General Services Administration
Public Buildings Service

GPG-037 | NOVEMBER 2018

ADVANCED LIGHTING CONTROLS AND LED

Light-Level Tuning Increases Occupant Satisfaction

Today's light-emitting diode (LED) sources last about twice as long as typical fluorescent lamps and consume roughly half as much electricity. For this reason, among others, they are fast becoming the default light source for new lighting installations. Energy savings from LED fixtures, moreover, can be augmented by integrating LEDs with advanced lighting control (ALC) systems, which are designed to provide light only when and where it is needed. The integration of ALC with LED fixtures is particularly effective in open-office plans, where occupants are engaged in a variety of tasks. In support of GSA's Total Workplace Initiative and its move toward open-office floor plans, GPG commissioned the Department of Energy's Pacific Northwest National Laboratory (PNNL) to evaluate five different LED systems with ALC in 76,000 ft^2 of primarily open-office space at a large GSA office building in Fort Worth, Texas. After the conversion to LED, light-level tuning and occupancy sensing reduced lighting energy by an additional 43%. Savings from daylight harvesting were minimal because most spaces did not have access to natural light. At the test-bed site, with an electricity rate of $0.07/kWh, the added cost of the controls was not life-cycle cost-effective. Controls can be cost-effective at the GSA national average utility rate of $0.11/kWh, when the added cost for controls is less than $70 per fixture.[1] Researchers also found that being able to tune light levels significantly increased occupant satisfaction with the new systems.

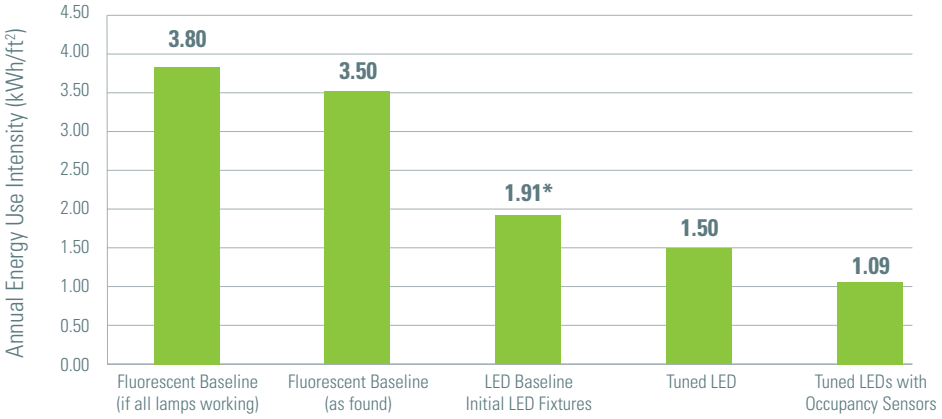
The GPG program enables GSA to make sound investment decisions in next-generation building technologies based on their real-world performance.

INTRODUCTION

Fort Worth
Annual Energy Use Intensity

Controls reduced lighting energy 43% from the LED baseline.

The annual energy use intensity (EUI) of 1.09 kWh/ft² is well below the reported GSA average of 3.25 and the national office average of 2.7.[2]



*Includes fixture count reduction from 1,212 fluorescent to 847 LED

"Without the benefit of lighting controls, many of our tenants found the LEDs to be just too bright. Once we tuned the new fixtures, people were much happier."

—Frank Campagna
Energy Project Manager
GSA Greater Southwest Region
U.S. General Services Administration

What Is This Technology?

LIGHT-LEVEL TUNING, OCCUPANCY CONTROL, AND DAYLIGHT HARVESTING

LEDs differ from other kinds of light sources in that their light comes from semiconductors rather than filaments or gases. LED's digital nature provides more precise dimming control than other lighting technologies, making advanced control systems more effective. The ALC systems tested in Fort Worth provided light-level tuning along with occupancy and daylight sensing, though few spaces had access to natural light. They all used advanced wireless protocols that have achieved cyber security approval from GSA to provide basic zone-level control. Some of the ALC systems installed in Fort Worth also offer individual fixture control, multi-channel sensor control, and system diagnostics and scheduling, though these features were not assessed.

What We Did

ASSESSED FIVE DIFFERENT ADVANCED LIGHTING CONTROL SYSTEMS

In 2017, GSA replaced T8 fluorescent lighting fixtures with five different LED and advanced control systems in 76,000 ft² of office space in Building 23 at the Fort Worth Federal Center. Five separate zones were designated as test beds. In three of the zones, the advanced lighting controls were integrated into the fixtures (one by the manufacturer, including "plug and play" lighting control logic and a self-configuring network; the other two using controls and sensors integrated into the fixtures by distributors). The remaining two zones used add-on controls that were installed in the field. To better meet the lighting requirements of the space, fixtures were moved and their overall number reduced.

To assess the retrofit's performance, PNNL researchers measured LED light levels, compared them with light-level measurements of the incumbent technology, and categorized energy savings by the different control strategies. They also surveyed occupants and conducted interviews with electrical contractors and facility managers about their experience with the new lighting.

FINDINGS

43% SAVINGS FROM ADVANCED LIGHTING CONTROLS The conversion from fluorescent to LED lighting saved 1.59 kWh/ft²/yr. Advanced lighting controls contributed an additional 0.82 kWh/ft²/yr in savings, with half of the savings from tuning the light levels and half from occupancy control. Control savings varied among the five zones, from 0.42 kWh/ft²/yr to 1.16 kWh/ft²/yr. Only a small percentage of overall square footage had access to daylight, so savings from daylight harvesting were minimal.

MET GSA OCCUPANT ACCEPTANCE THRESHOLD 77% of occupants found the new lighting to be acceptable for office tasks and 70% indicated that the light was comfortable. After installation of the new lighting systems, and before commissioning was completed, some occupants found the light too bright and fabricated barricades to block it. Once the light levels were reduced, occupants were more comfortable and removed their barricades.

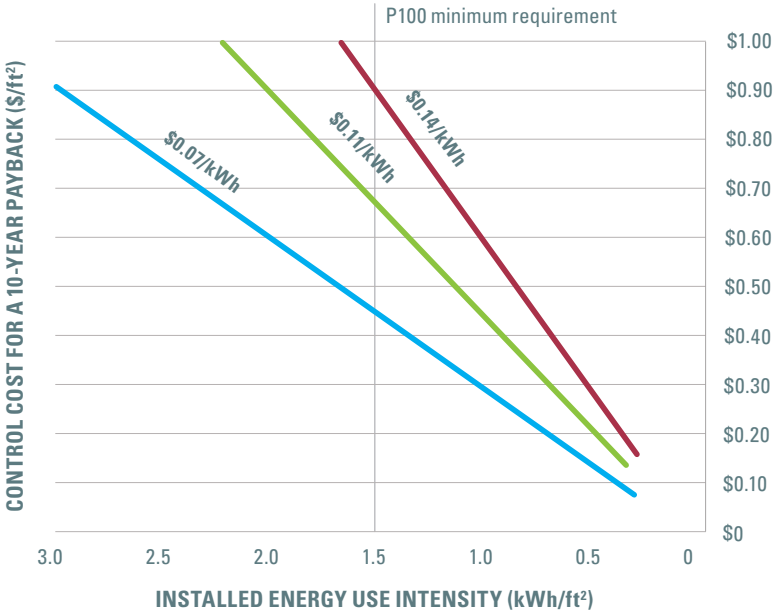
ADD-ON CONTROLS TAKE MORE TIME TO INSTALL More time was needed (10 to 15 minutes per fixture) to install the separate add-on controls.

NOT COST-EFFECTIVE AT TEST-BED LOCATION With a baseline lighting EUI of 1.5 kWh/ft² (two-tube T-8 LED troffers, one fixture every 100 ft²) and the GSA average utility rate of $0.11/kWh, the added cost of controls would need to be $70 per fixture or $0.70/ft² to achieve a 10-year payback. Controls pricing is affected by fixture density and the size of the installation. The greater the fixture density, the greater the installed cost per square foot. In Fort Worth, fixture density ranged between 60 ft² and 106 ft² per fixture. The size of the installation can also influence overall cost-effectiveness. A 10,000 ft² installation and a 50,000 ft² installation can require the same control infrastructure.

CONSIDER CONTROLS WHERE UTILITY RATES ARE HIGH Prioritize facilities with no existing lighting controls, lighting energy use > 3.25 kWh/ft²/yr,[3] utility rates > $0.11/kWh (GSA average), and the availability of utility rebates. In locations with lower utility rates or lighting energy use, consider LED systems with less expensive control options that provide only light-level tuning. Advanced lighting control systems are most likely to be cost-effective in open offices where occupants are engaged in a variety of tasks; they are also more cost-effective when integrated into the fixture rather than installed as an add-on in the field.

Advanced Lighting Control Costs for a 10-Year Payback*

The more efficient the lighting, the more challenging it is for ALC to achieve positive ROI



ALC calculator at gsa.gov/gpg can help determine site-specific payback

*Assuming a 10-hour, 5-day work week and 43% ALC savings

CONCLUSIONS

These Findings are based on the reports, " Evaluation of Advanced Lighting Control Systems in a Working Office Environment" which is available from the GPG program website, www.gsa.gov/gpg

For more information, contact GSA's GPG program gpg@gsa.gov

What We Concluded

THE MORE EFFICIENT THE LIGHTING, THE MORE CHALLENGING FOR ALC TO ACHIEVE POSITIVE ROI

At the test-bed site, the added savings from controls (43%) did not cover the added expense of the controls themselves (76% of total costs). In general, as lighting systems become more efficient, controls become less cost-effective. Still, life-cycle cost analysis demonstrates that currently available luminaires with plug-and-play factory integrated lighting controls can provide a positive return on investment for facilities with higher utility rates and longer occupied hours. This study also found that light-level tuning, which can be achieved with less expensive controls or fixture adjustments, increases occupant satisfaction.

GPG is conducting a follow-on study of networked lighting controls that incorporate other types of functionality, such as HVAC control and space allocation. The study will evaluate HVAC and lighting savings as well as non-energy benefits.

Lessons Learned

- Light-level tuning can be critical for occupant satisfaction. Tuning is a standard capability of advanced lighting control systems and is available as a fixture adjustment option in systems without advanced controls.
- Stand-alone lighting controls installed in the field can increase project costs.
- When spaces are overlit, significant energy savings can be achieved by reducing brightness. This should be carefully considered when evaluating a project's cost-effectiveness.
- Changing fixture spacing (e.g., existing 2'X4' troffers replaced with 2'X2' troffers) and fixture location (potentially requiring rewiring of electrical connections) can significantly increase costs but is sometimes necessary for lighting quality.
- Fixture density has a big impact on cost-effectiveness; a rule-of-thumb for open-plan offices is to place a fixture every 100 ft^2. Interior application spacing can range from 80 ft^2 to 150 ft^2.
- Select control systems that most economically provide the control functionality required.
- If investing in a lighting control system that is intended to integrate with the building's BAS, ensure that controls will meet cyber security requirements and can integrate with that system.
- Conduct a mock-up of proposed lighting equipment and evaluate it for glare issues.

Footnotes

[1]Assuming the minimum GSA P-100 EUI of 1.5 kW/ft^2

[2]Energy Information Agency Commercial Building Energy Consumption Survey 2012. https://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/e6.php

[3]Two-tube T8 fluorescent troffer, 18 hours a day, 1 per 100 square feet = 3.4 $kWh/ft^2/yr$

Technology for test-bed measurement and verification provided by Patriot, Enlighted, RAB, Philips, Flow Lighting and Lutron.