Plug Load Strategies for Zero Energy Buildings

A case study on the zero energy historical renovation of the Wayne N. Aspinall Federal Building and U.S. Courthouse

Photo from U.S. Army Corps of Engineers

Background

The Wayne N. Aspinall Federal Building and U.S. Courthouse in Grand Junction, Colorado, was constructed in 1918 and is listed on the National Register of Historic Places. In 2010, the U.S. General Services Administration (GSA), which owns the multi-agency building, received $15 million in American Recovery and Reinvestment Act funds to conduct a major renovation and modernize the entire building. GSA's goals were to (1) preserve the building's historic features, and (2) convert it into the most energy-efficient and sustainable historic building in the country (i.e., achieve Zero Energy Building (ZEB) status).

The major renovation was successfully completed in January 2013 and has been certified by the U.S. Green Building Council (USGBC) as a Leadership in Energy & Environmental Design (LEED) Platinum building. It has also has won several awards, including Best Rehabilitation/Renovation/Restoration Project from the Design-Build Institute of America and the ASHRAE Region III Technology Award First Place for 2014.

Achieving ZEB status was no easy task. The Aspinall Courthouse project team took many steps to greatly reduce the building's energy consumption, including a significant focus on reducing plug and process load (PPL) energy use. In doing so, the team was able to achieve ZEB Class-D status, meaning it conserves energy through energy efficiency measures, generates energy through renewable systems that are sited on the building, and purchases renewable energy credits.

Getting to Zero

GSA's two major goals aligned well with the historical aspects of the building, considering many of the original 1918 building features already lent themselves to energy conservation. For example, historic light wells maximize natural daylighting (reducing the need for electric lighting) and thick masonry walls help maintain even temperatures throughout the day.

ASPINALL FACTS

- Originally constructed in 1918
- Listed on the National Register of Historic Places
- Houses eight federal agencies and the U.S. Courts
- Certified USGBC LEED Platinum and achieved Zero Energy Building Class-D status.
- Plug and process loads make up 31% of the building's total energy use

The project team used a replicable design-build process that focused on ZEB performance and compliance with the National Historic Preservation Act of 1966, Section 106. Using this design-build process, ongoing planning and problem solving allowed GSA to comprehensively address historic preservation and energy challenges together—which was a key factor in the project's success in achieving ZEB status and becoming one of the nation's only ZEB historic renovations. The process targeted typical energy end users and high energy consumers by:

- Renovating the building envelope for optimal performance
- Reducing internal energy loads (such as lighting and PPLs)
- Installing high-efficiency heating, ventilation, and air conditioning (HVAC) systems
- Matching the building load with on-site renewable energy (solar photovoltaics [PV] on the rooftop).

Reducing Plug and Process Loads

PPLs consume about one-third of primary energy in U.S. commercial buildings [McKenney 2010]. Often, however, the ratio is even higher in ZEB projects, since the efficiency of the building envelope and HVAC systems is drastically increased. In office buildings, PPLs cover a wide variety of electronic, computer, refrigeration, and cooking devices, and in the last three decades, PPLs have increased building energy consumption due to an increase in demand for plug-in devices. For the Aspinall Courthouse, a number of PPL energy reduction strategies were employed to control PPL energy use, which are described in the following sections.

Implementing Plug Load Control Strategies

GSA established a PPL energy use target for all 50+ employees of 40,000 kWh/year (784 kWh/full-time employee).[1] To determine whether the target was being met, GSA **submetered** the building energy down to the circuit level. This advanced metering allows for real-time energy- and water-use monitoring, which helps inform those who manage the building utility costs. These data are also used to support the decision-making process for instantaneous control of the building systems for optimum performance.

To better manage PPLs, **occupancy sensors** and **load-shedding devices** were installed in many of the building's outlets. Wireless occupancy controls were chosen to minimize intrusion on historic plaster walls and ceilings; this maximizes energy savings and protects historic features. Additionally, many of the wireless controls are PV powered, which further reduces nonrenewable energy consumption.

GSA also distributed **advanced power strips** (APSs) to each occupant; these have built-in technology to reduce PPL runtimes and save energy when the devices are not in use. Each cubicle is equipped with desk-mounted occupancy sensors that are wired to an APS, which powers down equipment after the workstation becomes "inactive." Certain outlets in an APS can be used for equipment that needs to stay on at all times so the occupant has flexibility in plug load power management.

BUILDING IMPROVEMENTS INCLUDED:

- Advanced metering and building controls
- Efficient electrical and mechanical systems
- A geothermal heat pump
- A thermally enhanced building envelope
- A PV rooftop system
- Restored architectural features and original artwork

Photo from Kevin G. Reeves, GSA

[1] *This did not include elevator use.*

Photo from Kevin G. Reeves, GSA

Load-shedding devices were installed in many convenience outlets throughout the building. These devices operate on timers that are scheduled to turn on in the mornings and off in the evenings and over the weekends to eliminate parasitic (or phantom) loads from the plugged-in equipment.

Energy information is displayed in the lobby and through GSA's "Occupant Workstation Dashboard," which can be accessed by individual occupant's computers. This energy information system uses submetered data to educate occupants and visitors about the building's efficiency measures. It also encourages occupants to take action in reducing energy consumption in the building.

Rewarding Occupant Awareness and Response

GSA offers financial incentives to further engage the occupants in reducing PPL energy use; a portion of the rentable square footage fee that is collected from each agency for utilities is returned to the agency if it meets its plug load energy target. Targets are based on the rentable square footage, number of full-time employees, and the agency's day-to-day mission and activities.

Saving Energy

The total plug load energy use after the ZEB renovation was 655 kWh/full-time employee, totaling 33,500 kWh/year—approximately 16% under GSA's target. This equates to 0.94 kWh/ft2/year. Some agencies met their targets; others did not. Lessons learned from these experiences are described in the following section.

Lessons Learned

Lessons learned and experiences from interactions with the Aspinall Courthouse occupants are listed below.

- **Nighttime PPL energy use contributes to a large fraction of wasted energy.** By submetering the building after the major renovation, GSA learned that 31% of the Aspinall Courthouse energy use is associated with PPLs. A large focus of the project team was to reduce PPL energy use overall—and to minimize PPL nighttime energy use, which can add up to a lot of wasted energy. For PPLs, this meant turning computers and miscellaneous equipment off at night when not in use. The submetered data showed a significant reduction in PPL energy use at night – although, with room for improvement.
- **PPLs should be addressed and regularly monitored in energy efficiency and ZEB projects.** Energy monitoring and submetering should be included at the circuit level, if possible, to isolate building system performance and the performance of individual pieces of equipment. This approach enables building owners to isolate and monitor PPLs, and identify opportunities for individual energy reductions.
- **Consider occupant needs.** Various strategies work well for some agencies and not for others. Project teams must consider the agency and it's mission, operation, and occupants as they design control strategies and identify the most beneficial technology solutions.

- **Information Technology (IT) departments need to be included in the conversation.** Typical IT workflows can be unaccommodating of turning equipment such as computers off at night (for installing software updates, etc.). With this in mind, the IT department must be included in early design discussions to determine limitations and possible solutions to better control PPLs.
- **Buy-in is best when the entire organization commits to meeting energy targets.** Energy targets are met most successfully when all the employees in an organization work together to reduce energy consumption. This requires buy-in from upper management to support the procurement of high-efficiency equipment and to encourage staff to reduce PPL energy use wherever feasible. Internal incentives and recognition by upper management to staff for meeting energy targets can help accomplish these goals.
- **Consider the durations and structures of incentives.** Some of the Aspinall Courthouse agencies were very passionate about achieving energy efficiency goals established by the design team. Over time, however, the interest of some agencies waned. One important lesson is that short durations for incentives (rather than annual incentive options) help reinforce low energy consumption practices soon after goals are achieved. Real-time recognition can also help to continuously encourage occupants to meet their targets. To establish an appropriate structure for incentives, GSA discussed the structure of the incentive program with each tenant to customize how the individual agencies and staff could be rewarded if targets were met.
- **Incentivize more than PPLs.** GSA found that pairing PPL incentives with other energy reduction strategies, such as reducing lighting energy use or setting temperature set points higher in the summer and lower in the winter, was beneficial. The overall impact could be far more significant than incentivizing PPL reductions alone.
- **Make the reward big enough to drive change.** GSA established an incentive process in which at least 50% of the agencies saw an impact. Continually monitoring energy consumption and assessing whether the reward program is driving the change in energy reduction is an important process for successful incentive programs.

Resources

- Better Buildings Alliance Plug and Process Load Technical Solutions Team: *https://www4.eere.energy.gov/alliance/activities/technology-solutions-teams/plug-process-loads.*
- Chang, R.; Hayter, S.; Hotchkiss, E.; Pless, S.; Sielcken, J.; Simth-Larney, C. (2014). Aspinall Courthouse: GSA's Historic Preservation and Net-Zero Renovation. U.S. Department of Energy. *http://energy.gov/sites/prod/files/2014/10/f19/aspinall_courthouse.pdf.*
- Chang, R. (2014). Landmark Resurrection, Case Study Wayne N. Aspinall Federal Building and U.S. Courthouse. High Performance Buildings. Summer 2014. *http://www.hpbmagazine.org/attachments/article/11795/14Su-Wayne-N-Aspinall-Federal-Building-and-US-Courthouse-Grand-Junction-CO.pdf*
- GSA's Sustainable Facilities Tool, Net Zero Examples. *https://sftool.gov/plan/422/net-examples.*
- McKenney, K.; Guernsey, M.; Ponoum, R; Rosenfield, J. (2010). Commercial Miscellaneous Electric Loads: Energy Consumption Characterization and Savings Potential in 2008 by Building Type. Lexington, MA: TIAX LLC. *http://zeroenergycbc.org/pdf/2010-05-26%20TIAX%20Final%20Report.pdf.*
- NREL. (2013). Assessing and Reducing Plug and Process Loads in Office Buildings. Golden, CO: National Renewable Energy Laboratory. NREL/FS-5500-54175. *http://www.nrel.gov/docs/fy13osti/54175.pdf*