Retrocommissioning Within the U.S. Green Building Council's LEED for Existing Buildings (LEED-EB) Certification System

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ABSTRACT

In 2002, the U.S. Green Building Council (USGBC) began a pilot certification program for existing buildings, modeled after its highly successful Leadership in Energy and Environmental Design (LEED™) for New Construction certification. Over 90 buildings throughout the United States have registered as pilot participants and are "test driving" the certification's framework to certify their buildings. The pilot projects will provide crucial feedback to USGBC before the certification program is finalized and released in 2004.

LEED™ for Existing Buildings (LEED-EB) has several prerequisite requirements, and numerous measures that the participant can select from to best suit the strengths of their existing building and future operational goals. One of the most labor-intensive yet effective requirements in the energy and atmosphere section of this certification is the retrocommissioning prerequisite. This paper details the retrocommissioning effort of a large federal facility seeking LEED-EB certification. The paper explores the goals of the project, the LEED-EB retrocommissioning requirements, the actual process implemented, and specific findings from the project.

Introduction

In 2002, the U.S. Green Building Council (USGBC) released a pilot version of the Leadership in Energy and Environmental Design for Existing Buildings (LEED-EB) certification. The new certification system targets the billions of square feet of existing commercial building space with environmental benchmarks for optimizing building operations and maintenance. The pilot was introduced to provide guidance for building owners that either did not certify their building using LEED for New Construction (LEED-NC) or who were interested in following a framework to move toward more sustainable operations. The new LEED-EB rating system targets operational attributes including cleaning and maintenance practices, indoor air quality, energy efficiency, water efficiency, recycling, exterior maintenance, and systems upgrades to meet green building energy, water, indoor air quality (IAQ) and lighting performance standards (USGBC, 2003). Similar to LEED-NC in its framework, LEED-EB allows participants to certify a building by completing prerequisite requirements and then selecting point requirements from six categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, and Innovative and Professional Credits.

The LEED-EB pilot version was introduced to allow building owners to "test drive" the rating system by instituting its framework on a building of their choice, and then submitting the required documentation to USGBC for LEED-EB certification. At the time this paper was written, over 90 buildings were registered with the USGBC as pilot participants, covering a wide range of building types. Throughout the pilot program, participants were asked to provide feedback to the USGBC's LEED-EB review committee about the prerequisite and point requirements. This feedback was evaluated and subsequently used as a basis for adjusting the LEED-EB requirements. The rating system was released in early March 2004 for public review and comment by USGBC members. It is anticipated that final balloting and release of LEED-EB will occur in September 2004.

One of the most extensive LEED-EB Energy and Atmosphere prerequisites is retrocommissioning (RCx). Retrocommissioning is a systematic investigation process for optimizing building performance by identifying and implementing relatively low-cost operational and maintenance improvements (Haasl et al, 1999). This paper analyzes how retrocommissioning has been integrated into the LEED-EB certification requirements and provides a case study of a LEED-EB pilot participant, the U.S. General Services Administration's (GSA) Mark O. Hatfield Federal Courthouse.

LEED-EB Retrocommissioning Prerequisite

The LEED-EB Pilot version of the retrocommissioning prerequisite is summarized as follows:

- Develop ongoing functional and efficiency performance goals.
- Develop a comprehensive building operations plan (BOP) for how all systems should operate, including HVAC, lighting, and building controls.
- Prepare a RCx plan and test all systems to verify they are working according to the BOP.
- Repair or upgrade all systems found not to be working according to BOP, or create a plan to repair within five years. Retest systems.
- Submit BOP, RCx plan, RCx results (list of items found to not be working in accordance with BOP, repairs/upgrades, retesting results), performance goals, signed letter of certification from the commissioning provider.
- Each time occupancy of the building changes or building is modified, repeat the process.

When the Hatfield LEED-EB pilot began, the requirements characterized the Building Operations Plan as a document that "defines performance criteria that are consistent with the current needs for the building and primary systems" (USGBC, 2003). The development of this plan supplies building operators with all the details of the intended system operation through verified sequences of operation.[1] But what do these operating plan requirements mean in practice? The level of detail to which the building operation plan should be defined is an important topic. A plan that states, "The control system shall modulate the economizer dampers, heating valve, and cooling valve in sequence as required to maintain the discharge set point of the system, reset as a function of outside air temperature" is much different than providing a detailed sequence for <u>how</u> the system will achieve this requirement. A detailed sequence would include information such as the optimal point for locking out the economizer, how many control signals will serve the actuators, if a freezestat is included, the actual reset schedule, if the

[1] In early 2004, the USGBC presented new retrocommissioning prerequisite language in the draft released for membership review. The new LEED-EB retrocommissioning language requires "developing Owner's Operational Requirements, which addresses building functional and operating requirements, sustainability goals, and ongoing system optimization. The systems of concern typically include heating, cooling, humidification, lighting, water consuming, and facility control systems" (USGBC, 2004).

setpoints and reset schedule are adjustable, and so forth. We hope that the USGBC will provide better clarification for the building operation plan requirements when the public version of LEED-EB is released.

Through verifying correct sequences of operation, the building staff is left with correct documentation about how the system is intended to run. However, verifying all control sequences may be onerous if it requires testing or trending of all systems in a large facility, no matter how insignificant they are to the overall operation. A reasonable approach is to test only the major energy-consuming systems and spot check peripheral systems.

LEED-EB requires that if a building's system does not meet the operating plan's requirements, problems must be repaired or upgraded within a five year period. In this way, LEED-EB requirements can work within typical budgeting cycles that may not allow for all deficiencies to be fixed immediately. LEED-EB considers the operations plan a living document and requires it to be updated if the needs or performance requirements of the facility change in the future.

The Hatfield Federal Courthouse LEED-EB Pilot

The Hatfield Courthouse is a 16-floor, 560,000 square foot Federal court and office facility located in Portland, Oregon. The Courthouse used an abbreviated commissioning process when originally constructed and placed into service in 1997. Some functional testing did take place as part of its start-up, but the process did not include design phase commissioning, construction observation, or trend analysis. Currently, 330 full-time employees occupy the building with additional occupancy varying due to trial schedules.

GSA Region 10, which encompasses all Federal facilities in the Pacific Northwest, has continually shown interest in finding new ways to cut energy expenditures in its facilities. The GSA pursues retrocommissioning as a cost-effective strategy for reducing energy consumption. Traditionally, the retrocommissioning process focuses on identifying operational improvements that affect building performance and energy efficiency. Although retrocommissioning may result in recommendations for further capital improvements, the process typically emphasizes low-cost operational improvements and therefore the process is best suited for buildings with equipment that is not nearing the end of its useful life (Haasl et al, 1999). Only five years old, the Hatfield Courthouse was a prime Federal building candidate to undergo this process. In 2002, Portland General Electric's Retrocommissioning Program funded a scoping study of the facility.[2] The study indicated that large potential energy savings were indeed achievable through retrocommissioning.

Concurrent to the GSA's planning the retrocommissioning of the Hatfield Courthouse, the USGBC began soliciting participants for the LEED-EB pilot program. Hatfield was a good pilot candidate because the LEED-EB certification requirements closely aligned with the GSA's goals to improve the energy efficiency the environmental sustainability of their operations. Furthermore, the GSA understood the importance of evaluating the LEED-EB requirements and providing comments throughout the pilot to guide its development.

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[2] Scoping studies are used to identify potential retrocommissioning opportunities prior to committing financially to a full retrocommissioning investigation. A scoping study typically can be completed in 1-3 days.

The Retrocommissioning Process at the Courthouse

The Courthouse LEED-EB pilot retrocommissioning process commenced in the summer of 2003. The GSA directed the retrocommissioning process to not only identify opportunities to reduce energy consumption, but to improve occupant comfort and future building operations by both training the building operators and enhancing the operations and maintenance documentation. At the Courthouse, the LEED-EB retrocommissioning process included four distinct phases, which are closely aligned with the typical retrocommissioning process:

- Planning and project kick-off;
- Investigation;
- Selection of recommendations and implementation; and
- LEED-EB submittal and implementation of persistence strategies.

Planning and Project Kick-off

The Hatfield planning phase entailed developing the retrocommissioning plan, laying out the goals of the project, and identifying the retrocommissioning team members and their respective roles and responsibilities. The Hatfield retrocommissioning team consisted of: GSA regional and local managers, the building operations & maintenance contractor (BRCS), the controls contractor (Johnson Controls, Inc.), the LEED-EB coordinator (Brightworks Northwest, LLC), a case study partner (Iowa Energy Center), and the retrocommissioning consultant (PECI). Once the retrocommissioning plan was developed, a kick-off meeting was held to acquaint all of the team members with the plan and goals of the project. A separate LEED-EB point selection charette was conducted by the LEED-EB coordinator to help GSA further understand the LEED-EB prerequisites and begin selecting viable points for the certification submittal. After the RCx kick-off meeting and LEED-EB charette, the investigation phase commenced.

Investigation

To begin the investigation, PECI engineers interviewed the Hatfield Courthouse building operators to understand known problems. They examined the building's existing documentation, including mechanical and control drawings, sequence of operations, and maintenance logs.

Trending and functional testing. First, building operators were asked to recalibrate the key control sensors to ensure that quality data was collected once the trending and testing began. PECI then set up trends and collected data for several weeks. The trend data was downloaded on a regular basis, and analyzed by PECI and Iowa Energy Center staff. Anomalies identified in the trend data began the formation of the retrocommissioning findings. Several functional tests were also conducted, including a full building pressurization test to determine the infiltration rate and outdoor air flow measurements at different operating conditions. A nighttime walkthrough was also conducted to identify lighting control utilization and equipment scheduling issues.

Building operations plan. The staff interviews and building controls documentation were used to begin developing the building operations plan (BOP), a key component of LEED-EB retrocommissioning requirements. The BOP for the Hatfield project will include verified sequences of operation for the retrocommissioned systems. Through the verification process, it was determined that many parts of the original sequences were probably never programmed as documented. Furthermore, the documented sequences often did not provide the guidance necessary to operate the system. While the sequences are in need of significant improvement, it is a telling sign about the buildings industry that the sequences were actually more detailed than typically encountered.

Master list of findings and interim report. The master list of findings included 27 findings and was presented to the GSA in an interim report. Findings were grouped into four categories to address the GSA's prioritized goals for the project: major comfort and control problems, major energy waste, optimization, and other measures. Table 1 highlights twenty of these findings. The combined findings resulted in total annual cost savings estimate of $97,000. This estimate was reduced by 10% to $87,300 to account for interactive effects when the savings from implementing one measure affects the savings from another measure. This savings represents a 17% reduction of current utility expenditures for the facility. The total estimated implementation costs for the quantified findings is $128,000. If all of these findings were implemented, the estimated simple payback would be about 1.5 years (excluding the retrocommissioning study costs). Accounting for the retrocommissioning study costs, the payback is just over 2 years.

Selection of Recommendations and Implementation

The RCx providers and GSA worked together to decide which findings merited immediate attention, and how the findings would help to meet the LEED-EB retrocommissioning requirements. It was decided that the measures that were either comfort-related or the most cost-effective were to be implemented first, and the remaining measures would be phased in as funding became available. Many of the findings related to the control sequences fit into this strategy, as the control system measures account for much of the projected savings yet only about 25% of the total estimated implementation budget. The retrofit measures (courtroom VAV box control, pump impeller trim, and lighting controls) account for the remaining 75% of the budget. By implementing the lower cost control programming changes first, the GSA will see immediate comfort and energy saving benefits, and allow time to budget and requisition funds for the remaining measures over the next fiscal year cycle. LEED-EB allows up to five years to implement all the required repairs, but the GSA intends to complete all of selected recommendations in less than two years.

The rightmost column in Table 1 denotes the findings that must be implemented or must have plans for implementation within five years to meet the LEED-EB RCx requirement. The method for determining which findings are required to be implemented is described later in this paper, in the section *Lessons Learned and Tips on RCx from the LEED-EB Pilot.*

Table 1. Retrocommissioning Findings List

Finding	Method of detection	Estimated annual savings	Improve comfort & control	Estimated implementation and verification cost	LEED-EB?
Improve building pressurization	Observation, functional test	$14,600	X	$5,000	X
Chiller and chilled water valve control instability	Trending	$2,600	X	$5,000	X
Boiler plant temp and pump control, and staging	Trending	$4,800	X	$3,000	X
Cooling AHU discharge air temperature reset	Trending	Not estimated	X	$2,000	X
CO_2 Control for all courtroom fan-powered VAV boxes	Trending	$10,100	X	$50,000	X
Exhaust & return air recirculation into outside intake	Observation, trending	$6,800		$200	X
Trim pump impellers to achieve design flow without throttling	Observation, trending	$7,500		$22,500	
Reinitiate nighttime lighting sweep control and add overrides	Observation	$14,200		$20,000	X
Delay start of air handlers	Observation, trending	$8,700		$1,000	X
Economizer control	Trending, observation	$8,400		$3,000	X
Modify warm-up mode sequence	Trending	$7,600	X	$3,000	X
Reduce overventilation	Functional test	$4,700	X	$3,000	X
Cooling air handler static pressure reset	Trending	$2,400		$1,000	X
Heating air handler static pressure reset	Trending	$2,500		$1,000	X
Cooling tower control	Trending	$1,300		$1,500	X
Minimum VFD speed	Trending	$800		$800	
Outside air preheat operation	Trending	Not estimated		$1,200	X
VAV box calibration and maintenance protocol and operator training	Trending	Not estimated	X	$1,800	X
Night low limit	Trending	Not estimated		$1,500	
VAV box polling	Trending	Not estimated		$1,500	
TOTAL		**$97,000**		**$128,000**	

Out of the 20 findings in Table 1, the most interesting problems and their proposed resolutions are presented below. Solving these problems will save operating budget and improve comfort.

Building pressurization. Buildings that are negatively pressurized relative to the outdoors lead to infiltration of cold air. Due to comfort complaints during cold weather and obvious areas of infiltration, PECI performed a building pressurization test to quantify how much air it takes to pressurize the building. By closing all controllable exit paths for air and bringing in 100% outside air with the supply fans, the volume of air required to create positive pressure at the ground level was determined[3]. Even with exhaust fans and return fans shut off and relief dampers closed, the building's ground level could not be positively pressurized with all supply fans at 70% speed. Infiltration was estimated to be 100,000 cfm, or at least half of the outside air brought into the building during this test since the neutral plane was at about the middle of the building. The 100,000 cfm infiltration load equates to an estimated annual heating energy cost of $14,600 per year in air handler and boiler energy.

Another test was conducted to determine the effect of the return fans and relief dampers on building static pressure. This procedure would reveal the suitability of adding a building pressure sensor to control the relief dampers and return fans. The test showed that turning off the return fans improved pressurization, the relief damper opening is insignificant compared to the leaks in the building, and the building was still not positively pressurized at the lobby when all return fans were off and all relief dampers were shut. During the test, gaps were found underneath two of the air handlers, to the outside air plenum on one unit and to the relief plenum at the other unit. Airflow at the gap was measured to be 750 ft per minute, totaling a 11,000 cfm leak. As a result of these findings, all eight 40 hp return fans were turned off, and the gap underneath the air handler was sealed. Building pressurization will be further improved by finding and fixing more leaks.

Courtroom fan-powered VAV boxes. The 16 courtrooms at the Courthouse are served by dual duct series fan-powered VAV boxes. Per the original design sequence of operations, each fan was supposed to operate whenever the lights in the courtroom were ON, then the hot-deck and cold-deck air dampers would modulate as necessary to maintain space temperature. These VAV boxes are designed to require the series fan to circulate air into the space. However, these fans were never properly controlled and instead, the fans were only turned ON manually when the operators received a comfort complaint. If the fan within each VAV box does not operate, the restriction imposed by the fan prevents the cold or hot air from being delivered to the space. The air supplied from the cold and hot deck blows out of the VAV box and back into the return air plenum never reaching the occupants in the space. The series fans in the courtroom VAV boxes will be programmed to turn on based on the air handler schedule. The minimum ventilation rates will most likely be controlled either by measuring CO_2 in the courtroom, or a simpler strategy of reducing the minimum ventilation to zero when the lights are off.

Warm-up mode modifications. As the name implies, the warm-up sequence is intended to raise building temperature rapidly by closing all outside air intake dampers, shutting off exhaust fans, and supplying warm air to the zones. A warm-up sequence typically occurs before the building is occupied so that ventilation air and exhaust can be reestablished prior to actual

[3] Another ACEEE paper details this pressure testing process and its results (Sellers et al, 2004).

occupancy. At the Courthouse, the control system was programmed to initiate warm-up whenever the return air temperature measured in the mechanical room plenum was less than 70°F. This sequence is problematic since building infiltration (due to negative pressure) and short-circuiting of supply air to the return air plenum from the courtroom VAV boxes caused the return air temperature to be less than 70°F for a significant amount of time. During periods of cold weather, trend data verified that the warm-up mode was initiated while the building was occupied. During much of this time, the building actually had a cooling load. However, the economizer was locked out during the warm-up mode so the chillers had to operate to serve this cooling load. Additionally, the minimum outside air dampers and dedicated outside air fans were still running during warm-up. To correct the warm-up control sequence, a new sequence was programmed that enabled warm-up only when there is no cooling load and no occupancy.

Overventilation. The Courthouse has a maximum 400-person occupancy and a 200-person transient occupancy. The measured supply of outside air by the dedicated outside air fans introduced at least 32,000 cfm more than was required. To determine if the minimum outside air fans were even needed, a functional test was performed to determine the amount of air that would be drawn into each air handler through the minimum outside air damper section with the minimum outdoor air fans off. The results of this test showed that maximum ventilation requirements could be met without operating any outside air fans, even when supply air fans turn down to 30% speed.

Eliminate return and exhaust air recirculation. Due to the close proximity of the outside air intake and relief dampers, air being relieved from air handler 4 was recirculating back into the outside air intake of air handler 3. The "outside air" temperature as measured by the building control system increased by 5-10°F. This condition reduced the amount free cooling available when the air handling units were in economizer mode, leading to increased chilled water demand. Turning off the return fans has helped eliminate the exhaust air recirculation problem since air from the building is relieved through gaps in the exterior shell rather than at the relief damper near the outside air intakes. Furthermore, the gap underneath the air handler that allowed return air to flow into the outside air intake has been sealed.

Chilled water /AHU control. Site observation and trend data showed that control of the chilled water plant and air handling unit cooling coil valves was highly unstable. The discharge air temperature for the air handlers oscillated from 55°F to 62°F, with a setpoint of 55°F. Part of the discharge temperature control problem was related to rapid opening and closing of the cooling control valve to meet discharge air temperature setpoint. When the valves were 100% open, the discharge air temperature becomes too cold and the valves quickly closed. As the valves closed, the temperature rose well above setpoint and the valves quickly reopened. This rapid oscillation appeared to be partially the result of an improperly tuned control loop; i.e. the command from the building control system to open or close each chilled water valve changes much too quickly in relation to minor fluctuations in deviation from setpoint. This valve instability appeared to also cause significant instability in the entire chilled water plant, particularly operation of the secondary chilled water pumps and chillers. With the chillers cycling ON and OFF frequently, the chilled water supply temperature oscillated from 42°F to 63°F, with implications on the ability to meet cooling load at the air handlers. The sequence of operation will be modified and the control loops tuned to prevent these control problems.

LEED-EB Submittal and Implementation of Persistence Strategies

Once the retrocommissioning implementation process is complete, a final commissioning report will be prepared. Then the RCx provider will assist the LEED-EB coordinator with developing the required submittals for the USGBC. The submittal is planned for Fall 2004, and will document the building operations plan and whether or not the plan's requirements have been achieved. If any of the requirements are not met, then a schedule for meeting them will be put into place for implementation within the next five years.

The LEED-EB retrocommissioning prerequisite also requires the development of ongoing functional and efficient performance goals. The following actions will support ongoing system troubleshooting at the Hatfield Courthouse to meet these goals:

- Updating the sequences of operation will document exactly how the system is supposed to work, which is critical for effective troubleshooting.
- Consulting with GSA management on ways to improve service contracts will provide operators with incentives to keep systems running efficiently.
- The control system operator interface will be improved to help operators quickly notice when operating problems occur. Summary screens of key operating information will be programmed into the operator workstation interface.

The Courthouse may implement monitoring or enhanced metering to gain the additional LEED-EB credits. The monitoring credit (EA Credit 3.3, public draft version) requires a system for continuous tracking and optimization of systems, alarms to notify of deficiencies, and a system to attend to those deficiencies. This credit goes beyond the prerequisite since it requires documentation of the points monitored, alarms programmed, and a description of the system to repair problems.

The enhanced metering credit (EA Credit 5.1-5.3, public draft version) is similar to the monitoring credit in that it requires the facility to collect data and use it to improve building performance over time. Persistence can also be improved by implementing LEED-EB EA Credit 3.1 for Building O&M Staff Education. Building operator certification and factory training courses are readily available, yet the most effective training for many operators may be spending time with an experienced controls technician to further improve their understanding of the controls and develop troubleshooting strategies.

The bottom line is that all of these strategies will improve the persistence of benefits from the retrocommissioning process – keeping energy costs down, occupants comfortable, and the systems operating effectively.

Lessons Learned and Tips on RCx from the LEED-EB Pilot

As a result of participating in the pilot LEED-EB program, GSA and the RCx provider carefully assessed the requirements to provide feedback to the USGBC on ways to improve the certification. The following "lessons learned" summarize some of this thinking, and can help others implement the LEED-EB process.

Implementation. The RCx provider conducted a utility bill analysis and used the U.S. EPA's ENERGY STAR® Portfolio Manager tool to ascertain a benchmarking score to fulfill a LEED-

EB Energy and Atmosphere section prerequisite. The building must achieve a minimum score of 60 to meet the prerequisite. The facility can also achieve additional points through EA Credit 1: Optimize Energy Performance for increasing their ENERGY STAR® benchmarking score beyond 60. For this reason, it is important to implement repairs and adjustments as soon as possible so energy savings can count toward this credit. Improved energy savings will not be fully reflected in the ENERGY STAR® benchmarking score until 12 months after the repairs and modifications have been completed. If the credit for all retrocommissioning energy-saving improvements are needed for the desired level of certification, the LEED-EB submittal package may be delayed until the utility bills show savings for a long enough time to affect the benchmarking score.

Understanding the distinction between opportunities and problems. About one-third of the retrocommissioning findings at the Courthouse were not required for LEED-EB implementation since they were "opportunities" rather than "problems". While this distinction is not clearly defined by LEED-EB, it is important to consider. Some findings are opportunities to further improve operations, rather than instances where operation has deviated from the owner's operating requirements (a problem that is required to be addressed). In the Hatfield LEED-EB pilot, an interpretation of which findings were necessary to implement within the next five years to achieve LEED certification was presented to the GSA and the USGBC. Subsequently, these guidelines were accepted by the USGBC, and are provided below.

Case 1: Operation clearly does not follow intended control. These problems must be fixed for LEED-EB certification.
Case 2: Operation follows intended control, but leads to significant unintended problems. These problems must be fixed for LEED-EB certification. In some cases, we found the need to update the sequences to significantly improve control.
Case 3: Operation follows intended control, but optimization is proposed. These optimization strategies are not required to be implemented for LEED-EB certification. This case is differentiated from Case 2 because here, the system can operate as originally designed without adverse impact. However, implementing these recommendations could improve the energy efficiency or control of the systems.

RCx provider scope of work. When performing retrocommissioning within a LEED process, the RCx provider needs to be especially clear about with the scope of services to be provided. The RCx provider can become the mechanical "go to" person for the project for addressing issues well beyond the scope of the RCx prerequisite. The monitoring and metering credits and indoor air quality credits are prime examples of areas for a potentially expanded scope.

Owners may wish to have the RCx provider propose actions necessary to achieve credits other than the RCx prerequisite. These additional credits could include:

- EA Prerequisite 2: Minimum Energy Performance
- EA Credit 1: Optimize Energy Performance
- EA Credit 3.3: Building Operations and Maintenance: Building Systems Monitoring
- EA Credit 5.2-5.3: Building Performance Measurement: Enhanced Metering
- EA Credit 3.1: Building Operations and Maintenance: Staff Education
- EA Credit 3.2: Building Operations and Maintenance: Building Systems Maintenance
- IEQ Prerequisite 1: Outside Air & Exhaust Systems

- IEQ Credit 1: Outdoor Air Delivery Monitoring
- IEQ Credit 7.2 Thermal Comfort-Monitoring
- IEQ Credit 9: Contemporary IAQ Practice

Retrocommissioning Tips

Experience with this LEED-EB project as well as previous experiences has led to the following tips for implementing a streamlined and quality retrocommissioning process.

Focus on control problems to achieve energy savings at a low cost. Almost all of the 20 findings were control system-related with quick paybacks of usually one year or less. The causes of the control problems ranged from issues that existed since the building was built to control sequences that were overridden. If time is available to examine the trends and observe operations, it is not difficult to find problems. Taking a "systems perspective" when analyzing trends is key. Implementing solutions requires a good understanding of the interactive nature of all the systems.

Leave the building with an updated and detailed sequence of operations. In order to complete this task, a controls contractor that can easily interpret the original programming code is essential. Correcting problems within the existing controls programming is often difficult for controls technicians since most technicians have their own methods for implementing control sequences, and it may be difficult to obtain the original programmer to complete any changes. Proprietary control code further complicates this issue.

Address the control system's capabilities before setting up and analyzing trend data. Control systems with many points on each primary controller are typically difficult to trend at an adequate frequency (2 minutes or less). Too many trends at too high of a frequency can bog down the control system communications, leading to control problems and unhappy building operators. At the Courthouse, trends had to be collected in stages to avoid these problems. Collecting only certain points at a time can lead to frustrations when the data that was not able to be trended is needed for analysis.

Additionally, finding ways to efficiently process the data is extremely important. The Johnson Controls data format allocates one point per file and provides the time/date stamp in a series of six columns, which makes it difficult to graph until the time/date stamp is manipulated. Then, to view multiple data points, the data must be cut and pasted into a single file. During this project, the Iowa Energy Center processed the data using a software program they created to address this problem at their own research facility. Without this proprietary software, many more hours would have been spent preparing the data for analysis.

Make sure the building operators are aware of changes to the system. Include all operators when findings are presented to the owner. Discuss plans for implementation with the operators to avoid misunderstandings. Without clear communication, building operators may attribute new problems to the changes, regardless of whether they were caused by the changes.

Conclusions

The LEED-EB retrocommissioning process at the Hatfield Federal Courthouse has demonstrated success on many fronts. The process has reduced energy consumption, improved occupant comfort, led to better documentation of building operations, and helped to create an environment where these improvements will persist. Working within the LEED-EB rating system to achieve these improvements has provided the GSA with a framework for improving the sustainability of its large stock of existing buildings. Further, as a LEED-EB Pilot participant testing the LEED-EB retrocommissioning framework, the GSA and PECI were given an opportunity to provide constructive feedback about the retrocommissioning requirements to the USGBC.

We feel that LEED-EB certification's emphasis on retrocommissioning will increase the use of the retrocommissioning process in the United States buildings much like the USGBC's LEED for New Construction Program has helped increase the market penetration new construction commissioning. It is up to owners, operating staff, and commissioning providers to implement retrocommissioning in a way that is true to the LEED-EB retrocommissioning prerequisite's intent of bringing an existing building back to its intended operation and keeping it there.

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