Halfway to Zero Energy in a Large Office Building

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ABSTRACT

A 108,000 square foot Class A office building was completed in December 2004 in the Midwest with one goal being an energy cost reduction in excess of 50%. Other project goals were to meet corporate office needs for the owner, provide Class A office space at a conventional cost defined as $150 per gross square foot of office space (excluding land acquisition and parking costs), and achieve a LEED Platinum Rating.

The paper describes the design-build approach taken, including the role of a core project team that guided the integrated design and construction approach for the owner. The final energy design with State-of-the-Shelf components is described in terms of central design elements; building systems technical descriptions; construction cost; energy modeling estimates, and energy performance for the first twelve months of operation. The building has been awarded a LEED Platinum rating at 60 points.

Project implementation was accomplished with ongoing interaction of the owner, designers, and constructors for the entire design and construction cycle. These participants were guided by a core project team that relied on energy modeling and examples of building elements to guide project decisions. The management structure and processes were highly useful in meeting project goals.

The project demonstrates substantial energy cost savings in the first 12 months of operation, but it is too early to definitively conclude that a 50% savings will be achieved with State-of-the-Shelf technologies and within a conventional cost budget.

Introduction

Commercial and residential buildings in the U.S. account for 40% of the nation's energy use and the associated environmental consequences of that energy use (Lindholm 2006). This share is increasing, and in the case of commercial buildings, accounts for the majority of the growth in peak electrical demand since 1970. Using Wisconsin data for example (Wisconsin Division of Energy 2000), Wisconsin electricity use data from 1970 to 1999 shows that residential use grew at an average annual rate of 2.5% per year, industrial use at 3.4% per year, while commercial sector use grew 7.1% per year. By 1999, commercial electricity use accounted for 32% of all electricity use, second only to industrial electricity use at 38%. Furthermore, two sectors, paper and allied products and food and kindred products (Standard Industrial Classifications 26 and 20 respectively) account for half of industrial energy use in the state and have very flat electricity use profiles due to continuous operation (Hanson, Lang, Copty, and Evans 1978). Commercial buildings on the other had, have peak demands due to air conditioning and lighting loads on hot summer days that are coincident with the electrical system peak. National comparisons show Wisconsin energy use on a per capita basis and on a per Gross State

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Product basis to be near national averages (Geller and Kubo 2000). With the decline of manufacturing in the U.S., especially in basic, energy intensive industries and with good progress in residential efficiency gains, it appears that new commercial building growth is likely the leading contributor to demand growth resulting in the associated cost of new power plant and transmission and distribution construction.

This paper tests a set of assertions. The first assertion is that available, well-established design and construction practices and building technologies make it possible to halve the energy use, and make a parallel impact on peak electrical demand, in new commercial buildings. The second assertion is that these performance improvements can be obtained within what is considered a conventional project budget. The third assertion is that such a building can provide desired amenities such as views, daylighting, high indoor air quality, and similar attributes associated with sustainable or green buildings. Apart from the inherent value these building features may have to the owners, users, and providers of these facilities, there is emerging evidence to link these features to higher real estate values. For example, it has been found that energy cost savings from performance improvements have been shown to have a concomitant and positive effect on building appraisal valuation (Majersik 2003).

One method for testing these assertions is to design and construct such projects, and subsequently monitor their performance. The project that is the subject of this case study was planned beginning late in 2002 and completed at the end of 2004. It is a private commercial office building of 108,000 square feet located in St. Louis, Missouri. The benchmarks used for the first and third assertions are based on the U.G. Green Building Council's LEED® NC-2.1 rating system as this is the most widely accepted guideline for green buildings in the U.S. and perhaps the international market. The benchmark for construction costs is based on the actual cost of the building design and construction and is compared to known market costs for Class A commercial buildings.

The design, construction, building systems technologies, and the project management processes are described. The energy results to date are compared to modeling expectations during the design process. We conclude with some observations on the implications of this project for commercial building practice.

Case Study Methodology

Commercial buildings vary widely in size and function. One of the more common types is the office building. A Class "A" office building at approximately 100,000 square feet is used as this basis for our study.

Accomplishing the first assertion is based on meeting the energy target as defined by the Energy Cost Budget Method (ECBM) as used by the U.S. Green Building Council's (USGBC) LEED®-New Construction V2.1 Rating System at a 50% energy cost savings (USGBC 2003). The ECBM is based on ASHRAE 90.1-1999 and measures reduction in regulated loads against a baseline, excluding miscellaneous or plug loads in the energy cost savings calculation. Energy savings are an important aspect of the LEED® rating system and contribute to an operational cost savings for the building owner.

The cost assertion uses $150 per square foot in 2004 in the Midwest as a credible goal. The Society of Industrial and Office Realtors (SIOR) 2006 forecast of the St. Louis commercial market place provided a cost range of class "A" office space to be $78 to $192 per square foot. This cost data is based on sales of previously constructed properties completed prior to 2005.

The cost for our case study includes site work (excluding land cost); demolition; core and shell; professional fees for design and construction management; general conditions; commissioning and renewable energy systems.

Demonstrations that a green office building can be built in at this cost level would offer encouragement to the market place, and help dispel a pervasive misconception that green buildings cost substantially more than their conventional counterparts. Costly green buildings exist and are what Steven Ternoey has termed "jewel boxes" (Ternoey 2000). Examples of high cost green buildings include some LEED® Platinum buildings (Table 1), where costs range as high as $500 per square foot for buildings constructed prior to 2004. A review of these buildings reveals a number of factors that may contribute to higher costs:

- These buildings tend to be smaller intended for specialty use.
- Construction cost will vary dependant on geographical areas.
- These buildings may include laudable, innovative features such as solar photovoltaic systems and living machines. A living machine contains a series of ponds containing plants that perform the function of a sewage treatment plant. The goals of these projects were presumably to demonstrate such innovations, some of which are not yet commercially viable. Such examples can be important to advance building practice, but are not the goal of most building owners.
- These buildings may have used a traditional design-bid-build process rather than an integrated project delivery process.

Table 1. Some Notable and More Costly Sustainable Buildings

Building	Square Feet	Building Cost Per Square Foot	LEED Rating	Comments
Audubon Los Angeles	5,000	$560	Platinum	photovoltaics
Chesapeake Bay Foundation Maryland	32,000	$234	Platinum	photovoltaics
NRDC Los Angeles	15,000	$320	Platinum	photovoltaics
Lewis Center Oberlin College Ohio	13,600	$471	No Rating	photovoltaics living machine

High cost green buildings at lower ratings can also be found. For example, the San Jose City Hall complex is 530,000 square feet with a construction cost of $652 per square foot (Yoders 2005). While the project did not go through formal certification, the building team believes the project is at a LEED® Silver rating. In contrast to these high cost project, a recent study of over 100 projects (33% LEED® built) showed an insignificant cost difference between LEED built and conventional buildings (Matthiessen. et. al., 2004).

The method for testing the third assertion is LEED® certification.

The Test Case

The Alberici Corporation needed a new headquarters facility and set out to adaptively reuse an existing facility. The plan included the conversion of a 200,000 square foot manufacturing shed into a 108,000 square foot two story Class A office building, covered parking garage and a native plant landscaped campus. As the firm is in the construction business, it possessed specific knowledge of construction practices, and was experienced in design-build which it used on the project. The project was completed in December 2004.

The project began the process with the traditional team elements of an architectural firm, civil firm, and engineering firm until the end of schematic design phase. The traditional model was abandoned at the start of the design documents phase of the project. At this stage, the various design-build contractors acting as the engineers of record were added to the team to complete the design. This does not follow the traditional design-build approach. The management approach utilized a broad team concept with contributions on design and construction from all participants. This process was managed by the owner's core project team that was highly experienced with integrated project delivery. The core project team was controlled by the owner, Alberici Corporation, and the costs of the team are included in construction cost results. Integrated project delivery includes the application of integrated project delivery principles and extends these through construction. Figure 1 illustrates the traditional design-bid-build approach. Figure 2 illustrates the integrated process used for this project. Note that the project delivery process begins at the earliest stages of planning and continues well into the occupancy period.

Figure 1. Project Delivery: *Traditional Build Process*

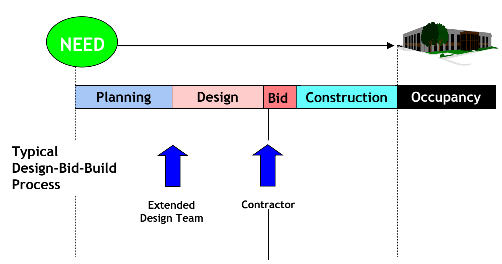
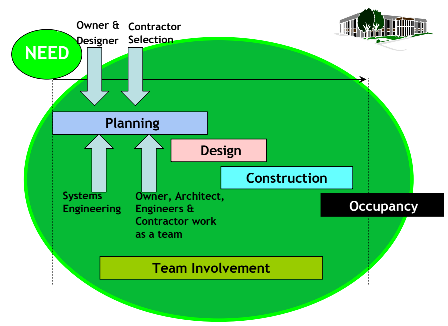


Figure 2. *Integrated Design and Delivery*



Project Management

The core project team managed the project to meet the above stated goals using the following key strategies:

- Focus on form following function using the DOE2 model to drive mechanical, electrical and architectural design, and construction choices
- Reuse the steel structure, roof and floor of the existing manufacturing building
- Practice Value Engineering as Value Enhancement within a budget.

- Use all team members from design and construction to inform design and construction choices. This input started in design charrettes and continued during project meetings.
- Apply an M&V protocol to the management of the building in order to manage the building pursuant to the stated performance goals and design

This project management process is best discussed in the context of understanding some of the building elements.

Design Elements and Construction Costs

Important Design Elements contributing to the energy performance and in a few instances the environmental performance included:

- Sawtooth elements to convert the original building's southwest orientation to a south as shown in Figure 3.
- Exposed structural elements and high ceiling heights to facilitate use of indirect/direct lighting
- Low lighting power density at 0.64 Watt/square foot including task lighting.
- Low Visual transmittance glass as noted in Table 2 to manage glare and maintain views without the use of window shades and allowing abundant daylight.
- Underfloor Air Distribution (UFAD) linked to a natural ventilation system (operable windows).
- Built elements such as bathrooms, kitchen, elevators, server room, copy rooms, and conference rooms restricted to the core areas of the building.
- 65kW refurbished Wind Machine
- Rapidly renewable materials including cork floors and wheat board case work
- Extensive use of recycled content materials
- Forest Stewardship Council certified wood for at least 50% of all wood products
- Low VOC emitting materials

The glass selection was an extension of the guidelines provided by the Daylighting Collaborative at the Energy Center of Wisconsin (Hanson, Vogen, Ternoey, & Lord) and the earlier work of Steven Ternoey (Ternoey 1985). While the vision glass is also consistent with the Prescriptive Criteria of the Advanced Buildings Benchmark™ (Johnson 2005), the unshaded clerestory glass on the northwest and southeast (not shown) does not follow the criteria in that it is at 0.9 for the VLT/SHGC (visual lighting transmittance/solar heat gain coefficient) Ratio. This choice along with the use of low visual transmittance view glass was driven by the desire to preserve views and avoid the expense of shades or blinds, while also providing daylight harvesting. After-occupancy measurements demonstrate daylight levels consistent with LEED performance criteria. The average area Daylight Factor (DF) calculated for regularly occupied areas of the building was 3.2, well above the LEED credit point achieving criteria of 2.0 DF.

Table 2. Glass Specifications at Center Glass (Gray Tint)

Orientation (partial listing)	Visual Light Transmittance (VLT)	Solar Heat Gain Coefficient (SHGC)	U Value	VLT/SHGC Ratio
NE View	0.35	0.23	0.29	1.5
NE Clerestory	0.35	0.23	0.29	1.5
S View	0.23	0.22	0.31	1.0
S Clerestory with external shading	0.35	0.23	0.29	1.5
NW View	0.18	0.19	0.31	0.9
NW Clerestory no external shading	0.18	0.19	0.31	0.9

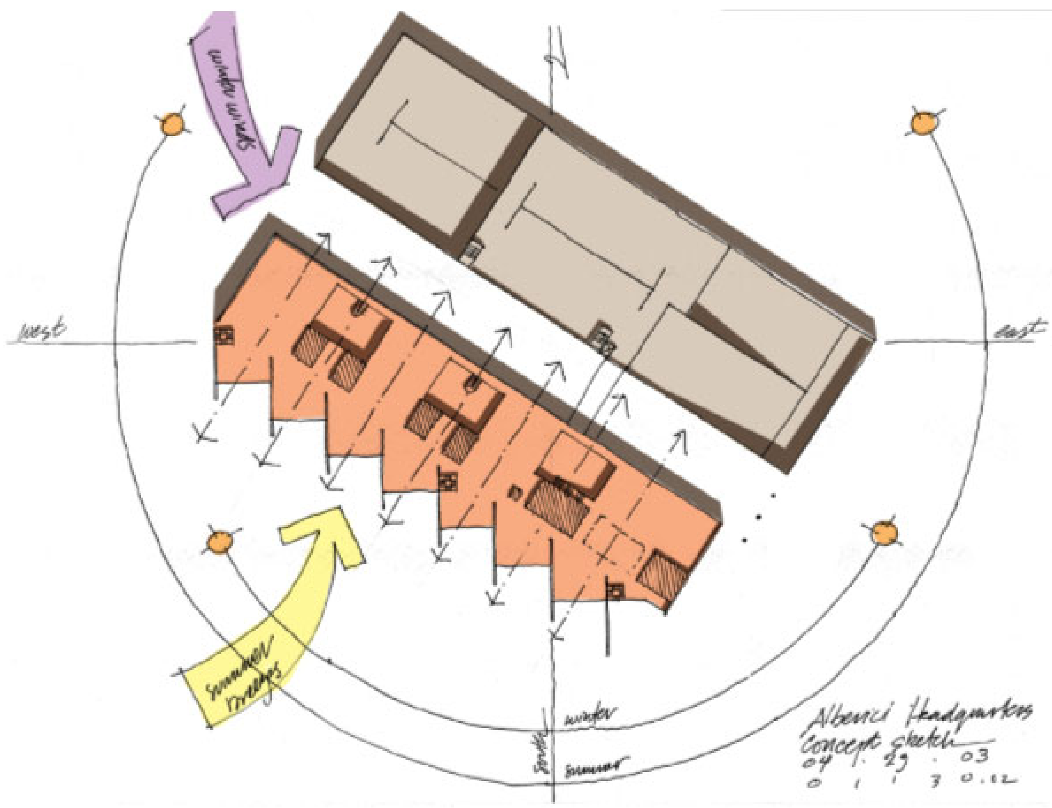
The lighting power density at 0.64 W/square foot including task lights was below what some designers initially believed possible while still providing a general lighting level of an average of 30-35 foot-candles for office work areas based on post occupancy measurements. This lighting level for office buildings is consistent with the Advanced Lighting Guidelines (New Buildings Institute, 2003). The majority of office lighting uses indirect/direct high efficacy fixtures with 4100K (Kelvin) T8 lamps.

The HVAC system features an underfloor air distribution system with user controllable diffusers in the core and thermostat controllable boxes containing hot water heat in the perimeter. Six air handlers supply total ventilation of 71,600 cfm (cubic feet per minute) at a total design of 61 bhp (brake horsepower) with variable speed motors that maintain the supply plenum pressure. Three heat recovery units supply a total of 17,000 cfm of fresh air that is adjustable based on CO_2 measurements. The system maintains a supply air temperature by allowing return air bypass so the central cooling coil can operate at lower temperatures for humidity control. Additional modes of operation provide economizer operation as well as natural ventilation, with fan exhaust assistance if required based on CO2 measurement. The use of natural ventilation is constrained by wind and rain conditions.

Chilled water is produced by two 104 ton HCFC free chillers. Variable speed motors control the cooling tower temperature as well as the secondary loop supply pressure. A water-side economizer uses a plate-frame heat exchanger to provide chilled water to the secondary loop when conditions permit

Two 1.4 MMBtu/hr input pulse combustion boilers supply 65 fan powered floor heating units in the perimeter, outdoor air tempering in the heat recovery units, and morning warm-up capability to the six AHU coils. A steam humidifier maintains minimum space relative humidity at or above 25%.

Figure 3. Building Orientation to Solar Gain



Seven bump out sawtooth additions re-orient glazed elevations to the south away from the original orientation to the southwest.

The final building cost including demolition, extensive site work, core and shell, professional fees for design and construction management including the core project team, general conditions, and renewable energy systems was $148 per square foot. Fit-out costs were $30 per square foot. With the possible exception of some discounts provided by one of the fit-out vendors interested in providing their product for the building, all of these costs were incurred and charged as they would be for any design-build project managed by the owner. Our cost data suggest that the ability to reuse some of the existing structure would not have substantially changed the cost of the building up or down. There were cost savings from reusing the existing slabs, steel structure, and some roofing elements. There were countervailing cost increases for demolition costs and various constraints in using existing structure.

Project Management and Value Engineering

A major decision point in the project occurred near the end of schematic design. When the design-build contractors were added to the team, early design concepts developed by the architect and engineering firms were closely reviewed. The preliminary building cost on the schematic design was estimated at the time to be $2.4 million over the project target budget. The result of this critical review substantially changed a number of initial concepts including:

- The selection of low visual transmittance and low solar heat gain gray glass in place of a clear glass to manage glare and solar heat gain
- A dramatic reduction in lighting power densities
- Change in HVAC design from geothermal to the more conventional system described above to support an open office building with an underfloor air distribution system.
- Elimination of the curtain wall system on the northeast face of the building in favor of a store-front type glass system

These decisions and subsequent design refinements were driven by energy and other performance goals and guided by energy modeling and cost management through cost trading. DOE2 was used for multiple building simulations.

Cost trading or value enhancement is the process of funding certain value or performance enhancing building choices by reducing or eliminating other features so as to stay within the targeted budget. The following examples illustrate cost trading. The proposed curtain wall system was traded for a store front system. The cost savings from this trade funded the upgrade in the glass used in the window system as well as providing considerable net savings. The value enhancement came from the glass change which made the building more energy efficient and provided glare control. Further savings were achieved by eliminating the need for interior shades and/or blinds while providing daylighting. The well field for the proposed ground-sourced heat pump system was estimated to cost in excess of $600,000 and was modeled to provide less than $10,000 per year in annual energy savings. The geothermal system was traded for a conventional system. The cost savings from this trade more than offset the costs associated with the energy recovery system. The reduction in the number of light fixtures provided cost savings while providing targeted light quality and levels.

Detailed consideration was given to a micro-turbine based combined heat and power system including an absorption chiller, but the estimated $500,000 cost for this system also yielded savings of less than $10,000 per hear and was dropped from consideration. In the end, the cost savings in the areas changed at schematic design totaled on the order of $2 million within the context of a project cost of approximately $16 million for the project elements defined above.

Building Energy Performance

Building energy performance is measured by comparisons using the ECBM as required by LEED® and the ENERGY STAR® Benchmark. These comparisons are useful in evaluating building performance, and both have their limitations. In the case of ENERGY STAR®, the Alberici Building has a fully equipped kitchen that serves employees meals on all workdays. This load is not accounted for in other comparison buildings. The Alberici building also has data servers that serve not only the site, but also other Alberici buildings in different locations. Hence it is incurring a server load that goes beyond the needs of this building. ENERGY STAR® accounts for data server load based on floor area of the server area and we are presuming that this properly accounts for the added building load in comparison to other buildings. In the case of the ECBM, modeled energy use can not be directly compared to actual data (directly monitored or taken from utility billings) because actual St. Louis weather conditions during the calendar year 2005 were quite different than the average thirty year weather that the modeling used.

In addition to these methodological complications, we are reporting results from a building that is not yet operating as is fully intended. This is due to factors related to an early building occupancy, some unique design features that we are working to fully understand, and to a slow start in training a new building operator who has very limited time for this function due to other job responsibilities.

The building was occupied in December 2004 before the building was fully completed and functionally tested. These occurred after occupancy. The unique design features that add to the complexity of operations are the UFAD and the natural ventilation system. These systems in buildings of this scale in the Midwest environment are relatively unusual and the commissioning agent was not highly experienced with these systems. Among the questions we are reviewing is what are the appropriate boundary conditions for using natural ventilation. Could we be using natural ventilation for more hours? This operations task is further complicated in that DOE2 does not include natural ventilation. Building occupants have the ability to control their supply air vents and hence we also need to understand how the building is being used. The ability to vary and test operational conditions is limited by the need to provide a high level of comfort to building occupants and avoid workplace distractions.

Thus, the following building performance results are for a work in progress. For reporting ECBM results, the original baseline model is recalibrated for actual building use schedules, actual miscellaneous load levels, and updated utility rates. Identical adjustments were made to the design model. The next step was to review actual data compared to expected sequence of operations and modeled performance trends for the building as a whole, and for subsystems such as chiller, fans etc. Finally, we modified the design model for known deficiencies in the building (e.g. the programming of daylighting controls was done well after occupancy as was ventilation recovery).

Comparing the results of the recalibrated design model including identified deficiencies in building operation to the recalibrated baseline model indicates a 30% reduction in regulated energy costs and a 20% reduction in total energy costs. Comparing the recalibrated design model with deficiencies removed to the recalibrated baseline model results in a 49% energy cost savings for regulated loads and an overall 35% energy cost savings. Thus, the original energy cost savings (51% for regulated load before considering renewable contribution) have only slightly changed, but final determination will have to wait until there is a year's worth of data after the remaining deficiencies are removed and building performance data are compared to design model performance trends.

Table 3 provides a comparison of model results for the baseline building following LEED® requirements; model results for the building with deficiencies as it was being operated as of late 2005; and model results for target or full design intent operation. The cost results use actual utility rates for 2005. The actual energy use is also provided as a sanity check, although direct comparison to model results is not meaningful because the weather was very different than average weather used in the DOE2 model. The actual weather in St. Louis in 2005 was substantially warmer than average (4,359 HDD in 2005 vs. 5,021 HDD in model and 1,893 CDD in 2005 vs. 1,437 CDD model). Comparison is further complicated in that the actual energy use includes data before building completion and commissioning completion, and other operational changes occurred during 2005.

Table 4 provides the same results with the non-regulated loads removed. Non-regulated loads include computers, servers, plotters, copiers, and kitchen. LEED® NC Version 2.1 removes these loads. The ultimate LEED defined savings also adds the contribution of renewables at about $7,000 per year from the wind machine, but this is not included in the Table.

The score for the ENERGY STAR® Benchmark is 58 from the actual data for 2005. The rating includes the standard office building parameters as well as the parking garage and onsite data center. One could speculate as to the impact of the atypical full-service kitchen on the rating for office buildings. The projected rating from the target design model is 85 not including the impact of wind and solar thermal renewables. The final rating will depend on twelve months of performance data after full design implementation.

Table 3. Total Energy Use and Energy Cost

Scenario	Electricity Megawatt-hours	Natural Gas Million Btu's	Energy Cost $
Base Model	2037	3863	$141,000
Design Model (Oct. 2005)	1715	2479	$111,000
Design Model (Target)	1480	1758	$92,000
Actual weather below was warmer than average weather above			
2005 Actual	1851	3502	$128,000

Table 4. Regulated Energy Use and Energy Cost

Scenario	Electricity Megawatt-hour	Natural Gas Million Btu's	Energy Cost $
Base Model	1208	3863	$100,000
Design Model (Oct. 2005)	886	2479	$70,000
Design Model (Target)	651	1758	$51,000
Actual weather below was warmer than average weather above			
2005 Actual	1022	3502	$87,000

Rather than undertaking a weather normalization process to make model data energy use totals comparable to actual data, we find more insight in comparing observed total building and system level energy performance trends to modeled trends. Figures 4 and 5 compare energy model results for total electrical use for the building as operated in late 2005 to the actual monitored data taken from data logged by the building management system for the period from start of operation on December 29, 2004 until February 20, 2006. Figures 6 and 7 provide the same comparison for natural gas use. In all these plots, average daily use is plotted against average outdoor temperature. Despite the fact that the building operation was being adjusted during this period, including the reduction of system operating hours to the October conditions, the model trends correspond reasonably well to the observed performance of the building. This is an important observation in terms of using model results to evaluate performance and for using modeling as a guide to bringing the building to its full performance potential.

Operational trends for lighting, cooling, fan, and heating energy are key elements in the monitoring and verification effort. They give performance targets for system level analysis. These trends were scrutinized in the same manner as the total electricity and natural gas weather relationships. These comparisons must recognize that differences in actual and modeled results can be due to system operation deficiencies and/or model inadequacies. The model tends to under predict cooling energy, particularly during colder weather, and fan energy, especially during heating.

Figure 4. Electricity Weather Relationship – Actual

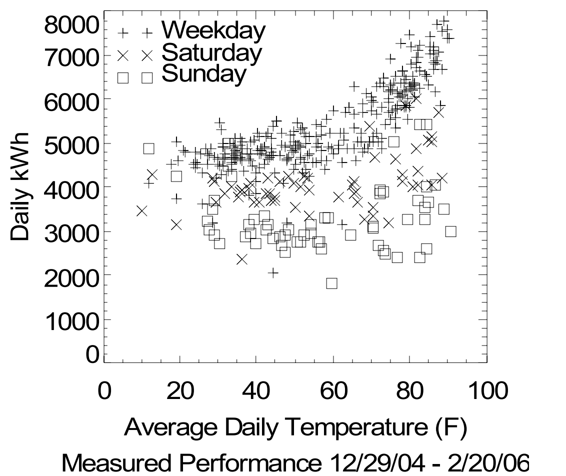


Figure 5. Electricity Weather Relationship – Modeled

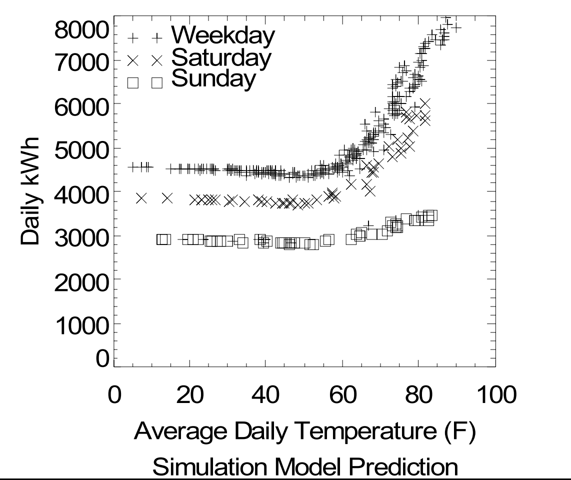


Figure 6. Natural Gas Weather Relationship - Actual

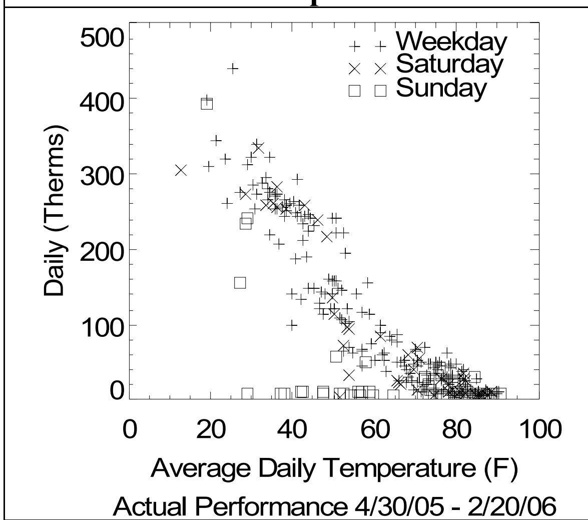
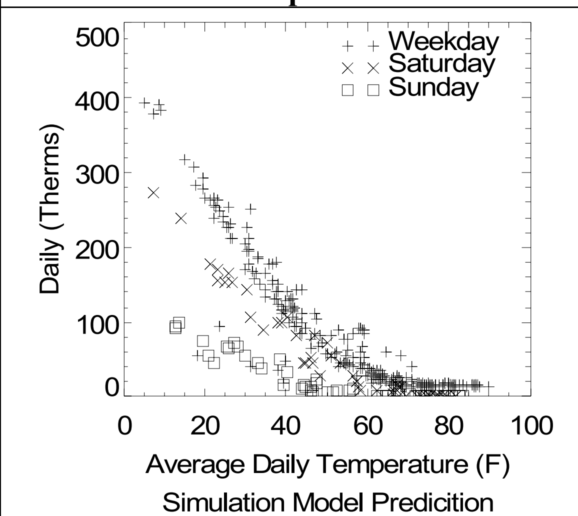


Figure 7. Natural Gas Weather Relationship – Modeled



Discussion of Energy Results and Building Operation

The energy performance has been fairly strong relative to the energy modeling expectations, but there are some areas still lagging after fourteen months of occupancy. The initial start up of the building in December 2004 was hampered by a commissioning team unfamiliar with UFAD and natural ventilation systems, and functional testing only after early occupancy. The peak kW draw from the building during the power system coincident summer peak is well limited due to the relatively small size of the chillers at over 500 square feet per ton of chiller and the low lighting power density.

Under the M&V (monitoring and verification) implementation, the first review of operations data took place in June of 2005. This review indicated that the building was being operated many more hours than the original model had assumed, an air handling unit was not being controlled properly, and the daylighting control system was not working as desired. It was also noted that the miscellaneous loads including large servers, cooling systems for the servers, kitchen equipment and other equipment were larger than had been estimated in the model. Some of these changes were due to decisions deferred to the construction stage or later. For example, Alberici data servers at the building are serving other company sites, which was not known at the time of the initial project modeling. While this does not present problems for building comfort and operations and these miscellaneous loads are exempted from the LEED® New Construction Version 2.1 energy cost savings estimation procedure, it did need to be accounted for along with the recalibration of the model for the actual building operating schedule. This model recalibration was done to facilitate comparison of model expectations to actual operations.

Some operational changes were made after the June 2005 M&V review and a more detailed review took place in October 2005. That review found that schedule adjustments had been made, but that the morning automated warm-up was not always functioning as intended and unneeded outside air was being introduced during the morning warm up before building occupancy. A further round of adjustments was made following the October review and is now being evaluated. Another round of adjustments is anticipated. An important finding from this ongoing test is the importance of commissioning and M&V.

The Core Project Team fully expected that the building operations and performance would need to be monitored and actively managed over time. This is standard operating procedure for larger well managed facilities. While some extra work might be required due to the use of the UFAD and learning to use the natural ventilation system, our experience in other projects is that energy efficient building operation requires a well-planned effort to establish. The Alberici headquarters is not up to its full potential fifteen months after occupancy, and another six months may be required to attain this. Our self critique is that we did not allocate sufficient time for the facilities operator and associated training. Time committed by the facilities personnel in building operation related to the performance the HVAC and lighting systems of the facility averages approximately 2 days per month. This should perhaps be doubled especially in the first six months after start-up. A consideration in achieving building performance is the knowledge of the building operator. In this case, the building operator is a young, capable, and inexperienced manager in regard to building HVAC operations. He utilizes an external controls consultant from a major building controls firm for programming support. That person has no previous experience with UFAD and actively controlled natural ventilation. There is a learning curve as unfamiliar or newer systems are introduced.

The major outstanding items are:

- The automated building warm-up control needs to be reviewed to assure that unnecessary heating or cooling is not occurring. The introduction of unwanted outside air during warm-up was corrected in October, 2005.
- The implementation of the daylighting controls needs to be completed. A plan has been established but building operator has not had time to implement this.
- The operational data suggest that the energy recovery ventilation (heat wheels) is not operating nearly as much as intended and that economizer bypass dampers are dumping outside air into the building at night. This needs to be corrected.

With these changes, we would anticipate that the building will operate at about a 50% energy cost savings for regulated loads. Implementing these adjustments requires continuing the process of data gathering from the M&V system, review of data for building performance, and adjustments in the controls or equipment to attain anticipated performance. Based on the results of each cycle of operational adjustments, the conclusion may be that: the building is operating as desired; the building operation needs to be adjusted and reevaluated; or the expectations for what is attainable needs to be adjusted for what can actually be done given the physical realities of the building. Ultimately, the model is an approximation of the building and the building is the reality that needs to be managed against its best possible performance.

Until the building systems including use of the natural ventilation are fully operational and data is available for twelve months of operation, we can not confirm the Alberici building has reduced energy use by approximately 50% as defined by LEED.

Conclusions

The status of achieving the project goals is as follows:

- The building was constructed for $148/square foot.
- The building was awarded at LEED®-NC V 2.1 Platinum rating at 60 points.
- The building energy cost savings are estimated by model simulation estimates based on observed performance data at 30% as of October 2005 operations using the LEED NC Version 2.1 ECBM based on ASHRAE.
- Modeling work, including comparisons of whole building operation as well as system level operation, indicates that if identified operational deficiencies are corrected the building should achieve 49% energy cost savings relative to the initial projection at 51%. This expectation will have to be confirmed with twelve months of data.

While this is a case study in progress, results at this stage demonstrate that a large office building that reduces energy costs by 30% and achieves a LEED® platinum rating can be delivered at conventional costs by a project team and an owner that firmly and together embrace the twin goals of energy performance and holding to a mainstream cost budget. The ongoing M&V activity and energy modeling work suggest that a 49% energy cost reduction should be achievable but can not be definitively demonstrated at his point.

Our experience in operating the building demonstrates the value of having an M&V plan which is one of the LEED credits. We and our building operator have found it essential to have this ability to gather data on various performance aspects of the building to understand its operation and the opportunities to either make adjustments to bring the building to the planned operational level or to make changes in the original plan to potentially further improve performance. While these statements are certainly true in a building with UFAD and natural ventilation where we are exploring desired operational boundaries, we suspect they are also true in many other new construction settings.

Attaining this performance in actual operations will be facilitated by designers, construction contractors, energy modelers/M&V planners, and commissioning agents experienced with this level of energy performance. While we worked as a core project team to coordinate this effort, there are probably other management structures to provide the leadership for an integrated project delivery with a firm focus on achieving a construction cost goal. Whatever the management approach to guiding integrated project delivery, project management will need to work with the building operator to track the building performance for at least the first year. The project team will need to decide how to allocate various tasks involving commissioning, M&V, and comparison of building performance to projected performance. We also believe there is a minimum threshold of building operator experience and time commitment required to operate buildings of this size. This might require as much as 5 person-days per month in the first year for a building of this type and size.

Others have come to similar conclusions (Torcellini, Judkoff & Crawley 2004). Building operations experience is an asset as well as a willingness to probe the capabilities of the building. Since commercial buildings are usually unique, first of a kind machine, the analogy may be to aircraft test pilots. We need to test more than take offs and landings. A few barrel rolls, loop de loops, and stalls are instructive. The best thing is that we don't need to lose the pilot.

Although we did not accomplish it within twelve months, we believe that it is possible to bring a building to full performance within twelve months. This will require both an experienced building operator as well as a team commitment to aggressive review feedback cycles. We waited for six months before we first reviewed operating data. We recommend looking at the end of the first month and reviewing at least every sixty days after that.

The Alberici Headquarters is what we term a third generation, sustainable building. The point of this statement is that our experience has shown that we needed to acquire some experience to move from a building meeting LEED® minimum energy requirements or modestly better to a building with 50% savings. Our experience took approximately five years through three cycles of design and construction to get to what we anticipate will provide 50% savings relative to a LEED® baseline at conventional construction costs. The important finding of this case study is that the goals set for this project have mostly been achieved to date, and we anticipate will be achievable. We encourage others to set similar goals for various types of buildings and report their experiences as we move buildings to much higher performance levels.

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