Field Validation of Lighting Retrofit with HVAC Integration and Plug Load Controls at City-Owned Building in City of St. Paul, Minnesota

Background

The city of St. Paul Streets Maintenance Division building houses the Department of Public Works staff who administer and maintain the public street traffic signals, signs, and lighting. This mixed-use building was built in 1970s, and the interior lighting was still mostly inefficient fluorescent fixtures. Because of the financial incentives of the project, the City agreed to retrofit certain areas of the building with a new networked, integrated lighting controls package. It included a complete lighting retrofit with a luminaire-level lighting controls system, automatic receptacle controls, and a tie from the lighting controls to the existing HVAC building automation system.

Project Summary

The city of St. Paul upgraded about 13,100 ft^2 of its Street Maintenance Division building with a new networked light emitting diode (LED) lighting system integrated with heating, Ventilation, and Air Conditioning (HVAC) and plug load controls. The city installed the lighting and plug load controls and worked with a lighting manufacturer to commission the networked lighting control system. A local HVAC controls contractor was hired to integrate the lighting with the HVAC system.

The key components in this project include LED fixtures and luminaire-level lighting controls (LLLC). This system incorporates dimming control, photosensing, and occupancy sensing capabilities for each individual fixture. The sensors communicate wirelessly with each other to create a flexible, granular mesh network throughout the building to control individual lighting fixtures, receptacles, air handling units (AHU), and HVAC systems. In addition to the new lighting fixtures and onboard controls, wirelessly controlled receptacles were installed.

PROJECT QUICK FACTS

- **Location:** 899 Dale St. North St. Paul, MN 55103
- **Building Size:** ~13,100 ft^2 (retrofit area)
- **Building Sector Type:** Administrative office building: private and enclosed offices, meeting room, lunchroom, repair shop, and storage room
- **HVAC Unit Type:** Two dual-duct, single fan, multi-zone, constant air volume (CAV) AHUs (each serving four zones). One single-duct, single-zone, constant air volume AHU. One rooftop unit serving one zone. Independently controlled hot-water radiant heating in perimeter rooms.
- **Building Automation System (BAS) Type:** Johnson Controls METASYS, Automatrix system with JACE
- **Occupancy Description:** 30 occupants, operating 7:30 am–4:30 pm CT, Monday–Friday
- **Utility Incentives:** $11,000
- **Project Completion Year:** 2021

The project was funded by U.S. Department of Energy (DOE) via the Scaling Up the Next Generation of Building Efficiency Packages Funding Opportunity Announcement (FOA), which "supports high-impact real building demonstrations led by strategically structured teams who will identify and verify the cost and energy performance of multisystem energy efficiency packages." The goal of the field validation was to test the performance of plug load integration and identify potential challenges and future opportunities. Members of this project team members include Slipstream (formerly Seventhwave); Cree Lighting; Legrand/ Wattstopper; Xcel Energy; and Pacific Northwest National Laboratory (PNNL).

Project Cost			
	Material (/ft²)	Labor (/ft²)	Payback (years)
Lighting	$2.95	$4.02	40.5
Lighting w/ Incentives	$2.53	$3.60	35.6
Plug Load	$0.03	$0.01	9.3
HVAC	—	$0.88	N/A
Subtotal	$2.98	$4.91	—
Subtotal w/ Incentives	$2.53	$4.49	—
Total	$7.90		44.7
Total w/ Incentives	$7.02		39.9

System setbacks are activated when all four zones are unoccupied. The building had predictable occupancy, and as a result, a schedule-based and occupant-driven approach would yield roughly the same results. Constant air flow (CAV) systems can only supply air at one rate. A CAV system restricts setbacks in response to occupancy, which limits the energy savings available from integrating mechanical and lighting systems.

Energy Saving Control Strategies

- Light-emitting diode (LED) fixture with a LLLC system that incorporates dimming control, photosensing, and occupancy sensing capabilities for each individual fixture.
- Plug load controls in cubicles in open plan offices, private offices, and conference rooms, and turning off equipment, like printers and chargers.
- Setback thermostat based on occupancy.
- Supply air temperature static pressure reset based on VAV box position (which is based on occupancy).

Project Cost Considerations

- Project used networked lighting controls which requires a certain amount of equipment independent of space size. At 25,000 ft^2 , this site is the minimum size threshold where networked lighting controls typically become more cost effective.
- Costs of lighting equipment contributes to a longer payback period. Similarly, integrating mechanical system added additional labor costs but did not result in any energy savings because the mechanical system was not conducive to occupant-responsive controls because it was a multi-zone constant air volume system.

Lessons Learned

- **Explore and identify financing options early in project planning.** Utility incentives and energy efficiency grants can help offset high costs, which is often a significant barrier to these types of projects. Initial project costs were beyond the city's budget. Incentives from Xcel Energy and indirectly from the DOE lowered the cost barrier for the city, allowing them to proceed with procurement, commissioning, and installation.

- **Ensure product and system compatibility.** Despite lighting system communicating via BACnet, integration with HVAC controls was a challenge. The lighting network and HVAC controls network were not instantly interoperable, as a result the lighting vendor had to make firmware and other modifications to allow the systems to communicate.
- **Allow extra coordination time for the first integration project.** It took several months and multiple discussions among the St. Paul's IT staff, the lighting commissioning agent, technical support team, and the local HVAC controls contractor to resolve the network communication issues.
- **Anticipate that a commissioning agent will need to make field adjustments based on real-world user needs.** The commissioning agent needed to make some adjustments to the designed light levels and lighting/plug load controls based on occupant feedback.
- **Much of the equipment could be installed by electricians who don't specialize in integrating advanced systems.** The lighting and plug load system installations were straightforward and completed by the city's staff electricians.
- **Building mechanical design drives integration success.** Multi-zone CAV systems are not ideal for lighting integration. All the zones had to be unoccupied before a setback occurred. This resulted in no savings from occupancy-based setbacks.

Potential Energy Savings		
Lighting Savings	1.7 kWh/ft²	63%
Plug Load Savings	Average 88 kWh/receptacle/yr	56%
HVAC Savings	N/A	—
Total Cost Savings	$0.45/ft²	

- **Occupancy levels dictate energy savings and return on investment.** Buildings with predictable constant occupancy may not be benefit from integration. Besides the multi-zone CAV limitation, the building staff had a regular schedule and were in the building most of the day, which meant there was no significant savings from occupancy-based setbacks.
- **Develop methods to periodically verify that systems are still integrated (e.g., 3, 6, and 12 months after initial integration).** During a particularly cold week, the temperature was manually adjusted, which interrupted the integration of the mechanical and lighting systems. This was only discovered because the building was still being monitored as part of this study.
- **Train building owner/operator staff during commissioning.** Once commissioning is completed by the vendor, it is beneficial to assign a local staff who can take ownership of the controls and can adjust settings as appropriate.

PNNL-SA-186345