Living in a High-Performance Green Building: The Story of EPA's Region 8 Headquarters

June 2013

U.S. General Services Administration
Office of Federal High-Performance Green Buildings

Executive Summary

Every building is a hypothesis waiting to be tested—a hypothesis about performance, occupant work effectiveness and comfort, and support for agency mission. And it remains a hypothesis until it is lived in, experienced, and evaluated through rigorous testing and observation.

This report is about living in a high-performance green building. As such, it is about adaptation and change, not about a “finished” product. Even as this report is completed, the building and its occupants are co-evolving to meet new challenges.

The Wynkoop building in downtown Denver, which houses a regional office of the US Environmental Protection Agency (EPA), is a “demonstration project” of the General Services Administration’s (GSA’s) Office of Federal High-Performance Green Buildings. This “build-to-suit” Leadership in Energy and Environmental Design (LEED) Gold office and retail space was designed and constructed through a design-build public-private partnership to be as sustainable as technology and budget could support, incorporating sustainability elements developed jointly by GSA (the government lessor) and EPA (the tenant agency). A prime objective of the design team was a sustainable facility that looked and functioned like “normal” class A commercial office space in its market.

As a learning laboratory, the EPA Wynkoop building may be the most extensively studied building in the country. The research deployed scientific teams from two national laboratories as well as academic and public-sector organizations to assess performance in acoustics, under-floor air distribution, data center energy use, daylighting, indoor water use, thermal comfort, occupant experience, workplace functionality, and green roof applications for the Denver climate. In all cases where the building was underperforming, the research teams made recommendations for improvements. Some of those improvements were made, while others wait for future funding. This full final report documents key findings and lessons learned regarding the facility’s design, construction, and actual sustainability performance.

The research provides a unique insight into how a complex building works. Most buildings go through fine tuning that may take many years. Yet we know little about how occupants and buildings learn to adjust over time and what kinds of changes they make. Building performance results are seldom made public. Furthermore, fine tuning is often ad hoc rather than subject to the rigorous research necessary to identify causes and propose solutions. Solutions were tested where time and funding permitted.

Key Findings from the Wynkoop Research

1. Performance-based contracting and integrated teaming were key factors in achieving sustainability goals and ensuring that the building was delivered on time and on budget.

The solicitation for offer (SFO) for design and construction included detailed lease terms; technical specifications for architectural, mechanical, and electrical components; and a detailed program of requirements. It detailed numerous requirements and preferences relating to sustainable design and efficiency and established strict terms for achieving LEED and ENERGY STAR certification. The design and development team was required to achieve a minimum of LEED Silver certification within 14 months of reaching 95 percent occupancy, or risk a penalty of $250,000 annually to be subtracted from the rent. Similarly, the developer was required to provide and maintain an ENERGY STAR rating within 14 months of occupancy, or make changes to achieve the rating and offer the government a rent reduction during noncompliance.

Communication. The performance-based framework encouraged the team to share and respond to new information and design issues in real time, which moved the project forward more rapidly than would have been the case if lengthy change orders were needed to resolve every issue. Numerous examples show how the multidisciplinary nature of the core team allowed more thorough evaluation of potential outcomes, without the constraint of specifications hard-wired into the contract. One example of the team's effort to balance sustainability and construction cost was the evolution of the exterior sunshades. Both the team and EPA wished to enhance daylight, prevent solar gain, and control low-angle glare in the early morning and late afternoon. In addition, the project needed to balance the desired performance with construction cost and blast security. The original design called for 36-inch-deep horizontal shades on the south facades, and 36-inch-deep vertical fins on the north facades. The security and blast consultant recommended changing the shades and fins from fritted laminated glass to perforated metal, to perform better in the event of a blast. Consulting engineers Syska Henessy performed energy and daylight studies to reduce the depth, and therefore the cost, of the shades and fins. As a result, the horizontal shades were reduced to a depth of 20 inches and the fins to 11 inches. The interior light shelves called for on the south facades were also studied to see if they could be removed without compromising daylight performance, but were left in the design. Architects Zimmer Gunsul Frasca (ZGF) used both an Ecotect software model and a physical model to study these issues, and passed the models to Syska Henessy for further study, in an unusually direct collaboration process.

Risk issues. The overall process was not without difficulties. For instance, in an effort to transition this project from conceptual design to an engineered solution, after the development contract was awarded significant changes were proposed to the structural ceiling system; heating, ventilation, and air conditioning (HVAC) mechanical system; and the developer's team structure. GSA and EPA had to evaluate the impact of each change and negotiate with the developer to find a fair agreement that provided good value to the government. The SFO requirements were largely performance-based, with some prescriptive terms. This played a role in the evaluation of the HVAC system change, since government team members realized that they had to accept any system that met the basic performance requirements. The SFO required LEED Silver certification, which is performance-based, but did not prescribe exactly how to accomplish this. It included a LEED scorecard showing EPA's preferences for which LEED credits to pursue, but there was no way to enforce this preference. In the end, the building exceeded goals and achieved LEED Gold certification. However, some LEED credits were not achieved due to documentation issues.

Although GSA and EPA assumed the risk of items that were not strictly controlled in the contract, Opus (developer and architect) assumed risk on unknowns such as the level of changes required by local governments and the site contamination. For example, GSA's option to negotiate the land purchase before selecting a developer required Opus to commit to contract terms beyond its control. When soil contamination was discovered on the site, the government-negotiated contract and accelerated closing schedule allowed Opus no recourse with the landowner, resulting in increases in onsite costs for the project.

Despite these risks, the performance-based nature of the contract allowed the core team to adjust strategies in real time, completing the project on budget, on schedule, and at a higher level of performance than the minimum specified in the SFO.

2. Building performance was significantly influenced by occupant behavior patterns and variations in occupancy, yet these social factors were either not taken into account in design development or accounted for in a very rudimentary manner.

Several studies in the Wynkoop building showed that occupant behavior could influence a range of performance factors, including energy, water, and daylight.

Energy. Even though the building is performing well and has an ENERGY STAR rating of 96, it consumed substantially more energy than projected. The actual energy use is 76 kBtu per square foot per year, versus 52 kBtu modeled in the “as built” final model.

Much of this greater usage can be attributed to the building’s data center and to plug and process loads, which account for a large share of energy use but were not factored into the original modeling. For instance, after video technologies were installed in the conference center and meeting rooms, the building’s ENERGY STAR rating decreased by 2 points. The report recommends several commonsense, cost-neutral conservation strategies for the data center, as well as greater attention to efficient use of work technologies by occupants. Recommendations included turning off computers when away from the desk for more than 30 minutes, as well as turning off shared resources (printers, copiers) when they are not being used. Another factor in the higher than anticipated energy usage is a pronounced “stack effect” in the building, with the upper floors noticeably warmer than the lower floors, which also affected energy use by requiring additional conditioning on these floors.

Water. In the first year of operation, total water use was 1.65 million gallons higher than expected. Correcting an installation error at the steam system discharge point reduced water consumption dramatically, but additional questions were raised about the use of water fixtures in the restrooms and fitness center. Research showed that occupants were not using the dual-flush toilets properly, because of a strongly conditioned response to push the flush handle down, triggering a full flush that uses more water. EPA installed new handles on all toilets that now trigger a low flush when the handle is pushed down and a full flush when pulled up. It was not possible, however, to confidently quantify the savings that this change produced from the data developed in this study. Other water issues studied were related to building occupancy, which turned out to be difficult to ascertain because data on occupancy are not gathered systematically for either employees or visitors. Occupancy is a key element of water modeling, so the lack of accurate data makes it difficult to project actual water use.

Daylighting. The daylight design included expectations that occupants would operate the blinds effectively in some areas of the building—that is, close them to control direct sunlight or glare, and open them again when the situation improved. However, a survey conducted as part of a daylight assessment found that very few occupants actually operated the shades as expected and that they were frequently left closed, negating the use of daylight for general lighting purposes. An environmental quality survey administered to all employees found concerns with glare.

Vegetated roof. An extensive study of the building's vegetated roof, compared with a standard control roof on a nearby LEED building, showed that the vegetated roof provided significant benefits by modulating roof temperatures that increased the overall lifespan of the roof and decreased energy use. However, the study also concluded that the plantings would need to be irrigated during the growing season. The vegetated roof was also effective in retaining stormwater. Using consolidated findings from the Wynkoop research, EPA concluded that converting just 1 percent of roofs in the United States from conventional to green roofs could avoid about 70,000 tons of construction and demolition waste annually, based on the assumption that the serviceable lifespan of a green roof is 2.5 times that of a conventional roof.

3. The interior design of the space is successful in supporting solitary work and planned meetings, but the space and work technologies are less beneficial for informal work, flexibility, and mobility within and outside the building.

A functionality assessment by GSA focused on better understanding how the physical environment influenced individual and group work effectiveness, and how the changing nature of work is influencing EPA's approaches to the workplace.

Informal work. GSA identified a need for more space devoted to informal and unstructured group work. People cited difficulty knowing who was at work and a lack of space for networking and "light conversation." There are some informal teaming areas, but these are largely unused to avoid creating noise that could disturb adjacent individual workstations. People appear to want more informal, opportunistic connections and interaction within and across teams and a greater sense of camaraderie—the very qualities that are inhibited throughout the building by the high workstation panels valued for providing visual privacy and promoting concentration. Several survey respondents also mentioned a desire to be able to have quick meetings focusing on visual materials used in their work, such as maps and data printouts. However, EPA rules prohibit posting such materials on cubicle partitions or walls in the work areas.

Investing in flexibility. Investment in appropriate technologies and changes in policy are necessary to promote shifts to new ways of working. Responding to changes in the nature of work requires an integration of policy, communication, and procedural solutions to traditional workplace and technology challenges. As an experimental step in this direction, some EPA groups have rearranged their workspaces to enable greater personal choice and to better suit their flow of work. Wireless technologies for mobility and headsets for improved voice privacy make it easier to move work to new locations within the building.

Adoption lag. The interest in flexibility and new ways of working have taken hold more strongly among EPA regional leaders than among the employees in the building. However, as more experiments are rolled out, there will be more opportunity to test what works and what doesn't and how to solve lingering concerns. An "action research" effort is especially valuable to capture lessons learned and best practices while changes are being made, rather than waiting until the end of a project when policies, behaviors, and spaces feel set in place and more difficult to revise. Such experimentation and testing will enable EPA to make more informed decisions and set up appropriate training as it pursues goals for space reduction and increased telework.

4. Commissioning of a complex building takes considerably more time and effort than normally planned for. The Wynkoop experience shows that commissioning is an ongoing process as the building and its occupants co-evolve over time.

Translating design intent to facility management and operations can be challenging. This is especially true when the technology in the building is new and requires intense research and learning. EPA's commitment to using the building as a learning lab and teaching tool has played an important role in fine-tuning building performance, but it has also taken more time and effort than expected. Another tenant might not have been as inclined to accommodate the effort of fine-tuning the many systems. As noted by one of the project leaders, "If it had been someone less patient, they would just say, 'This system is not working; it needs to be replaced now.'"

Active management. Shortly after moving in, EPA realized that active management would be required to ensure that the building met its high-performance goals and that occupant behavior was a critical factor in reaching this end. EPA and the building management team established a performance tracking system and actively collaborated on everything from operation of mechanical systems to cleaning and recycling and tenant education. EPA also developed an environmental management system that integrates federal building performance and reporting requirements with building operations and interlocks with building management systems.

Ambient conditions. In addition to water and energy research, EPA assessed the performance of the interior lighting system and occupant response to it. The T5 fluorescent pendants are linked to daylight sensors that control the amount of light emitted depending on the amount of natural light available. Shortly after occupancy, defective ballasts in the dimming lights led management to replace all of the original ballasts at significant expense. Also, an error in the program controlling the automated blinds was creating significant glare, which took several months to resolve. Even with the systems working properly, building management's perception is that the staff generally is not satisfied with the dimming lights. The occupant survey supports this perception. Results show that when occupancy is low and lights are turned off in work areas, the light is perceived as too dim.

Concerns with the sound masking system, located in the under-floor air plenum, also led to extensive acoustic testing and recommendations for improvement. Unlike the ceiling grid where the sound from the masking system is diffuse, the sound from the under-floor distribution system is likely to have high spatial variation in sound level and spectrum. Essentially, a diffusive sound field is more difficult in an under-floor system, because each air diffuser becomes a point source or "hot spot." The research showed that the HVAC system is unusually quiet; HVAC is generally an important part of acoustic treatment, because it provides low-frequency noise. However, the sound masking in the UFAD system lacked output capacity at low frequency. The research team recommended and tested a successful solution to reduce hot spots and diffuse the sound more effectively.

5. Building components (energy, water, air, light, sound) were designed and studied largely as separate entities, yet their interactive effects may be much greater than realized.

The Wynkoop research explored several areas of interaction between design components and approaches, but much remains unexplored. For instance, a workplace functionality assessment identified ways in which the interior design, coupled with EPA rules about space use, created barriers for teamwork and informal collaboration. Furthermore, the daylighting research revealed that design for daylight to reduce energy consumption may run into difficulties, as noted above, when building occupants don't behave as anticipated.

Another area worth further study is the energy-water nexus. Energy is needed to circulate and pressurize water used inside the building. The building is served by city-supplied water pressure for floors 2 through 5; a booster pump generates proper water pressure on floors 6 through 9. Tests showed that pressure varied dramatically between the floors. This could affect toilet flushing and faucet use. Water for showers, washing hands, and other uses (washing dishes) is heated through an energy-efficient heat transfer process from city-supplied steam. Anecdotal accounts show that occupants complained about the faucet water in the restrooms being too cold. This could be the result of either low water pressure or insufficient temperature. In either case, this situation could lead occupants to keep faucets running longer while they wait for the water to heat up.

Another issue is the gap between measures of ambient conditions in the building and occupant comfort. Even though temperature and acoustic conditions fell within the recommended ranges, occupants were uncomfortable. Fifty percent or fewer were satisfied with temperatures, noise, and speech privacy. It should be noted, however, that similar problems exist in most buildings where occupants have little or no control over thermal conditions or acoustics.

Summary and Conclusions

Research value. Research at the Wynkoop building has produced or demonstrated methods for assessing indoor water use, building thermal performance, workplace functionality, acoustic performance of sound masking in the under-floor air plenum, rapid assessment of indoor environmental quality, installation of systems to avoid air leakage, green roofs for the high mountain desert climate, data center energy improvements, and behavior change to reduce plug load energy use. The results will be widely shared through webinars, conference presentations, white papers, and outreach to audiences who can use the findings to improve the performance of their own buildings.

The building can readily be considered a success as a living laboratory and teaching tool. It is also a successful example of performance-based contracting, an integrated team process, and overall environmental performance. There continue to be some comfort problems, especially with thermal conditions, which are notoriously difficult to resolve without high levels of individual control over temperatures and airflow. Other problems, such as noise from human activity, are behavioral and outside the control of designers. Some problems will require changes in rules or in funding allocations.

The research also raises important questions about designing for change and flexibility, and anticipating the future during design and development, especially for modeling energy and water use for green building certification. Changes in demographics, occupancy levels, occupant behaviors, organizational policies, and operational practices can affect the data used in models.

Above all, the research shows that an office building is more than a structure to house a workforce. It is a complex ecosystem of people, work practices, and business decisions all linked toward one end—carrying out an organization’s mission. The work will continue to fine-tune the building and address the myriad challenges of the future, from energy to changes in work practices, even as the formal research program comes to an end.

Is the Wynkoop building a “successful” green building? The project has certainly met many of its goals, many of them tied to achieving a LEED-New Construction Gold rating for its design. But this certification, like all evaluations, is a snapshot representing a certain moment with particular conditions, measured with particular techniques and technologies, and based on specific assumptions. Different and ongoing analyses employing different techniques, assumptions, and technologies at different time periods are crucial—to verify previous findings, to examine whether conditions have changed, and to determine whether any changes have affected building performance.

Finding the source of problems and ways to fix them requires serious analytical and creative work by a motivated interdisciplinary team. Prominent examples in this case were the building’s vast overuse of water due to the steam system and the creative shading solution for the atrium. Sometimes the more intensive focus of professional research is needed to understand both how technical systems are working and how occupants are interacting with them, as with the under-floor system, energy use in the data center, and the toilet fixtures.

Ultimately, “success” is not something that can be declared based on any single snapshot in time, but only based on an ongoing, broad-based, interdisciplinary commitment to measure, evaluate, invest in, and maintain performance. EPA’s ongoing focus on and commitment to this building, therefore, is the most positive indicator of its continued success and improvement.