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Lighting Technologies

Produce Energy Savings

Advanced lighting controls can accommodate multiple energy management strategies at the same time



Figure 1: Procter & Gamble Building, Toronto, Canada

BY TERRY MOCHERNAK

The U.S. spends about one quarter of its entire electricity budget on lighting, equating to approximately \$60 billion annually. According to the New Buildings Institute, lighting comprises an average of 37% of a typical commercial building's total energy consumption. The U.S. Department of Energy has projected commercial sector lighting to remain the most important individual end use in terms of energy consumption, at least through 2020. Nevertheless, lighting has traditionally not been considered a "controllable" energy load, since load management has historically focused on interruptible loads such as motors, chillers, and HVAC systems.

This is because, until recently, the only available option was to turn lights off via conventional means such as relay-based control panels and occupancy sensors. However, with the advent of more cost-effective dimming ballasts and the commercial availability of digital addressable dimming systems. Lighting is finally coming into its own as a powerful load management tool and as a critical component of the overall building energy management strategy.

Driving Forces

Significant market pressures continue to stimulate the need for ever more efficient lighting technologies. On the regulatory side, the adoption of ASHRAE 90.1-2004 has imposed much tougher standards on commercial building energy usage. Similarly, Title 24 legislation in California has required automated shut-off lighting controls and daylight-responsive control for several years now. The Federal government has also shown its commitment to energy conservation, as outlined in the Energy Policy Act of 2005 (EPact 2005). This legislation includes a \$1.80 per-square-foot (ft²) tax deduction for new construction exceeding ASHRAE standards, with a specific deduction of up to \$0.60/ft² for interior lighting. EPACT 2005 also requires that the existing 500,000 Federal facilities must achieve new energy efficiency standards by 2015 and that new federal construction must exceed ASHRAE 90.1 standards.

The marketplace has also seen tremendous growth in adopting the U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) point-rating system that provides a recognized standard for the construction industry to assess the environmental sustainability of building designs. Of the six LEED topic areas—site development, water efficiency, energy efficiency, material selection, indoor environmental quality, and design innovation—energy efficiency is the single largest driver of LEED certification points. Considering that lighting is typically the largest energy load in commercial buildings, lighting efficiency becomes a paramount consideration in achieving LEED certification.

Conventional Controls

Lighting control can quite simply be boiled down to two basic strategies—on-off

switching and dimming. By far the most dominant form of facility-wide switching is relay-based lighting control systems that switch lights by electrical circuits. This type of control can automatically turn lights on or off either by time-based schedules or astro-nomic control. The most prevalent form of automated local switching is the occupancy sensor, which controls specific areas and turns lights on and off based on occupancy.

... it is now possible to integrate lighting control systems with other building automation systems.

Generally, the most common application for dimming of lighting is by means of daylight harvesting. These systems measure the amount of natural daylight in an area and supplement it with enough artificial lighting to maintain recommended light levels. A photocell is used to measure daylight levels and is connected to and directly controls the dimming ballasts. Consequently, daylight-harvesting systems generally require one photocell per zone and function as a closed-loop system. Daylight-harvesting systems are generally restricted to a small portion of a building (typically perimeter luminaires only) in areas with an abundance of natural sunlight.

Conventional lighting control technologies have many limitations. For example, relay control systems can only switch lights at the lighting circuit level, which generally covers an area of 2,000–5,000 ft². This technology is therefore incapable of providing switching control of smaller zones, much less individual luminaires. The fact that these systems operate on a time schedule that has little correlation with the actual occupancy behavior within a particular space (i.e., schedules are generally set based on “first in” and “last out” methodology) severely limits their ability to optimize energy savings.

Similarly, daylight-harvesting systems also operate autonomously from other lighting control strategies, but are restricted to a small portion of a building and generally deliver a poor return on investment due to

high cost. On the other hand, occupancy sensor control can be an effective switching strategy, generally providing an average energy saving of 25-35% across an entire building and demonstrating a reasonably good payback. However, once again, occupancy control is a one-dimensional switching strategy that is generally not integrated with other control strategies.

Thus, the two main difficulties with conventional lighting control technologies are: (1) the inability to control luminaires on a discrete basis and (2) a lack of centralized intelligence necessary to employ multiple lighting control strategies at the same time. These deficiencies are now being addressed in the form of advanced integrated lighting control systems that have begun to enter the market.

Advanced Lighting Controls

Unlike their predecessors, advanced lighting controls are centralized, facility-wide control systems designed specifically for energy management applications. Such systems are generally integrated with a facility's information technology networks and provide addressability and control down to the individual luminaire. With the proliferation of open protocol communications standards for building automation systems, it is now possible to integrate lighting control systems with other building automation systems. Most advanced lighting control systems employ one or more proprietary protocols, such as BACnet or LONWorks, that use the Internet (TCP/IP) as the communications medium between control networks.

Once the control point can be addressed at the luminaire level, multiple lighting control strategies can then be implemented simultaneously. This capability results in a dramatic increase in energy savings potential with, in some cases, only a modest increase in the marginal cost of delivering this added functionality. The objective of advanced integrated controls is not just to reduce lighting-related energy consumption by some degree at the expense of reduced lighting levels, but to extract maximum possible energy savings by delivering the correct amount of light when and where required.

This all-encompassing, “holistic” approach to lighting control can dramatically increase a facility's energy reduction

Hospital's Lighting Control Retrofit Brings Healthy Savings

The R. Fraser Elliot (RFE) building houses Toronto General Hospital's executive suites, admin offices, research labs, food services, and emergency medical services. Constructed in 2001, this six-story, 175,000 ft² mixed-use commercial building was originally equipped with the most energy-efficient fluorescent lighting technology available, including T5 direct/indirect light fixtures, T8 2 by 4-ft deep-cell parabolics with electronic ballasts, and a lighting control system.

Problem

On average, lighting accounts for almost 40% of typical commercial building energy costs—a fact that led the facility operator, University Health Network (UHN), to explore innovative ways to further reduce their operational overhead through a facility-wide strategy to:

- Reduce lighting energy consumption by 50%
- Achieve a consumption-based payback of under five years (excluding incentives)
- Reduce lighting demand by 35%
- Provide demand-responsive load-shedding capabilities
- Maintain illumination levels consistent with IES standards and customer requirements
- Provide computerized lighting control via centralized and distributed software applications
- Improve overall lighting quality (including eliminating over-lighting) and workplace ergonomics

Solution

A number of energy-reduction strategies were investigated to achieve UHN's aggressive project objectives. Based on a number of factors—including the ability to accommodate personal control, task tuning, daylight harvesting, smart time scheduling, occupancy sensing and variable load shedding—UHN chose Toronto-based Encelium Technologies' Energy Control System (ECS) as the cornerstone of the retrofit. Electronic dimming ballasts, high-performance lamps, occupancy sensors, photo sensors, electronic wall con-



Night view of emergency entrance of R. Fraser Elliot Building, Toronto General Hospital, Toronto, Canada

trollers and lighting control hardware / software were installed in approximately 95,000 ft² of the building.

Measurement and Verification

A 25,000-ft² floor representing typical building lighting conditions was selected as the control area for measuring and verifying the lighting control system. Prior to retrofit, the lighting circuits of the designated control area were isolated and submetered for 60 days with a Revenue Canada-certified electrical meter to establish an energy consumption baseline. After the installation and activation of the Encelium system, energy data were recorded in the control area for two sample periods of seven consecutive days over the course of two months.

Results

The retrofit delivered energy savings that exceeded customer expectations through the deployment of the following energy management strategies: personal control, task tuning, daylight harvesting, smart time scheduling, occupancy sensing and variable load shedding. Lighting quality was improved by elimination of over-lighting in many areas. Individuals were able to control the light levels in their

workspace by use of the personal control software and in fact, generally tended to further reduce already task-tuned light levels through this feature. Other results included:

- Lighting energy consumption (kWh) reduction of 74% versus pre-retrofit baseline
- Lighting energy demand (kVA) reduction of 37% versus pre-retrofit baseline
- Improved lighting quality and workplace ergonomics
- Maintained IES recommended light levels
- Annual energy cost reduction of \$47,000 or \$0.45/ft²
- Simple payback from energy savings of four years (net 3.2 years with incentives)

Retrofit Area Specifications	Projected Savings
Retrofit Area—95,000 Sq. Ft.	588 MWh
Luminaires—1232	\$47,000
Dimming Ballasts—1220	3.2 Years Net Payback
Occupancy Sensors—148	33% Rate of Return
Photo Sensors—28	177 Ton CO ₂ Emissions Eliminated
PCs w/ Personal Control Software—340	

Estimated annual savings for the R. Fraser Elliot building

Project Summary:	
Energy Savings (Lighting)	
Demand (kW)	37.0%
Consumption (kWh)	74.0%
Energy Performance (Lighting)	
Demand Reduction	49kW
Consumption Reduction	588MWh/year
Utility Rate (effective)	
Demand	\$4.54/kW
Consumption	\$0.07/kWh
Control Area Specifications:	
Square Footage	25,000
Luminaires	244
Dimming Ballasts	240
Occupancy Sensors	29
Photosensors	4
PCs Equipped with Personal Control Software	85

Lighting Technologies Produce Energy Savings

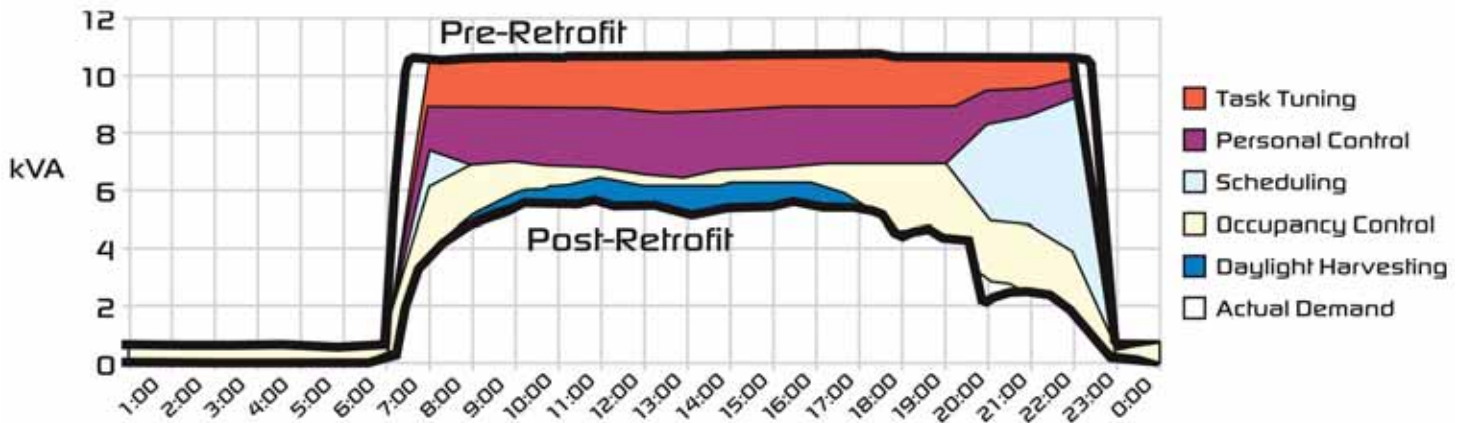


Figure 2: Data compiled at P&G Building showing pre- and post-retrofit energy consumption and demand levels, and the contribution of each energy management strategy to the realized savings

potential from a common baseline of 25-40% with conventional technologies to 65-80% with advanced lighting control systems. Side benefits include reduced maintenance costs due to lower lamp burning hours and an annual net reduction in HVAC energy costs (even in northern climates) as a result of less heat being produced by the lighting system during summer months. The “real world” value of advanced lighting control systems to the operational bottom line of modern office high rises like the Procter & Gamble building in Toronto, Canada, (see figure 1) has been quantifiably demonstrated. In figure 2, the color bands illustrate the individual contribution levels of each of several energy control strategies. The reduction in energy

consumption and demand after the control system retrofit can only be described as dramatic, at 66% and 45%, respectively.

Multiple Energy Management Strategies

Advanced control systems can employ as many as six different energy management strategies at the same time (see figure 3), as opposed to conventional technologies that can simultaneously employ, at best, one or two switching strategies and perhaps one dimming strategy. Consequently, in addition to the three most commonly used strategies—occupancy control, daylight harvesting, and time-scheduled switching—three additional lighting control strategies have

now become cost-effective and practical to implement.

- Task tuning, described as setting default light levels through dimming, based on the specific use or task in an area, can now be employed on a discrete workspace basis. Because lighting requirements typically vary according to different workspace conditions in a building, uniform and often excessive light levels can be eliminated.

- Personal dimming control allows each building occupant to use their desktop computer to adjust the light level to suit their own personal workspace preferences. When this personal control feature is accessible directly from the desktop, studies have shown that occupants use it extensively. Moreover, most users typically reduce lighting levels well below standard building light levels, thereby making it a powerful energy management strategy. Similar studies have also shown that occupants having greater control over their work environment also experienced enhanced productivity, reduced illness, and absenteeism (caused by over-lighting) and greater overall job satisfaction.

- The sixth energy management strategy, load shedding, is now possible through effective control of lighting loads. Load shedding is a technique for dropping building electrical demand (by way of dimming lighting), either to reduce demand charges by eliminating demand peaks or to reduce overall building consumption in response to energy price spikes. Some systems can actually shed lighting loads selectively and in varying degrees for different areas of a building, based on priority.

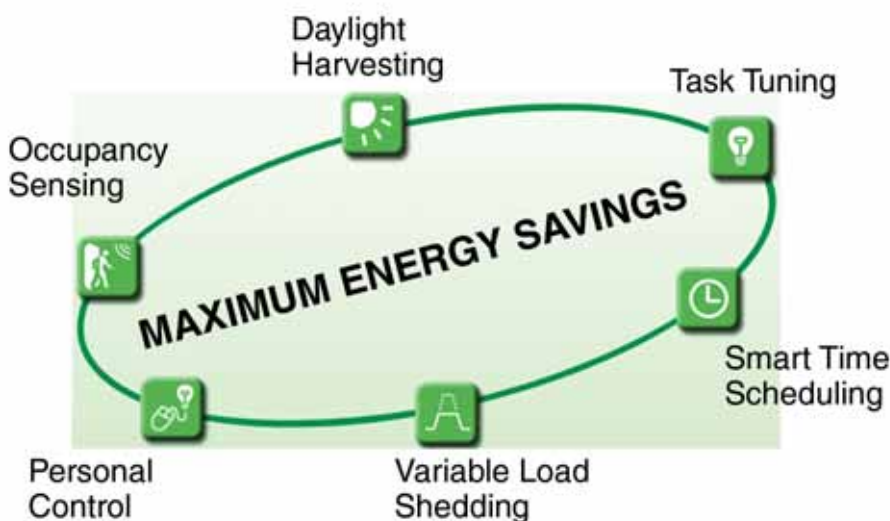


Figure 3: The multiple energy management strategies that may be employed at the same time by advanced, commercial building lighting control systems

Lighting Technologies Produce Energy Savings

Another advantage that advanced lighting control systems have over conventional systems is the ability to configure all system settings via software, either locally or remotely, from a central building system computer—instead of manually adjusting hardware or wiring if building use is altered or reconfigured.

Smart systems can also potentially be integrated with other building systems such as card access, security, and building automation systems. It is even possible to integrate these systems to the extent that when an occupant swipes a security card to enter a building on a weekend, for example, the building system will identify who they are, where their office is situated, and what their personal lighting preferences are. The system will automatically illuminate a “pathway” to the occupant’s office (without illuminating the entire floor) and then configure the light levels to the individual’s preferred set-

tings. Some manufacturers are also developing wireless versions of these systems that

Another advantage is the ability to configure all system settings via software from a central building system computer.

will further simplify matters by eliminating the low-voltage communication wiring to each light fixture. To this end, open-source mesh network technologies such as ZigBee (IEEE 802.15.4) and Z-Wave, are now being adopted for both commercial and residential applications, respectively.

Tomorrow’s Energy Savings Today

The impact that advanced lighting controls can have on the overall energy performance of

a commercial building should not be underestimated. If one assumes that lighting makes up an average of 37% of total building energy consumption and an average 65% energy savings are realized, this results in overall reduction in building energy consumption of 24%. At the same time, lighting quality is improved, occupants enjoy greater workplace satisfaction and productivity, and facility managers gain greater control of their lighting loads in the face of volatile energy markets and supply uncertainties. The era of the high-performance “smart building” is indeed upon us, and commercial building operators are beginning to see advanced lighting controls play a more central role in their integrated building energy management programs. *e&pm*

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