LEED® Commissioning of Innovative Systems: New Systems, Same Process

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Synopsis

With the increasing interest in LEED® certification by owners and architects, engineers are getting the opportunity to expand their designs to include building systems that may not have been considered previously, such as graywater systems that use discharge from the reverse osmosis/deionization system for reuse in toilet flushing, composting toilet systems, and geothermal heat pump systems. Standard fundamentals of commissioning still apply to the new systems, although it can be argued that commissioning becomes even more critical as many of the engineers are not as familiar with these systems as they are with "standard" building systems. The three case studies in this paper review some of the aspects of the three systems mentioned above and a commissioning approach to them. Among the considerations is whether or not the designers are adding systems for the sake of LEED points that do not add value to the building, do not meet the owner's requirements, or that the owner is not prepared to operate and maintain.

About the Author

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Introduction

Building owners have accepted and embraced the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) programs. In some respects, acceptance of the programs has provided architects and engineers the opportunity to become more creative in their approaches and the systems they design into buildings. The developers of the LEED programs recognized building commissioning as a best practice in the design and construction process and have included elements of the commissioning process among the prerequisites and credits. While a properly developed and executed commissioning process can be valuable for any project or system, it can be argued that commissioning is even more valuable in LEED projects because some of the systems included in LEED buildings are "newer" to design teams and owners. The fundamental commissioning elements of ensuring the owner requirements are defined, the building is designed and constructed to meet those requirements, systems are tested, and training and documentation are provided to the owner. Documenting, testing, and training become especially important when design teams are tasked with meeting certain LEED certification levels. If the design team is not careful, decisions can be made that are based more on LEED requirements than on the building program requirements. Supporters of LEED will argue that such decisions represent a misuse of the program because LEED was developed as a tool to be used in the design and construction process, and not meant to replace good design practices.

This paper will cover three systems that have been commissioned on recent projects. Some were included in the project in direct response to LEED, others were included in the building to meet the owner's program requirements and also corresponded with LEED. For each system, the owner's program requirements will be identified, how the system selection met the program requirements, and particulars of system operation and testing will be discussed.

Graywater System

The project is a six-story, 60,000-square-foot teaching and research laboratory. The building includes a recirculating pure water system that supplies the laboratories. The graywater system utilizes the waste stream from the pure water system as toilet flushwater for the lavatories. The pure water system utilizes reverse osmosis and deionization. The reverse osmosis unit forces water through a semi-permeable membrane at high pressure, which allows the water, but not most other dissolved solids, to pass through. The water that does not pass through the membrane is therefore higher in impurities than the feedwater. This waste stream is considered non-potable and typically is discharged to sewer. The graywater system collects the waste stream and utilizes it for toilet flushwater.

Owner's Project Requirements

The owner called for a modular layout for the labs to allow flexibility and easy modification as researchers on the staff changed and their research needs changed. The building requirements included the need for a pure water system for the laboratory spaces.

The owner also identified a targeted level of certified under the LEED-NC program.

Design Considerations

The project team conducted an early review of the LEED requirements to evaluate and identify feasible credits that could be achieved on the project and determined that credits in the water efficiency category would be achievable. Further review of the water consuming systems in the building led to the conclusion that there was a synergy between the RO/DI system and the toilet flushwater requirements.

For the projected usage at the building, the selected RO/DI system produces 51 gallons per hour of “wastewater.” There is a combination of continual flow and backflush. The expected water generated is 72,000 gallons annually. Based on the design criteria for the building, the anticipated water requirement for flushwater is 70,000 gallons per year. Overall, the system was projected to reduce 87% of potable water use in the building. The system contributed to achieving three Water Efficiency Credits: Credits 2, 3.1, and 3.2. Other buildings might use the reclaimed water for irrigation purposes; however, this building was designed without an irrigation system.

The building program located the main mechanical room in the penthouse and the RO/DI equipment was located there. A traditional design would have the RO/DI waste and backflush drain to the sewer. This building’s design drains to a storage tank on the ground level, where reclaimed water is fed through a booster pump up to the lavatories in the building through a dedicated riser. The storage tank is equipped with a make-up water valve connected to city water as a back-up water supply. The tank also has an overflow, so excess water discharged by the RO/DI is drained.

As stated previously, the overall intent of this system is to reduce potable water usage in the building. Water consumption is random, based on usage of the toilets in the building. However, general usage patterns can be predicted based on typical occupancy schedules for the building. Waste from the RO/DI system has a flow when RO/DI is being used in the building and an intermittent backflush. If these two items are not coordinated with adequate storage capacity, this system could operate such that the water consumption occurs between backflushes and enough water is consumed that the tank refreshes with city water. The backflush then occurs, sending the reclaimed water to drain, effectively defeating the system intent.

Commissioning provider feedback and questions during the design phase prompted discussions among the project team and allowed all parties to become comfortable with the system. One point of discussion was whether the booster pump should be connected to the back-up power system. This building is located in a campus setting with two sources of normal power, and power outages are extremely rare. The campus design standards call for only equipment related to life safety to be connected to the alternate power source.

Through the commissioning process, the owner's maintenance staff was allowed to review and comment on the system design which helped them to accept the design approach. It is unlikely this would have happened otherwise. Although this was a new system at the owner's facility, the primary equipment components were familiar to the maintenance staff and the basic operating concepts and benefits were explained to and discussed with them. Therefore the system helped achieve one of the owner's requirements (LEED certification), was acceptable to the operating staff, and they were capable of maintaining it. This was also the first time the engineering team had designed such a system and the engineer reported that the design phase reviews by the commissioning provider were helpful.

Functional Testing Concepts

The graywater system is composed of several individual components: feed from RO/DI, storage tank and controls, booster pump and controls, and distribution piping and toilets. The functional testing method followed the standard approach of working through each of the individual components to ensure that they were properly installed, start-ups complete and functionally checked. Following that, a system test was conducted. The RO/DI and booster pumps were packaged equipment sets with start-up services provided by a manufacturer's representative. The tank controls were installed by the plumbing contractor with coordination through the building management system controls contractor. Commissioning scope of work included observation of start-up and functional testing. For this installation, the RO/DI system was one of the last systems put into operation, so the tank controls, make-up water controls, and booster pumps were all functionally tested first.

RO/DI Discharge

Every system needs to have its boundaries defined. For the graywater system, the source of the graywater is the RO/DI wastewater and backflush. The RO/DI system itself was not considered to be part of the graywater system. However, there is a key system interaction between the two. The commissioning process helped to coordinate the settings and ensure that this interaction was accounted for during RO/DI start-up.

Tank Controls

The tank control design sequence called for tank level sensors at three water levels. A low tank level shuts down the booster pump and generates an alarm. The second level activates the city water make-up sequence. The third level deactivates the city water make-up sequence. When exposed to air, the tank level sensors are an open contact and as water levels change and a sensor is submerged, a closed circuit is created. As part of the initial control sequence pre-functional check, each of the float control cables could be labeled and initially checked using a bucket of water so that they could be easily manipulated through their sequences. Another option could be to have the tank filled to a certain level and raise and lower the sensors in the tank to expose and submerge them. The tank level settings were coordinated with the plumbing contractor based on the engineer's original anticipated water consumption patterns. Over the initial period of operation of the building, this was monitored to confirm the settings were correct and adjustments were not required.

Packaged Booster Pump Set

The packaged booster pump is a skid-mounted duplex pump set with a control panel. The commissioning scope of work included observing equipment start-up and checks by the manufacturer's representative. The start-up process included setting operating pressures and testing the control sequences for the pump set, such as pressure control, lead-lag pump operation, and safeties and alarms. The engineer explained the graywater system operation to the representative to make sure the representative understood how the pump set worked within the context of the system.

Integrated System Test

Once all components and equipment are placed into operation, the overall system can be tested. When conducting any functional test, the commissioning provider has several options at its disposal for testing systems. In order to develop a test procedure the commissioning provider must understand the overall system operation. Starting at the end-use, the basic system operation follows:

1. Toilets flush, which drops the pressure in the water line.
2. The booster pump set senses line pressure drop, and the pump energizes to maintain pressure set point.
3. As the pump operates, it draws water from the storage tank.
4. Independently of pump operation and withdrawal of water from tank, the RO/DI backflush fills the storage tank.
5. Storage tank levels fluctuate based on relative drawdown and refresh rate.
    - Tank level controls open the city water make-up valve if the tank level drops too low.
    - Water drains out of the overflow in the tank if the level gets too high.

Another important test is the power outage test. The system is composed of several pieces of equipment and components all powered from different sources. An important operating consideration is how a power outage will affect the system. During the larger building power outage test, the system operation was observed. The building design calls for the RO/DI system to be on normal power, the booster pump set to be on normal power, and the tank controls to be on normal power. Upon loss of power during the outage test, the normally open valve went to its full open position, allowing city water to start filling the tank. If this situation is not discovered, and depending on the length of a power outage, a large amount of water could have been wasted. Ideally, this situation would have been picked up earlier in the process, but ultimately identifying such problems is why systems are functionally tested. The building is in a campus setting with two sources of normal power, so power outages are extremely rare, but this is still an important test to conduct.

Composting Toilet System

The project is a three-story 18,000-square-foot conservation center that houses offices and a conference facility. The new building was constructed adjacent to a former residence that was also converted to office space. The owner is a land and historic property conservation organization. The facility was built to consolidate offices for several of the owner's programs and also provide conference space to be used for seminars and be available to other conservation groups as part of new conservation initiatives and outreach programs. The building includes a composting toilet system.

Owner's Project Requirements

One of the owner's primary objectives was to have a building that would provide a demonstration of sustainable design and operating strategies. The owner was familiar with composting technologies from other properties it owns. These properties are more remote, where composting was a necessity rather than an option. The owner had not used composting technology in a more traditional building. The owner believed that composting toilets would add to the demonstration value of the building and was comfortable with the technology.

Although not the prime factor in the decision to use the composting system, the system also provided a benefit related to a sewer connection moratorium. The town in which the facility was located had enacted a sewer connection moratorium while waiting for a sewer upgrade project. The new building project would have not been permitted until the sewer upgrade was complete (a delay of several years) if it had incorporated a traditional plumbing system. For most owners, this reason alone could justify the system.

The owner recognized that the LEED-NC program goals were similar to its own goals for the project and decided to pursue a LEED Gold rating.

Design Considerations

With the use of a composting toilet system already established for the project, the project design incorporated the system. The composting system was designed to handle the toilet flows, while the sinks are drained separately. The team identified that LEED credits in the water efficiency category were achievable with the system.

The composting system selected for the project utilizes foam flush porcelain toilet fixtures that have the appearance of a standard toilet. They are connected to two compost vessels in the basement. The compost vessels are vented via an exhaust fan to the roof. The exhaust fan not only vents the compost vessel, it also creates a negative pressure in the vessel, which contains any odors. The exhaust through the toilet replaces any requirement for bathroom exhaust and as such it needs to be coordinated with the HVAC design. The oxygen flowing through the compost vessel is an integral part of the composting process. The composting process requires nitrogen, oxygen, and carbon. Nitrogen is provided from the toilet waste, oxygen from the air flow, and carbon from a bulking material, such as wood shavings. This combination creates an environment where bacteria and organisms will break down the toilet waste into usable compost material. The liquid waste is separated out. The system is not water free, as water is used both for the foam flush toilets and to moisten the compost bed. Water use is approximately three ounces per flush and one to two gallons per day per compost vessel. The foam flush system combines the water with soap to form a foam solution that keeps the bowl clean and helps to lubricate the drain pipe. Other considerations for the design include: electrical power for the toilet, because it contains a microprocessor that regulates the foam flush mechanism; space for the compost vessels and placement of them under the toilets; and access to the compost bed for maintenance and for removal of the compost solids once every one to five years. The building includes a building management system and the compost exhaust fans are tied into the building management system so an alarm will be generated if they shut down.

Based on the design criteria for the building, the anticipated water requirements for flushwater would be approximately 67,000 gallons per year with a conventional system. The composting system is expected to reduce this number to 1,300 gallons annually. The system was projected to contribute to the overall reduction of 90% of potable water in the building. The system contributed to achieving three of the Water Efficiency Credits: Credits 2, 3.1, and 3.2.

Disposal and reuse options for the liquid discharge and compost material need to be reviewed for specific project locations. This project location allows for use of the compost, provided it is buried at least one foot below the surface, but does not allow for reuse of the liquid. The building location provided adequate space and landscaping to accommodate burial of the compost solids. The liquid line was designed to be connected to the existing sewer line on the site.

Functional Testing Concepts

A composting system is relatively straightforward. The testing effort is really a combined start-up/functional check, working through each of the individual components to ensure that all were properly installed, all start-ups complete, components functionally checked, and settings documented. For this project, start-up services were provided by the manufacturer of the composting system. The involvement of the building operating staff in the start-up process provided excellent hands-on training. The foam flush toilets can be set to a manual setting so they will flush when a flush button is pushed, or to an automatic setting that will flush the toilet at set intervals. This project used the manual option. The proper flush settings should be confirmed, tested, and documented for future reference by the operating staff. The building management system exhaust fan alarm should be tested. To test it, the fan is shut off by its disconnect switch and the building management system sees the fan is off and generates an alarm. The fan is restarted and the alarm clears. The automatic watering control setting should be confirmed, tested, and recorded. As part of the start-up process, the manufacturer's representative provides a recommendation for this setting based on projected usage. The liquid removal pump should be tested. When the system is ready to be put into operation, the carbon bulking agent (woodshavings) are added, the initial charge of bacteria is added, then the two are mixed and moisture is added. As part of the start-up services for this system, the manufacturer's representative paid several visits over the initial months of operation to confirm proper conditions in the compost vessel. For this project, as part of the installation checks, it was noted that the plumbing contractor included a bend in the waste pipe just prior to it going into the compost vessel. This was unnecessary as the pipe could line up directly into the vessel. This was corrected. During the final check for the toilet flush settings one was found that had been set to the automatic flush setting.

As with any proper training program on building systems, the occupants and maintenance staff received appropriate training for the composting system. The building contains a conference area that will regularly be used by individuals who are not in the building on a day-to-day basis, so instructional signs are posted in the lavatories on the system. The owner used this opportunity to provide an interpretive sign about the composting system that is part of a larger "building as training tool" program.

Ground-coupled Heat Pump System

The project is a three-story facility housing offices and a large meeting area. The building includes a ground-coupled geothermal heat pump system. It is noted that involvement of the commissioning provider did not begin until after the start of construction.

Owner's Project Requirements

The owner recognized that the LEED-NC program goals were similar to its own goals for the project and decided to pursue a LEED certification. The owner did not have specific requirements for the HVAC system, but it had other general overall goals. These included minimizing energy consumption and life-cycle costs, providing systems compatible with the architectural and programmatic goals of the project, providing mechanical systems compatible with a hybrid mechanical/natural ventilation system, and providing local controls. In discussions between the design team and the owner, a ground-coupled geothermal heat pump system was chosen.

One issue that was not discussed with the owner was maintenance requirements of the system. This would normally be a topic for consideration if a commissioning provider had been involved.

Design Considerations

The project team conducted an early review of the LEED requirements to evaluate and identify feasible credits that the project could achieve. The team identified that credits in the energy and atmosphere category would be possible with a heat pump system. The engineer's evaluation determined that a distributed water-to-air heat pump system utilizing a standing column well as the ground-coupling method would be the most economical for the building. The standing column well is an open loop that draws water from the bottom of a well and injects it back into the ground at the top of the well. The water column becomes the transfer medium to the ground around it. The wells are approximately 1,500 feet deep and two wells were drilled for the site.

Other options considered included a horizontal closed loop and a water-to-water heat pump system with fan coils.

Mechanical ventilation for the office area of the building is provided by a central energy recovery ventilator that is ducted to each heat pump. There is a building management system that controls the time schedules for the systems and also puts the system into a natural ventilation mode. When outside air conditions are appropriate, the mechanical HVAC systems in the office area of the building are shut down and an email notification is sent out indicating that occupants can open their windows. The building design incorporates a clerestory with operable windows and a ventilation well between the first and second floors that provides induced air flows when the clerestory and office windows are open. The meeting area has separate heat pumps and energy recovery ventilators that are independent of the natural ventilation mode.

Selection of a ground-coupling method is very site-specific. The selection of the standing column wells for the geothermal system was made with the knowledge that similar installations had been made in the general area and they had good operating track records. Past standing column well operations show groundwater temperature fluctuations from 45ºF to 60ºF from winter to summer, which should be taken into account when calculating operating efficiencies. A well system may also require permitting from the local or state health or environmental departments.

Heat pumps are often touted as being "maintenance free"; however, as with any equipment, they do require periodic maintenance. Such maintenance includes strainer blowdowns, filter changes, controls operating checks, and performance and refrigerant checks. The units should be placed such that they can be accessed for maintenance. The design engineer placed units above the ceilings in spaces such as the copier room, storage room, hallways, and a conference room to avoid putting equipment above offices as much as possible. Unfortunately, the engineer did not discuss any of the maintenance requirements of the system and the owner was left with the misconception that the heat pump system was "maintenance free."

As noted earlier, the commissioning provider was not involved in the project until construction had begun, but several comments on the design were identified at that time:

- The designer had originally called for the natural ventilation mode to be controlled based on outside dry-bulb temperature only. This approach did not take into account outside air humidity and so it was recommended that this sequence be modified.
- Heat pump equipment schedules contained incomplete information.
- The initial heat pump groundwater loop design did not call for any method of filtration of the groundwater. It was recommended that a method of filtration be included.
- During the commissioning providers first site visit the mechanical contractor claimed that the design did not call for insulation of the groundwater loop within the building. This situation was identified and addressed before walls were enclosed, but otherwise would have gone uncaught and would have led to moisture and potential mold issues.
- A review of the approved controls submittal indicated that the control method of the pumps (lead-lag) to be programmed did not match the design sequence (parallel operation). Further investigation led the construction team to realize that the specifications were not followed for the well pumps. Specifications and plans provided

an estimated pump size and capacity for bidding purposes, but called for the final pump selection to be completed after the wells were drilled and tested. This process was not followed and was not caught by the engineer who approved the submittal. This oversight resulted in having to replace the pumps that had already been purchased and installed, unfortunately too late.

- A review of the heat pump submittals and design documents indicated that there were local safety controls on the heat pumps that were not connected or alarmed back to the central building management system. The units do contain alarm indication LEDs, but the majority of units are mounted above the ceiling where the LEDs are not visible. This meant that the only way anyone would know if units tripped off was if space temperature was affected. At the time this was noted, it was too late to cost effectively make a change, however the commissioning provider was able to instruct the building operators that this condition existed and provide troubleshooting tips.

The design selected for this building did achieve several of the owner's requirements, but could have been clearer and better executed. This was the first project with this type of ground-coupled heat pump system that the engineer was involved with. The involvement of an independent commissioning provider during the design phase would most likely have identified the potential for several of the issues noted above and helped to prevent them.

Functional Testing Concepts

The geothermal system is composed of several individual components: standing column well, submersible well pumps, pump VFDs, distribution piping, distributed heat pumps, and controls. The functional testing method best followed is the standard approach of working through each of the individual components to ensure that they were properly installed, all start-ups complete and components functionally checked. On this project, the process identified several issues that needed to be addressed. Following the resolution of these items a system test is to be conducted. The heat pumps were packaged equipment with start-up services provided by a manufacturer's representative. The pump controls were installed by the controls contractor along with the building management system.

Standing Column Wells and Pumps

For a standing column well, the well water must meet drinking quality standards and be tested. The well may need to be developed to improve water flows. Generally, this involves injecting high-pressure bursts into the well to open up fissures to improve flow. The wells should be flow-tested with the static draw-down levels noted. These functions are all typically performed by the well contractor. As with any installation involving piping, the piping from the well to the building should be leak-tested prior to burial. Depending on the method used, at system start-up, the volume of water required to fill the piping within the building loop will have to be drawn from the wells. This draw may cause excessive drawdown on the wells and needs to be monitored to prevent pump cavitation. A pressure-sustaining valve on the return side of the system at the building entrance can keep the system from draining as the pumps are shut off during unoccupied periods. The well should be sealed with a sanitary well head seal to prevent any surface water from getting into the well. The piping and pumps should be cleaned and disinfected. Well pumps typically cannot be sized until the wells are drilled and tested and the static drawdown level is determined.

Distributed Water-to-Air Heat Pumps

The distributed heat pumps are above-the-ceiling horizontal units, each controlled by an individual zone temperature sensor through the building management system. The building management system starts and stops the heat pump fans and enables the heating/cooling control based on a daily time schedule. The heat pumps are set to heating or cooling mode based on the space sensor reading. The units can be equipped with two-position isolation valves that open when the heat pump is called to heat or cool and close when the compressors are off, thus creating a variable flow system. The system design called for these isolation valves. However, the mechanical contractor did not initially install them. The heat pumps are equipped with internal controls, such as safeties. Start-up of the units included testing the internal controls and safeties. As part of the start-up and equipment checks, the commissioning provider contacted the manufacturer to obtain a start-up checklist and required the installation contractor to complete it. This documentation provides a baseline of equipment performance and would not have been provided if the commissioning provider had not pushed for it.

Building Management System

The building management system submittal contained several basic conflicts with the intended operations; however, it had been approved by the engineer. The source for many of these conflicts was that the designer had not provided a sequence of operations in the design documents. As identified during the initial review by the commissioning provider, additional information on details of the operating sequences was required to develop functional test procedures. A copy of the questions was sent to both the engineer and the controls contractor and several responses received from each conflicted with the other. These conflicting items were noted, discussed with the project team, and ultimately resolved.

The building management system maintains the equipment operating schedules and operating modes, monitors and controls space temperature, monitors space ventilation performance, and generates operating alarms. Confirmation of the sensors and communications was performed as part of the system start-up, including point-to-point checks by the controls contractor.

Integrated System Test

Once all equipment and components are placed into operation, the overall system can be tested. As when conducting any functional test, the commissioning provider has several options for testing. In order to develop a test procedure, the overall system operation must be understood.

The building had an overall operating schedule controlled through the building management system. The time schedule sequence was tested by adjusting the schedule to shut down the system in five minutes. When the five minutes had passed, the system automatically shut down.

A tour of the building was performed to check and confirm that the heat pumps were shut down. The schedule was then adjusted to restart the system in five minutes. When the five minutes had passed, the system started. The well pumps, the heat pump fans, and the energy recovery ventilation unit are started. Once flow is established, each heat pump can heat or cool as needed.

In occupied mode, the heat pump fans operate and the basic system heating and cooling operation follows:

1. Heat loss (or heat gain) in the space cause fluctuations in space temperature.
2. Space temperature sensors initiate a call for heating (or cooling) through the building management system in response to temperature changes.
3. The control system cycles the heat pump accordingly, opening and closing the isolation control valve at the heat pump.
4. As the valve opens and closes, pressure in the water loop alters and the change is sensed by a differential pressure sensor.
5. The VFDs on the well pumps respond to the pressure changes by adjusting the pump speed up or down to maintain pressure.
6. As the heat pumps operate in heating (or cooling) mode, heat is transferred from (or to) the groundwater and the return loop temperature lowers (or rises.)

The sequence was easily checked by altering space temperature set points relative to the current space temperature. To start, all set points were set to the current space temperatures, so no units were heating or cooling. This building was small enough that individual heat pumps could be switched to heating mode one at a time, with each successive heat pump adding load to the groundwater loop. The water distribution system was designed with a diversity factor to account for the fact that all heat pumps would not heat or cool simultaneously. Units were started up to the diversity factor and beyond to see how the flow distribution would respond. The system flows had already been checked as part of the balancing process, but this test confirmed that the overall system would still operate properly under load. As each unit was started, isolation valve, compressor, and discharge air temperature response were all confirmed.

The system has a natural ventilation mode that will shut down mechanical cooling when the outside conditions are appropriate, and then send an email notifying the occupants that windows can be opened. This function was tested by modifying the setpoints for the natural ventilation mode. If a space is not being properly ventilated in this mode as identified by space carbon dioxide sensors, the system is indexed back to mechanical ventilation mode. System response was confirmed and the system was returned to normal operation.

The space temperature set points were then adjusted to shut down the heat pumps one at a time and system response was checked.

The first system test was conducted for the heating mode, so the process was repeated for the cooling mode. Seasonal tests should also be conducted to confirm proper operation throughout the year. Trend logs can be used during the testing process to track system response and provide additional documentation on the test. The building operator participated in the test process because it provides excellent hands-on experience with the building operations and control system.

The building does not have an emergency power system, but a power outage test was conducted to see how the system responded to a power outage, particularly to confirm that the system would restart itself upon return of normal power and return to normal operation.

For this project, operational issues were primarily identified and addressed during the individual equipment checks. These checks would not have occurred to the level of rigor that they did without the involvement of the commissioning provider. The mechanical contractor and construction manager on this project did not have any experience with this type of system. Once the issues were corrected, the integrated test could be conducted. The commissioning provider also stayed actively involved during the operating period to further assist the building staff in understanding the system operation and troubleshooting if any operational issues arose.

LEED Decisions

One issue that commissioning providers should be aware of on LEED projects is that project teams can become focused on obtaining points and include items that do not meet an owner's requirements or that the owner does not have the staff to maintain. The commissioning process begins with documenting the owner's requirements and decisions on the project are benchmarked against the requirements from that point on. Even if an owner states that a specific LEED certification level is desired, there are a variety of options to achieving that level and individual credits should be evaluated against the owner's requirements. For the projects included above, the LEED decisions were in line with the owner's program requirements, but this is not always the case. One example that has been observed on different project is an extensive sub-metering system is designed, but the owner does not have staff that is capable or available to monitor the data. Another example is a design that included a building management system instead of local controls that would provide adequate control functionality for the space use, but less ability to utilize enhanced control sequences. If used properly, both of these systems can offer benefits to a project over the life of a building and the best time to install them is during construction, but if they can't be maintained or used, there benefits will not be realized. This is not to say that decisions should be made based on the owner's current staffing or budget issues without looking ahead over the life of the building, but design decisions should be based on realistic expectations. In one of the example situations the system was installed but is not currently used. In the other situation, during the commissioning review process and follow-up discussions with the owner and design team, it was determined that the system should not be used in the project.

Conclusion

One of the benefits of the commissioning process is that it is flexible and easily modified for specific projects and systems. In fact, it is a fundamental element of the commissioning process that each project is unique and requires a unique approach. The commissioning provider needs to work with the owner and the design and construction teams to identify critical system operating parameters and functionality. Issues need to be identified and addressed early in the design and construction phases. The functional testing process is then used as final confirmation that the system is operating properly. This is a subtle yet distinctive difference from a test to identify deficiencies. The commissioning process should be set up so that any issues are identified early in the equipment start-up and check-out process and addressed before they have a negative affect on the project schedule and building operations.

While a properly developed and executed commissioning process is valuable for any project or system, the three case study examples show that commissioning is even more valuable in LEED projects because some of the systems included in LEED buildings are "newer" to design teams, construction teams, and owners. This unfamiliarity increases the likelihood of gaps in the design and/or installation. In some of the cases above, the commissioning provider's design phase involvement helped to identify potential issues, foster discussion about design and operating strategies, and provide a forum for the operating staff to have an input into the decision making process. In all of the cases above, the commissioning provider's construction phase involvement helped identify potential issues before they became long term operational issues for the owner. The LEED programs promote sustainability. But if misapplied, an untrained operating staff attempting to operate a poorly designed, untested, and undocumented building is not sustainable, no matter what "green" technologies were included. The commissioning process helps to ensure that the owner will fully capture all the benefits a sustainable building can offer over the long term.