Complicated structure: It was a developer-led project. The GSA is the leasee and the IRS is the occupant and tenant. The team was pre-formed by the developer. It was a design-build, so the architect helped pick the MEP and contractor. The project team was formed early, so it was a collaborative effort from the start.

PROCESS

The architect knew the GSA would talk about energy efficiency, so it was a consideration from the beginning. When Craig started work to lay out the building, his team considered things they knew from experience, such as the importance of an east-west orientation.

An in-house energy modeler wasn't used until later in the process. Rather, Craig talked about relying first upon a personal understanding of what it takes to be a high performance building: "So the first stage is intuitive. Once we get past the intuitive stage, we go on to the scientific stage where we have a design, and we test it and see how well it really works."

The contractor was involved from the start of design, and the MEP was there very early on, but after there was an initial layout for the building.

The contractor made contributions, such as providing input during a decision to change out some of the glass on the east side of the building to reduce the heat load. The MEP had an effect on systems selection, but they were given the design including the under floor air strategy. The architect introduced the idea of under floor air, and the contractor later refined how it would be built and how it would work.

The main low-energy strategies were:

- Daylighting
- Energy efficient lighting
- Under floor air distribution
- Orientation (which also relates to the daylighting strategy)

Craig further discussed the role played by the under floor air design: “We used under floor air for a few reasons – the volumes are huge – half are two stories high, so we didn’t have to move all that air. Also, the system allows the building to be turned on and off in increments of 1000 sf. This allows the IRS to adjust – in April it might be crowded, but in November it might be dead, so only a third of the zones are on, where people are sitting. The zones that are off can be set back. That was pretty easily dealt with using the under floor air system. Similarly, the lighting was zoned with occupancy sensors.”

One energy efficiency strategy that was considered but ultimately abandoned was the use of natural gas for heating. The rate schedules favored an all-electric building, discouraging the use of natural gas. The economic model done by the MEP showed that the gas would not be cost effective. Interestingly, Craig noted that the project probably would have included natural gas today since the comparative advantage has gone away.

Daylight modeling was done in late schematic design. Energy modeling was done in late schematic design, including a second model where the east façade glass was changed.

It’s hard to say if a reduction of equipment beyond the typical was achieved – especially given that there were redundancies that were required.

ECONOMICS

The value engineering and costing was done fairly early on in this project, as part of the lease negotiations. By the end of schematic design, the lease negotiations were either wrapping up or already complete. The lease had performance requirements written into it. For instance, the IRS required that the lighting have 50 fc. The design team then needed to work to meet these requirements, and they were able to do so within the budget.

LEED played a role in economics discussions – there was pretty much a side-by-side comparison of economics with LEED points. For instance, one LEED credit related to humidity control – in the building’s climate, it did not make sense to spend the money to achieve the credit without a significant benefit.

DELIVERY AND OCCUPANCY

The building was commissioned, and the design team wasn’t aware of anything beyond what would typically get tuned in the commissioning process.

GSA is monitoring energy use, so there is a continued interest in the building's energy use.

There have been some challenges in the operation of the building, but nothing specifically relevant to energy use – for instance the employees wanted to stock the retention pond with goldfish, so the design team needed to figure out how that might be able to happen after the fact.

Occupants turn over very quickly, and they haven't heard of any complaints.

OTHER

One of the MEP managers has said that one of the biggest energy hogs is the pair of 500' long moving walkways that remain on all the time. There have been discussions about how to address this energy use, but no solution as of yet.

BILL EDWARDS (BE) AND CHRIS PARIS (CP), JE DUNN
GENERAL CONTRACTOR FOR THE IRS KANSAS CITY SERVICE CENTER

Conducted August 25, 2009

TEAM AND GOALS (BE)

The team was formed as a public-private partnership between the U.S. General Services Administration and Pershing Road (PRDC), a private developer. JE Dunn was brought on to the project as the general contractor at the same time as the architectural design team.

The performance goals were set very early on in the process, with the Contractor and Architect issuing a Basis for Design, and the GSA subsequently negotiating lease agreements that contained specific performance requirements including floor area, energy performance, LEED certification, rent, operation costs, insulation, material qualities, etc.

Given performance requirements, JE Dunn then solicited proposals to meet those guidelines from design-build mechanical and electrical subcontractors.

Since the performance goals had been established in the lease, Bill felt that the team then had flexibility in the process since their directive was to simply work within the performance requirements.

PROCESS (BE)

Soon after the team was established, JE Dunn contracted a firm to perform a detailed energy model for the building. This energy model helped establish priorities of strategies to meet the performance goals established in the lease. Working with the full design team, a variety of low-energy strategies were developed. These included daylight sensors, occupancy sensors, building orientation and equipment selection. The energy model was critical because the lease agreement contained requirements for first costs as well as operational and maintenance costs. A strategy was used when the analysis of first cost, usage cost and equipment cost showed that it would pay off.

Bill estimates that this selection of strategies through energy modeling was occurring concurrently with the schematic design process of the architect.

Other strategies that relate to energy include the use of a zoned under floor air distribution system, the carving of an atrium in an existing historic building and efficient equipment operation schedules. Bill emphasized that these strategies were developed as a team, rather than individually. An example of this would be the solution to insulating the first floor slab, a structural floor that also was the ceiling for below-ground parking. The solution of painted spray-on insulation was a result of meeting concerns of energy use (from the energy model), security (the tenant was concerned with security issues of a lay-in ceiling), and maintenance (the facilities representative had concerns with the bare surface of spray-on insulation).

Mock-ups were used frequently in the design process. When the energy modeling showed a benefit to replacing high efficiency glass on the east façade, mock-ups helped the process of selecting an acceptable frit pattern.

Bill credits a organizational move in encouraging teamwork: during the design and construction, a temporary office was established as a place for the developer, contractor, facilities management, client, and client's consultant could work. In this way, people became friends: "We shared a coffee pot," Bill says, "it's a lot easier to solve a problem with friends than with someone you have to make an appointment with."

ECONOMICS (BE)

A further example of economic analysis that played a role in the project was in the decision to design an all-electric building. When the contractor suggested that electric heat would be ultimately more cost-effective than natural gas, some consultants who were unfamiliar with the region were skeptical. However, the team was able to run an analysis using the energy model that showed indeed, electricity was in fact the more economical option.

DELIVERY AND OCCUPANCY (CD)

The under floor air system was not new to the contractor, although the sheer size of the project stood out as different from other projects.

The building was commissioned. Although it was somewhat new to us at the time, it was a typical process where nothing stood out beyond the routine testing and tuning of equipment.

SAM BATCHELOR, DESIGNLAB ARCHITECTS
PROJECT MANAGER FOR THE INTERNATIONAL FUND FOR ANIMAL WELFARE HEADQUARTERS

Conducted August 13, 2009

TEAM AND GOALS

The top goals of the project were not specifically energy-related. While overall environmental stewardship was indeed important to the client, the specific goals were those central to the organization: openness and transparency for workspaces, and wildlife habitat protection and restoration, water conservation, and use of renewable materials for the greater environment.

LEED was not an initial goal, rather it became an option once it was clear that the incremental cost to achieving at least certified status was simply the certification fee. The rating target was subsequently increased to silver and then gold when incremental costs were quantified and approved by the client. With areas that were a priority for the client, they increased the performance beyond LEED requirements, for instance using 93% certified lumber (51% FSC certified). LEED did have a positive impact on energy efficiency. A more expensive and more efficient HVAC system was kept in the project because a side-by-side comparison with the LEED chart showed that the number of LEED points would be reduced as a result, a cost that outweighed the potential savings of cheaper equipment.

The team was established through the landscape architect that had been retained by the client from a previous design effort. The architect then brought on various subcontractors. The contractor was hired by the client in a CM at-risk arrangement, so the contractor was involved in the design process from early on.

PROCESS

Risk was managed partly through the completion of multiple mock-ups throughout the design process. This allowed the contractor to gain familiarity with the design, reducing added costs associated with unconventional assemblies. The process of mock-ups also had an effect on ultimate energy use of the building: one mockup allowed a sail-like light reflector to be tested. When it was shown that this would indeed direct natural light into the open office environment, the team found they did not need to add extra artificial lighting to the space.

Daylight simulation tools were used throughout the process by the lighting consultant. While the building was never modeled as a whole, individual spaces were modeled as needed in the design process. Energy simulation was used twice on the project, once approximately at the end of schematic design, and once upon completion for the LEED submission.

The most important strategies for energy reduction were low-tech. Although ultimately a highly efficient system was installed (including an evaporative cooler), smart moves helped to reduce the need for energy expenditure in the first place. These strategies included taking advantage of the specific orientations of the facades to allow the winter sun to enter the building, while blocking it during the summer. The strategy of providing daylight rather than natural light was pursued as well, in order to provide a lower-energy option for occupants. However, the strategy depends on manual controls rather than automated controls with sensors and dimmable ballasts.

ECONOMICS

Value engineering and cost estimates were performed at every round of design work. While life cycle costs were not explicitly considered, the tradeoffs of initial cost compared to long term value were considered qualitatively.

DELIVERY AND OCCUPANCY

A boiler installed in the building has been performing unsatisfactorily, an issue that the project team is currently addressing. Shades were installed after occupancy to deal with glare during winter months. The spacing of the louvers allowed winter sun to penetrate and warm the space too effectively. The shades were roll-down types on the inside of the glass. Since the shades are interior, the pocket of air between the shades and the glass still gets heated and acts as a buffer from outside cold air, but may not provide as much direct heat gain in the winter as before. Other than these issues, nothing else stands out in the commissioning, delivery or occupancy of the building that would have a significant impact on energy use.