PERFORMANCE BASED OUTCOMES – A BOOKEND APPROACH PROJECT: STONE 34

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ABSTRACT

Stone 34, a 130,000 sq. ft. mixed-use commercial office building, exceeded the aggressive performance standards of Seattle's Deep Green Pilot. The requirements of this program include achieving at least 60% of the "Living Building Challenge" imperatives, a 75% reduction in total annual energy usage compared to CBECS data, a 75% reduction in potable water usage, and re-use of at least 50% of storm water that falls on the site. The Deep Green Pilot requires validated performance after 12 continuous months of operation, and both the design team and ownership team faced financial penalties if the building failed to meet the program targets. This paper will explain the "bookend approach" that the design and ownership team used to ensure that the occupied building met the performance requirements.

INTRODUCTION

The City of Seattle created the Deep Green Pilot to encourage the construction of more commercial buildings that clearly demonstrate substantial reductions in energy use. In return for achieving the aggressive performance targets, the city allowed the developer to construct a building with a higher Floor Area Ratio (FAR). This resulted in approval to build an extra story on the project which otherwise would not have been allowed per current zoning.

Delivering a building within the bounds of a performance guarantee typically requires intense collaboration between the design team, construction team and the owner, however in this case the stakes were especially high. If the building failed to meet the performance targets, the city would assess penalties of up to 1% of the construction value. As part of the performance guarantee, the mechanical contractor's fee was at risk if the building failed to perform. As a DBOM (design-build-operate-maintain) organization, the mechanical contractor proposed and implemented the bookend approach to ensure predictable results. The "pre-construction" bookend involved properly setting performance expectations, performing detailed whole building energy simulation, developing buy-in across stakeholders, and rigorously documenting design and energy modeling values. The "post-construction" bookend included a timely yet thorough review of real-time metered data to reconcile actual performance with modeled data and recommending operational changes to ensure compliance. Two bookends created a framework that kept the design intent clear from early design to occupied operation. Also key to the bookend strategy was having a single entity DBOM contractor that could provide full mechanical design, energy modeling, construction, commissioning, and measurement and verification. The single entity completing a detailed third party review by both the City of Seattle (as the Authority Having Jurisdiction) and and International Living Futures Institute ensured objectivity and accountability in the realized performance of the project. The following four strategies describe the cricital elements of the bookend approach:

1. Understand the limits of modeling software early and have a detailed strategy for how and when modeling will inform the design. Meeting the performance requirements relied on complex mechanical and control systems that could not be explicitly modeled in available software packages. The savings associated with these systems were developed as detailed custom calculations in Excel. It was critical that defensible and realistic estimates were developed prior to including the advanced systems in the design, as well as getting approval for these calculations from the authority having jurisdiction (AHJ).
2. Cultivate a deep and transparent knowledge of how energy conservation measures and high performance equipment actually contribute to the performance-based requirement across the

entire design team. High performance buildings depend on a variety of conservation measures to be successful; those measures depend on buy-in and collaboration across multiple disciplines to be effective. The modeling team developed a deep knowledge of each conservation measure from across numerous disciplines to ensure that the model accurately reported the impact (or lack thereof) of each proposed measure and took a lead role in communicating the impacts to all stakeholders. For this project, advanced equipment such as heat recovery equipment and phase change thermal storage posed exceptional challenges.

3. Draft appropriate lease language so that tenants understand and are held accountable to the energy consumption guidelines set forth during design. Review lease language in a transparent manner and re-educate tenants just prior to and during the first few months of occupancy. Review as necessary to keep the building on track to meet performance targets.
4. Establish and agree upon the measurement and verification (M&V) plan to prove compliance/success of the energy model early in design. Proper quantity and placement of meters (meter infrastructure) is essential for understanding operational issues before those issues lead to long-term impacts on consumption targets. Early agreement and coordination allows appropriate metering equipment to be incorporated into the design and budget estimates. Once all of this is in place, inevitable operational course corrections can be achieved swiftly.

PROJECT REQUIREMENTS, DELIVERY STRUCTURE, AND DESIGN CONCEPTS

In order to meet the energy reduction requirements of the Deep Green Pilot, the team determined that the project's design energy target needed to be 31.7 kBtu/ft^2-year (excluding "process loads," defined later). This rigidly-defined target dictated that the energy impacts of each major design strategy be carefully considered.

Envelope, shading, and daylight modeling studies were conducted early in the design to optimize the envelope and lighting conceptual design. The mechanical system ultimately included a dedicated outdoor air system (DOAS) with chilled beam terminal units, a heat recovery chiller and fluid cooler, condensing boilers, and phase change material thermal storage tank. This system maximizes opportunities for heat recovery throughout the year when compared to more traditional HVAC options. Preliminary modeling results indicated that, after lighting and envelope optimizations, space heating use presented the most significant single opportunity for energy savings. The most innovative aspects of the system design are the implementation of phase change thermal storage and the complex controls logic required to operate the hydronic plant in a way that maximizes heat recovery.

The mechanical design of the project was structured as a "Design Assist," with preliminary Schematic Design and energy modeling completed by a design consultant. The remaining design development and construction documents, energy modeling, mechanical construction, and M&V scope were all completed by the DBOM contractor.

The DBOM team provided energy modeling updates at major project milestones to ensure that the project was on track to meet the energy targets established at the project inception. Upon completion of the detailing/pre-construction phase, the design team adjusted the model to reflect the final detailed design and equipment procurement, final controls sequence of operation, aligned all occupant-driven energy assumptions with finalized lease language, and established monthly targets for each end use and associated metering device.

Once M&V targets were established, the performance assurance team created automatic tracking, energy alarms and notifications, comparison diagnostic tools, dashboard views, etc. in anticipation of the requirement to quickly troubleshoot unexpected results.

LIMITATIONS IN MODELING SOFTWARE

The active chilled beam & DOAS system chosen for this facility presented unique challenges in estimating energy use for the fully occupied building. The perimeter spaces have the ability to heat or cool depending on seasonal envelope loads. A single heat recovery chiller provides both standard temperature and high temperature chilled water, and heating water based on the mode of operation and overall load. This chiller is also coupled to a thermal storage tank filled with a phase change material that freezes at 55°F.

At the award of this project, the modeling team was using two modeling platforms, eQUEST and TAS. Neither software was capable of explicitly modeling all of the elements of the system. After some iteration, eQUEST was used for developing 8760 load calculations and accessory energy uses. Central plant energy usage calculations were completed in Excel. Excel provided greater transparency and flexibility, but made tracking model iterations and design optimization changes to the model more difficult. The AHJ reviewed and approved the proposed calculations prior to submitting the project for permit, giving the team confidence that future review and performance would be predictable.

CULTIVATE DEEP CONSERVATION KNOWLEDGE

The aggressive energy conservation targets mandated by the Deep Green Pilot goals necessitated a meticulous mechanical design to ensure performance. Detailed consumption estimates could only begin once the basis of design for the energy model was agreed upon by the owner, the tenant and the city, and final system selection had been determined based on conceptual modeling. In the final system, the central plant operates in one of 7 different modes to optimize performance. It was essential to understand how the system worked across all operating conditions and how many hours per year were to be spent in each operating mode to accurately estimate performance. The DBOM contractor created a decision tree and mode frequency diagram to illustrate how and when each operating mode would perform. These visuals were reviewed by the commissioning team, the M&V team, the controls contractor and the owner to create buy in for the proposed system.

The commissioning, M&V, energy modeling, and mechanical design teams were all part of the same DBOM organization and worked in the same office – maximizing opportunities for collaboration. The owner and controls contractors were separate entities, which retained accountability. As a whole, this division built confidence and trust, while also streamlining decisionmaking and concensus building.

GET IT IN THE LEASE

Many studies have documented the substantial impact of occupant behavior on total energy consumption. It is very challenging for a tenant to understand how specific energy targets will influence their daily operations. Even a tenant that is well-educated about how their actions affect building energy usage can easily get lost in topics such as gross vs. net conditioned area measurements, end use energy consumption per square foot, and plug or lighting power density targets. Creating trust between the design team and the tenant and owner required patience and full disclosure between all parties. Future design teams should encourage tenants and owners to get final energy targets and meter outputs in the same terms (e.g., office lighting kWh/year). The actual meter infrastructure on site must be designed and installed in a way that reflects the targets listed in the lease documents and in this case, also reflects the requirements of the Deep Green Pilot requirements. The alignment of infrastructure and lease language is doubly important in the future life of the building and new potential tenants take occupancy. Tenant lighting and plug load targets must be set aggressively enough to encourage adoption of technology and tenant behaviors to drive down usage, but liberally enough to allow reasonable flexibility in operations.

The flagship tenant was identified early in the project so the speculative office development shifted to become a build to suit project. Since this tenant was moving from an existing facility, real time data for plug loads and occupancy densities were measured, and used to justify preliminary expectations and estimates with the AHJ. Two items that were very important to document with the AHJ early on were "process loads" and speculatively leased retail spaces. Process loads (e.g., Research & Development Lab, Server Room) were included in the performance gaurantee but monitored separately in case their usage was found to be atypical of normal office usage. Due to the wide variation in energy usage associated with restaurants, restaurant equipment energy usage in the retail space was separately submetered and excluded from the performance guarantee. The flagship tenant is a running shoe/apparel company with very physically active staff. 50% of the employees were expected to shower on-site as part of daily operations, which substantially effected negotiation with the AHJ regarding the water consumption performance guarantee. The basis of design (including space specific criteria) was rigorously documented with the owner (in the form of our contract), the tenant (in the form of a lease) and the city (in the form of a memorandum).

AGREE ON THE M&V PLAN EARLY, THEN WORK THE PLAN

Prior to construction, both the estimated energy use of the proposed building, and the reference model upon which the energy performance targets were based were developed using whole building energy simulations. After construction and occupancy, real data from the M&V and commissioning teams began to inform the continued operation of the building. The term "Couse corrections" was used to describe changes in operation that would keep the project on track to avoid financial penalties from missing performance goals. These changes were the single most important factor in meeting the performance goals. No future team should reasonably expect that a new building will start up and operate exactly as modeled. The M&V team created a real time graphic to track actual plant mode of operation compared to the decision tree modeled mode based on building conditions and real time weather data. Figure 2 in Appendix A shows an example of the interface which depicts the actual mode of plant operation compared to the modeled (calculated) mode of operation. This diagram was one of the primary tools to verify whether the system was working as expected, and identify possible solutions when course corrections were necessary.

As depicted in Figure 2, actual central plant operating modes are compared against the modes expected per the decision tree, based on actual weather and heating/cooling load data. It is less important for any given hour to show a discrepancy; instead, the value of this information lies in the ability to recognize patterns of unintended operation. During the time period shown in Figure 2, there is significant operation under Modes 1 & 2 in both the Actual and Calculated Mode Trends, as expected and desired. However, abnormal operation of Modes 3 and 4 in comparison to the calculated mode prompted the M&V team to investigate why the plant operated in less-efficient Modes 3 and 4 more often than expected. Using this view, the M&V team was able to work with the design team and controls contractor to identify specific issues and fine tune the system to ensure plant performance met design performance criteria.

Not every element of the collaboration went smoothly. The team discovered that it is imperative that the design team reviews the actual code language from the controls contractor. A major course correction was required after it was noticed that during a simultaneous call for heating and cooling (typically resulting from both envelope loss at the perimeter due to cold ambient temperatures, and office equipment heat gain in interior office spaces), the boilers were activated to produce heat, rather than the heat recovery chiller. The chiller, which was designed to be the primary heating source, produces heat nearly ten times more efficiently than a traditional boiler. The control sequence was not correctly identifying the difference between simultaneous heating and cooling, and calls for heating only, which resulted in a substantial "missed opportunity" for savings. If not monitored, such missed opportunities put the performance guarantee at risk, and if not corrected quickly, can be difficult to recover from the lost opportunity within the guarateed performance period.

Figure 3 in Appendix A clearly highlights this case. Shortly after starting the monitoring for the building, the M&V team identified abnormally high gas use at the site. Figure 3 shows the modeled target building gas usage (blue on lower monthly bar chart) with gas use above expecations in October and November (red on the top cummulative chart and the bottom monthly chart). With daily monitoring, the M&V team notified the design engineers that something was not right within one week of the start of trending. By the second week of November, the engineering and M&V teams had identified the gas overage was due to unexpected operation of the central plant, and an all hands meeting was held with the design engineers, the controls contractor, the M&V team and the commissioning team.

At that meeting, it was determined that the design intent which read, "when there is a call for heating" was programmed as "when 15 or more zones call for heating" – this language did not accurately reflect the needs of simultaneous heating and cooling. When this came to light, a controls change was made and behavior started to shift towards the expected mode of operation by the next day. The gas performance improved and as can be seen in the Figure 3 cummulative and monthly charts (green) the actual consumption started to drop within the target limit for the the months following the corrective action.

Figure 4 in Appendix A shows the detailed visualization of performance used by the M&V team to troubleshoot, identify, and verify the correction of the controls program for plant mode operation. A picture tells a thousand words, and in this case was used to clearly identify high gas use rates for the building when a minimal number of zones were calling for heat, both in occupied and unoccupied time periods. The orange/blue line at the top shows the outdoor temperature (right vertical axis). The shaded dots represent the number of zones calling for heat and their relative position on the left vertical axis shows the amount of gas being consumed per zone. As you follow these shaded dots from the left (pre-corrective action) to the right (post-corrective action), they level off and form a constant bar at zero gas being consumed per zone. This depicts the correction to the control system that allowed the heat recovery chiller to provide heat in lieu of the natural gas boilers.

If M&V had relied on monthly utility bills instead of actively monitoring the facility in real time, the building would have operated in a substantially less efficient mode for several months before the issue was noticed, identified, and corrected.

Another instance of taking action based on the M&V plan addressed occupant plug load management. Every occupant in the office portion of the building was provided with an addressable plug strip that could be managed by the building engineer. Figure 5 in Appendix A shows the impact of actively managing these plug strips. The building engineer used sub-metering reporting to actively manage plug load with significant energy performance savings in comparison to the tenant's previous baselined energy use at their previous space. Plug and lighting loads were both actively shared with occupants and incorporated into facility operating policies and behavior programs to help achieve these results. As shown here, actual plug load performance (green) remained below model target performance (blue), and enabled with real time monitoring tools was further reduced over 70% over the first 4 months of facility operation.

RESULTS IN OPERATION

At the end of the performance period (9/1/2014-8/31/2015), the final measured EUI was 26.1 kBtu/ft^2-year, beating the Deep Green Pilot target by 15.4%. After some initial operational adjustments completed in November 2014, the actual monthly energy use has been lower than the modeled use for 13 of the 15 months tabulated to date. The system performs much better than expected in the heating months, but it appears there are opportunities for improved performance in the shoulder season. An additional anticipated mode of operation could be enabled that allows partial heat rejection to the fluid cooler and heating water loop in high cooling, low heating demand hours (i.e., typical of shoulder season conditions).

At full occupancy, the actual total building electric usage is approximately 8% below the modeled target, and is fairly stable, fluctuating from 10% below to 6% above target. The actual gas usage is considerably more variable, at 19% below the modeled target on average, but with a variability of 55% below to 40% above target. The variability is largely attributable to the condensing boiler operation in conjunction with the heat recovery chiller. The results show significantly better gas usage performance during peak heating months, but slightly worse than expected performance in September and October (shoulder season months). Again, this suggests that implementation of an additional plant mode of operation to address shoulder season days would provide an operational benefit.

2016 electricity and gas usage is trending slightly higher than 2015. This is largely a result of lease finalization of some previously unoccupied spaces.

The project was also able to demonstrate achievement of the potable water reduction and stormwater re-use goals, beating the required performance targets by 27% and 2%, respectively.

CONCLUSION

This paper has outlined the effectiveness of a bookend approach to delivering high-performance buildings. To be successful, it is critical to understand the limitations of available modeling software, understand how the often complex building systems will interact with one another, include key operating parameters in tenant lease language, and obtain team-wide agreement for M&V early in design that includes followup "course corrections" once the building is occupied. High value lessons learned include:

- Conduct plug load studies and share simple calculations to establish tenant usage targets. Set targets to a measureable quantity, tied directly to a specific meter.
- Temper internal and external expectations on using an energy model to provide "real-time" energy feedback in the design process, especially for complex models.
- Be strategic about what aspects of the design will be post-processed outside of standard modeling pacakages, but don't be afraid to take that approach, especially when plant controls logic is complex.
- It's difficult to determine whether phase change material thermal storage is "fully melted" or "fully frozen" in operation.
- Occupant plug load management strategies can result in extremely large energy reductions in operation, even if they're often modeled the same in baseline and proposed models.
- Carefully consider heat sources, heat sinks, and how heating and cooling demand curves overlap (or don't) over time in design to maximize re-use of building energy.
- M&V tracking, coupled with occupant education, and timely adjustments to system operation, is essential for ensuring a successful outcome on projects with a performance guarantee.
- Reviewing a sequence of operations developed by a controls contractor may not be enough ensure design intent has been captured. In a complex, custom controls design, time reviewing the controls logic in the building control system software is time well spent.