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Achieving energy efficiency through integrated lighting controls

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Table of contents

Description	Page
Introduction	1
Know control: turn on to smarter, more versatile lighting control options	2
Code compliant construction: the new mandate for energy efficiency	2
Great expectations: lighting power density and control requirements	4
Discover COI (Control Over Investment): save energy and money with integrated lighting control solutions	4
Conclusion	5
Highlighted resources	5
About Eaton	6
Sources	6

Introduction

With reports from the U.S. Energy Information Administration indicating that "21 percent of the total energy used in commercial buildings and 38 percent of all electricity used in commercial buildings is used for artificial lighting" (Gelfo, 2013), it's no wonder that recent building codes have given automated lighting controls the spotlight.

Of the approximately 3,684 terawatt-hours (TWh) of electricity produced in the United States annually, about 18 percent (or 700 TWh) is used for lighting. Up to 92 percent of lumens (total light emitted) used are taken up by non-residential settings.

Lighting affords one of the simplest means to both conserving energy and reducing carbon dioxide (CO_2) emissions (Kay, 2012). With intelligent lighting control systems, we "can [further] reduce the amount of energy waste[d] from lighting" (Rubinstein, 2011). Today's lighting control systems can provide real-time information on energy utilization or send alerts when events occur or problems are detected. Significant resource gains, cost savings, design flexibility and user benefits are possible.

A 2013 Navigant Research Report suggests that "worldwide revenue from networked lighting controls will grow from $1.7 billion annually in 2013 to more than $5.3 billion by 2020." Of this figure, the forecast finds revenue from occupancy sensors, photosensors and lighting network control gear alone could reach nearly $2.7 billion.

"As falling prices for light emitting diodes (LEDs) drive up adoption rates of LED lamps, the adoption of lighting controls will also accelerate" (Navigant Research, 2013). Increasingly, more stringent code compliance requirements and a growing interest in lighting design versatility are key factors driving this demand.

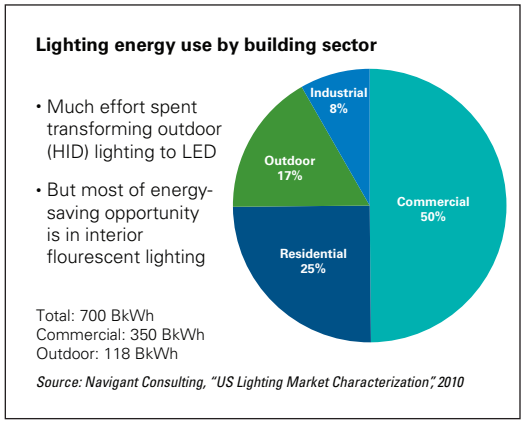

Figure 1. Lighting energy use by building sector

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Know control: turn on to smarter, more versatile lighting control options

Almost everyone is familiar with the dimming switch. Early efforts to control lighting allowed an individual user the ability to directly control available light in a specific environment. Other basic controls include manual, personal and room control.

A second set of options emerged with the introduction of sensors to the space. Motion sensors detect whether or not a user is present and illumination is needed. Programmable controls such as occupancy sensing vacancy sensing and auto shutoff rely on motion-based sensing to turn lights on or off as needed.

With the addition of integrated controls and tuning, lighting automation affords powerful energy savings and exciting design solutions. With these controls, sensors are integrated directly within the fixture or luminaire. This makes it possible to gauge energy and lumens output with precision, while controlling specific fixtures individually. Integrated controls also allow several different control strategies to work in unison—for example, occupancy sensing, daylight harvesting and personal dimming might all be employed at once to achieve optimal efficiency.

In September 2012, the General Services Administration (GSA) reported on the energy savings potential of occupancy response control. The evaluation focused on three control strategies: personal controls, occupancy sensing and institutional tuning and scheduling. The study spanned seven locations across five buildings with different occupancy and work style patterns. Results showed energy savings that ranged from 27 to 63 percent with payback for continually used spaces achievable in less than 7 years (GSA, 2012). Spaces with long operating hours and varying occupancy patterns benefited most.

Even more recently, the GSA released findings from a study of Integrated Daylighting Systems (IDS). Daylight harvesting is the use of daylight to help offset energy consumption from artificial lighting. "IDS measures prevailing natural light against predetermined lighting setpoints and signals electronic dimming ballasts to minimize electric light output accordingly"(GSA, 2014). The study estimates potential energy savings from IDS—where daylight harvesting is one of several components in a well-integrated lighting control system—to be as high as 60 percent.

A range of other lighting controls address more detailed aspects of the holistic lighting infrastructure, including multi-building control and monitoring, receptacle control, zoning and emergency controls. Renowned lighting expert Francis Rubinstein provides a thorough overview of the differences and nuances of available options in *Lighting Controls in Commercial Buildings*.

Table 1. Potential energy savings from integrated lighting controls

Occupancy sensing scenario	Annual lighting cost savings		Size (sq ft)	LPD (watt/sq ft) ①	Lighting hours	Commercial electricity cost (cents/kWh) ②	Annual lighting cost (U.S. dollars)	
	Percentage	U.S. dollars					Without occupancy sensors	With occupancy sensors
Restroom 	60%	$101	300	0.98	5,600	10.2	$168	$67
Private office 	45%	$27	150	1.1	3,500	10.2	$59	$32
Corridor 	35%	$48	450	0.66	4,500	10.2	$136	$88
Warehouse 	75%	$152	1,000	0.66	3,000	10.2	$202	$50
Standard classroom 	40%	$170	1,200	1.24	2,800	10.2	$425	$255

① These are the lighting power densities (LPD) allowed by space or whole building per ASHRAE 90.1-2010.

② This was the average kWh cost in the U.S. in 2011 as reported by the Energy Information Administration.

Code compliant construction: the new mandate for energy efficiency

Every builder should consider an integrated lighting controls strategy early on in new construction or retrofit projects.

Each state within the United States currently requires some version of the American Society of Heating, Refrigerating and Air-Conditioning Engineers' ASHRAE 90.1 building standard. An October 2013 ruling by the Department of Energy (DOE) mandated commercial compliance with the minimum requirements set forth in ASHRAE 90.1-2010. All jurisdictions in the U.S. will soon be required to comply with it or a superior state energy code. California's Title 24 is perhaps the most stringent of all state codes; it went into effect on July 1, 2014.

ASHRAE 90.1-2010 introduces the greatest leaps in lighting controls requirements in some time. All new construction and retrofit projects with greater than 10 percent of the connected lighting load modified must comply with the new ASHRAE 90.1-2010 requirements or a stricter code. This means that even small lighting upgrade projects may need to meet code compliance. Significant changes include stronger lighting control requirements tied to specific lighting control applications and stricter lighting power density (LPD) values.

Automatic shutoff is prominent in the ASHRAE 90.1-2010 code and requires methods to achieve automatic shutoff in most spaces. Typically, shutoff must occur within 30 minutes of vacancy. "At least one control device (e.g., light switch, dimmer, or occupancy sensor) is required for each space enclosed by ceiling-height partitions to control that space's general lighting" (Schultz and Chow, 2011).

Prior to this code update, around half of the energy used by a lighting system was consumed while portions of the facility were vacant. Occupancy sensing and time scheduling systems eliminate wasted energy by minimizing the operating hours of the lighting system while accommodating the variable work hours and habits of the building's occupants.

Daylighting strategies are also given emphasis in the updated code. Mandatory control provisions are set for spaces with primary and secondary sidelighting (large windows) and/or toplighting (skylights).

Many of the code changes address specific control of task-oriented spaces. A combination of auto shutoff and daylighting may be required for employee lunch and break rooms; conference and meeting rooms; classrooms, lecture halls and training rooms; storage or supply rooms of 50 to 1,000 square feet; copy and print rooms; office spaces up to 250 square feet; restrooms; and dressing, locker or fitting rooms. Additional requirements are defined for parking lots and garages.

Commissioning is required by ASHRAE 90.1-2010, which ensures correct installation, testing and maintained usage. It's clear that this requirement is a result of both the increasing capabilities and complexity of lighting control options, as well as the higher mandates for achieving energy efficiency in the commercial sector. "If the controls [and their intent] are not well-understood or do not function properly once a building is 'turned over' or the renovated areas are occupied, there is little chance the projected energy savings can be realized" (Allen, 2014).

Rubinstein points out that luminaires that incorporate integrated sensors avoid many of the potential commissioning issues faced when using area-based sensors. Look for products that feature factory-installed sensing systems such as the Metalux Encounter™ with integrated sensors from Eaton.

To achieve optimal energy efficiency while securing code compliance, consider lighting controls that integrate addressable systems with software control available from multiple devices and touch screens. For the commercial sector, this approach introduces basic lighting intelligence and intuitive design elements that can result in significant energy savings.

Addressable control systems reduce the amount of line voltage wiring on a project by 50–80 percent as compared to a relay-based solution. This is because control shifts from circuit level (relays) to individual devices (addressable) greatly simplifying the electrical design and the wiring installation.

Digital addressable controls offer two distinct advantages: 1.) Each ballast/driver has a unique ID (address); and 2.) all of a facility's fixtures can be networked together. As a two-conductor data wire-based solution, digital addressable control systems enable a simple enterprise-level solution that a building manager can program, manage and maintain for best-in-class energy management capabilities.

Addressable controls may be either wired or wireless. Although both can be used within a facility, addressable wireless controls are especially common for outdoor applications.

Previously, addressable controls dealt only with large zones where a relay might control 20 amps or 10 fixtures at once. With the new digital addressable controls, however, the fixture itself is smart. Controls can "address" a specific driver or even an individual fixture for illumination or power adjustments, maintenance and reporting.

Software-based addressable control allows for fully personalized lighting ergonomics. Multiple points of access allow end users to interact with the lighting system in the most convenient way possible: whether by wall stations, web-based software, VOIP telephones or mobile devices. Addressable systems such as Eaton's Fifth Light System allow for intelligent lighting control via either a mobile device or a centralized dashboard software solution.

Remote controls borrow the paradigm of anywhere, anytime control using mobile devices and software. Today's users are accustomed to home security systems with remote control access via mobile apps; the same functionality is expected in all aspects of the workplace. With this approach, wall stations may not be needed at all; using a combination of occupancy sensors and a mobile device, a user can control the lights while approaching the building.

App-based controls also integrate easily with an iPad® or mini tablets that can mount to the wall for in-room or complementary control needs. This approach makes it easy for updates to be made to the control interface at any time, significantly improving the user experience on an ongoing basis.

For facility managers, a user-friendly, enterprise-wide view of all the lighting, power and energy use in their building (or buildings) is critical for effective operations. Many different software packages are available with a range of automation features to support maintenance, reporting and analytics.

By running automatic system checks and then delivering a detailed status report, Eaton's Fifth Light System keeps maintenance crews in the loop via automatic email notifications. The monitoring system can detect luminaire tube and ballast or driver failures and provide detailed system diagnostic reports.

More importantly, the Fifth Light reporting software allows building managers to view, track and chart the energy consumption of their lighting system on a user-by-user, floor-by-floor and tenant-by-tenant basis. All the lighting and power being used in the building—down to control of a specific fixture or group of fixtures—can be monitored and maintained quickly and easily from a single dashboard.

Great expectations: lighting power density and control requirements

ASHRAE 90.1-2010 has set new expectations for controls requirements in energy codes moving forward. For example, the code may require controls for only turning lighting on to 50 percent power or less by default within a designated space. In these scenarios, an "occupant needs to manually flip the switch to energize the remaining lights, thereby illuminating the space 100 percent" (Allen, 2014).

Prepackaged lighting control systems are a simple and easy way to achieve the necessary offset in LPD required for code compliance. In some states, tax credits are incentivizing the commercial sector toward implementing controls for higher LPD offsets. There are specific incentives for demand response under Title 24 (see details in DiLouie, 2014). The federal Energy Policy Act of 2005 (EPAct05) features similar incentives specific to lighting retrofits. Available incentives on a state-by-state basis can be found by visiting *http://www.dsireusa.org* (Chow, 2014).

Discover COI (Control Over Investment): save energy and money with integrated lighting control solutions

Recent implementations at the local, state and national levels demonstrate increased savings, improved efficiency and faster return on investment from new construction and retrofit projects employing integrated LED-based lighting control systems.

"LED retrofits can save 40 percent or more energy when compared with traditional light sources such as incandescent, halogen, and high intensity discharge (HID)" (Chow, 2014). By adding integrated controls to the LED lighting mix, it's possible to gain smarter control in each room along with maximum lighting flexibility for individual tasks or specific user preferences. Each light fixture can be individually controlled so that two people sitting side by side can both have their unique preferences met at the same time.

Integrated LED control solutions can also better address energy use and lighting design aesthetics in spaces that were previously extremely difficult to light efficiently. Large or awkward spaces benefit from a mix of integrated controls, tuning and fixture grouping schemes. Rubinstein offers an example of fixtures bundled into large zones that can be programmed to operate in concert with occupancy sensors and addressable wireless controls: "When any fixture in the group senses occupants, all fixtures in the group turn on to a 'background' lumens level; the fixtures above specific occupants can then manually or automatically brighten to a higher level" (Rubinstein, 2014). Areas where major energy efficiency gains can be seen from this approach include high bay lighting; outdoor and site lighting; and some specialty lighting applications such as patient lighting.

The Sustainability Club at the National Science Foundation (NSF) Smart Lighting Engineering Research Center (ERC) demonstrated a major luminaire replacement project on the campus of Rensselaer Polytechnic Institute. More than 300 par 30 halogen luminaires operating 24/7 were replaced with LED fixtures in the Great Hall and Darrin Communication Center (DCC). The halogen lights consumed an estimated 200,000 kilowatt-hours per year, costing the campus about $13,000 in energy costs alone. With an estimated lifetime of only 3,000 hours, these luminaires were constantly in need of replacement, a time-consuming process that required a ladder and two employees.

Initial energy savings projected at 80 percent allow for a return on investment within just 18 months and significant energy savings annually. The largely student-led project in the DCC alone will realize an estimated $21,000 per year in energy and labor costs savings as well as a reduction in Rensselaer's annual carbon footprint by 123 metric tons of CO_2.

With many new construction and renovation projects ongoing or in the planning stages, Washington State University (WSU) sought a lighting control system capable of meeting both new building codes and retrofit requirements across a diversity of space functions and task-based applications. WSU's campus comprises more than 630 buildings; the school's example projects included interior and exterior renovations of Martin Stadium, design of a new residence hall and installations at recently completed research laboratory facilities such as the Veterinary and Biomedical Research building.

WSU's presiding concern was auto shutoff control to satisfy building codes and minimize energy waste. Eaton's Greengate lighting control system was chosen for its impressive customization capabilities and for its ability to support goals and requirements for LEED® certification.

As an energy management solution, Greengate accommodated the specific needs of a wide variety of spaces requiring the same key lighting control components—the Greengate lighting control panel, occupancy sensor and photosensor. "We combine the timeclock control from the lighting control panel and occupancy sensors to execute the full sweep off, required by Washington building codes, without leaving people in the dark," said Brian Funke, construction manager for WSU.

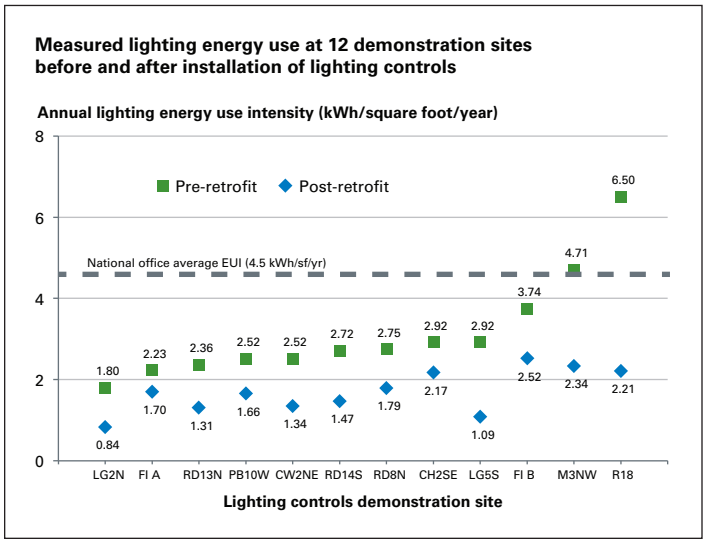

Figure 2. Energy savings from lighting controls at 12 demonstration sites (source: Rubinstein Lightfair 2014 presentation)

LEDs are a higher efficacy light source. By offering more lumens per watt per square foot, LEDs reduce overall lighting power consumption while vastly improving illumination design flexibility and aesthetics.

Chow (2014) outlines several other reasons why LEDs have become attractive: low environmental impact from a combination of energy savings, longevity and a lack of hazardous materials; no UV (ultraviolet) rays or IR (infrared) heat radiation; ideal for frequent on–off switch cycling common in meeting requirements for occupancy sensors; LEDs have instant full-on output such that no warm-up is required; and they lower life cycle costs both in efficiency and longevity.

At the 2014 Lightfair, Rubinstein summarized preliminary results from federal test sites exploring efficiency gains specific to integrated LED lighting systems and controls. He concluded that overall, "LED lighting is [now] easier and cheaper to control than fluorescent lighting" (Rubinstein 2014).

The federal demonstration sites provided provocative data. Consider the Goodfellow Building—a 6,100 square foot open office space. It had a 58 percent savings in LPD with 2 kWh/square feet saved in energy use. Surveys showed that occupants were generally more satisfied with the LED lighting, answering positively to questions about even distribution of light and pleasant brightness in workspaces.

Two additional test sites—Metcalfe and Summit—explored the efficiency gains possible from solutions that integrate the sensor directly with the luminaire. Preliminary findings are summarized in **Figure 3**.

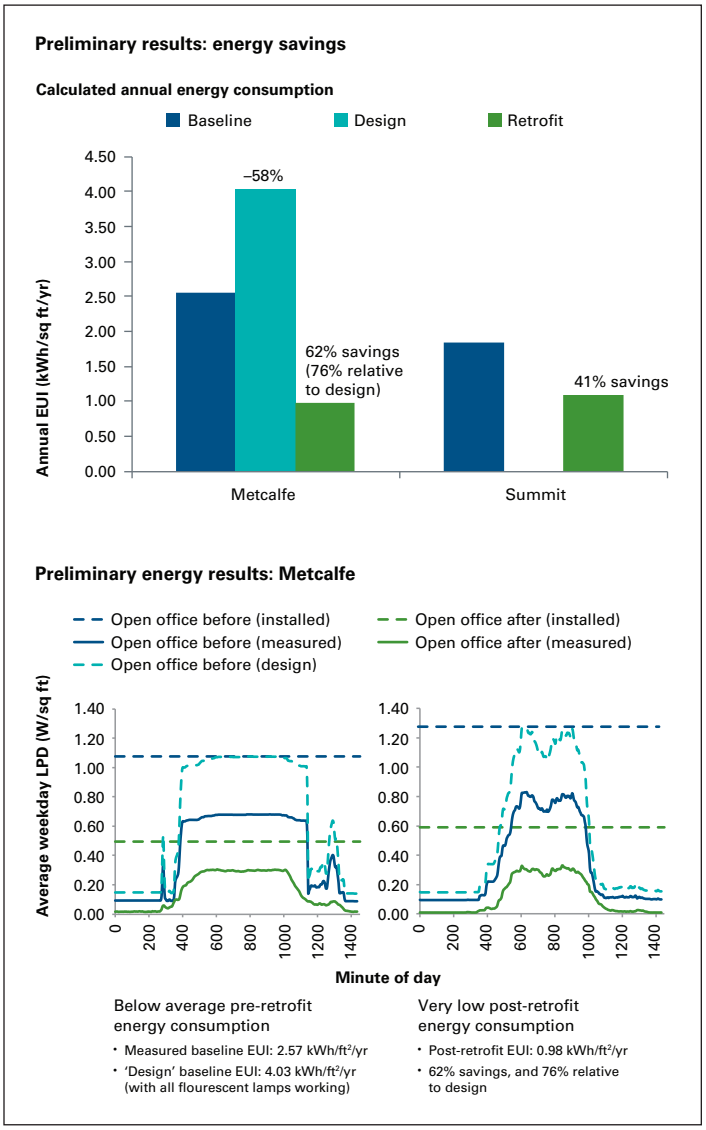

Figure 3. Preliminary energy consumption savings at two demonstration sites (source: Rubinstein Lightfair 2014 presentation)

Conclusion

In conclusion, Rubinstein says it best when he notes that: "Regardless of light source, all lighting should be intelligently controlled" (Rubinstein 2011). With its increasing potential and complexity, lighting design is quickly emerging as an art and a science. At the same time, intelligent and intuitive lighting control has become a key strategic investment for the commercial sector. As LED prices continue to fall, there will be increasing interest in the energy efficiency gains and control versatility options made possible by integrated lighting control systems. The combined use of intelligent controls with LED luminaires affords greater usability and human-centered design—that is, lighting controls that are more "resilient, efficient, and uplifting" (Rubinstein 2014). Good lighting can have an incredible impact on human performance and well-being in the forms of "increased productivity, safety, security, personal comfort, sales, attendance, and profit" (Kay 2012), to name just a few.

Integrated controls help organizations meet and exceed increasingly more stringent energy code requirements from basic to complex with a high level of visual and energy performance. Pre-packaged solutions both simplify and optimize the code compliance process. By selecting intelligent lighting control solutions carefully and with the help of a qualified and trusted vendor, better lighting, improved efficiency and the full range of benefits from human-centered design and aesthetic versatility can all be had for a reasonable and quickly recoverable cost.

Highlighted resources

Eaton's Lighting Systems and Solutions business outlined key considerations for reviewing, researching and planning compliance under the more stringent standards in the application note: *Understand the differences between ASHRAE 90.1-2010 and ASHRAE 90.1-2007 and how to ensure code compliance*. With handy pointers to the most relevant and up-to-date information sources, Mark Gelfo's article *Energy Codes and Lighting Design* is another great place to start the code compliance assessment process.

The Illuminating Engineering Society LEM-7 Guide to Energy-Saving Lighting Controls was released in April 2014 in partnership with the Lighting Controls Association. Written by Craig DiLouie, LC, this brief guide outlines the latest energy-saving strategies, design considerations, equipment and communication protocols for indoor and outdoor lighting control systems.

In late 2013, Navigant Research published a lengthy report entitled *Intelligent Lighting Controls for Commercial Buildings*. This report features market analysis through 2020 by region and commercial building type with a technical focus on networked lighting controls. Information is available on advances in sensors, ballasts, drivers, switches, relays, controllers and communications technologies with profiles of select industry players.

About Eaton

Eaton delivers a broad range of innovative and reliable indoor and outdoor lighting luminaires and controls solutions specifically designed to maximize performance, energy efficiency and cost savings. Offering one of the broadest selections of products in the industry, we serve customers in the commercial, industrial, retail, institutional, residential, utility and other markets.

As lighting technologies have advanced, we have been at the forefront of the industry in helping businesses and communities leverage the latest technologies to improve efficiency, reduce costs, enrich the quality of life and protect the environment.

Eaton is dedicated to ensuring that reliable, efficient and safe power is available when it's needed most. With unparalleled knowledge of electrical power management across industries, experts at Eaton deliver customized, integrated solutions to solve our customers' most critical challenges.

Our focus is on delivering the right solution for the application. But, decision makers demand more than just innovative products. They turn to Eaton for an unwavering commitment to personal support that makes customer success a top priority. For more information, **visit www.eaton.com/electrical**.

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