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FEATURE

What's New in Lighting Energy Technologies?

Almost 40 percent of the electricity used in commercial facilities in the U.S. goes toward lighting, and the quantity and quality of that lighting has a great impact on the working environment—no wonder energy managers pose lots of questions about how to use lighting most effectively and efficiently. Here are some of the questions that we are most frequently asked concerning the areas of daylighting, fluorescent lighting, and the new technology on everybody's radar screen—light-emitting diodes (LEDs).

Daylighting

What are the benefits of daylighting systems, and why should I consider using them? Well-designed daylighting systems, which use daylight to supplement electric lighting, have the potential to provide two major types of benefits: lower energy bills and an improved indoor environment. Energy bills can be reduced in three ways: electric lights can be dimmed or turned off in response to changing levels of daylight, peak demand charges can be reduced, and cooling energy costs can be cut. Daylighting may increase winter heating costs, but in most climates, space-conditioning costs will be lower with daylighting. Energy bills may also be cut if a daylighting system uses dimming ballasts that can enable a facility to participate in a demand-response program.

The amount by which energy bills are reduced will depend on a number of factors, including the type of building, the availability of sunlight, the type of controls used, and local energy costs, among others. In practice, energy use for lighting has been cut by roughly 20 to 80 percent through the application of daylighting technologies. For example, at a grocery store in Valencia, California, skylights and daylighting controls helped cut lighting

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energy use by 30 percent, with most of the reduction occurring during peak demand periods.

There is one caveat to keep in mind when calculating energy savings due to daylighting—the estimated savings will depend on what you use for the base case. When a daylighting system's energy costs are compared with those at a facility built according to local codes, you will generally see larger savings than if you compare them with costs at a building that uses high-efficiency lighting technologies without daylighting.

In order to minimize utility peak demand charges, daylighting systems typically need to be controlled by a system that can monitor demand and ensure that a cloudy period at the wrong time of day doesn't increase the peak. This can be accomplished by a system that can either keep the lights dim at the right time or cut some other load, such as space cooling.

The positive results of improved indoor environment are harder to quantify, but there is plenty of anecdotal evidence that there are benefits. Some studies by Heschong-Mahone Group have attributed increases in student test scores to natural lighting, and one 1999 study documented 40 percent higher sales in a retail chain's stores that had skylights.[1] More recent studies, funded by the California Energy Commission, also found evidence of such benefits, but the results were less dramatic—daylight was associated with an aggregated 6 percent average increase in sales among daylit stores.[2]

Research has highlighted other non-energy benefits derived from daylighting as well. The Lighting Research Center found that programmers in offices with natural light spent more time at their computers than did those with windowless offices.[3] There have also been reports that residents in senior living facilities sleep better and live longer when regularly exposed to daylight, and hospital patients located next to windows recuperate more rapidly.

I've heard that there are frequently problems with daylighting systems—what kinds of things can go wrong?
Daylighting problems have two major causes: the way in which daylight is brought into the building, and the way electric lighting is controlled in response to the daylight. If daylight is not brought in properly, it can lead to problems of glare and overheating. If glare isn't addressed in the initial design, people will close the blinds and there will be no benefit.

The control systems that modulate electric lights in response to changing daylighting conditions are more problematic. In a recent study of more than 100 installed systems, Prasad Vaidya, an energy analyst with The Weidt Group, classified control-related problems into underdimming, overdimming, and cycling.[4]

- *Underdimming* occurs if lights are left on at full power when they could be dimmed or if they aren't dimmed as much as possible, which leads to a less-than-optimal quantity of energy being saved. This type of problem often goes unnoticed—few people complain as long as they have enough light to get the job done. Poor installation and commissioning, overly complex system design, poor planning, and improper placement of sensors can lead to underdimming.

- *Overdimming* occurs when a daylight dimming system dims the lights too much, delivering inadequate lighting for the required tasks. This particular problem does not go unnoticed, and it's likely that either facilities staff or the occupants will disable the system. Possible causes of overdimming include dark furnishings, poor calibration, poor sensor placement, and excessive contrast between brightness at the windows and the interior brightness.

- *Cycling problems* arise when a daylighting system responds too readily to changing daylight levels and annoys the occupants. This is most often the result of poor calibration or no calibration at all.

What steps can I take to make sure that any daylighting system that I employ actually does what I want it to? There are a number of steps you can take:

- *Make commissioning part of the process from the beginning*. Commissioning a daylighting system consists of adjusting photosensors so that the electric lighting system responds properly to the presence of daylight. Unfortunately, with today's analog sensor technology, calibration is more art than science. Typically, a technician with a screwdriver stands on a ladder and adjusts the sensitivity of each sensor. There are no markings, so the technician simply adjusts the system until it works—but not necessarily until it works optimally. The technician keeps coming back until there are no more complaints. The process is complicated by the fact that the same signal from photosensor to ballast will produce different levels of dimming with different manufacturers' products. New products under development should help make commissioning easier.

- *Keep it simple*. Keeping a daylighting system as simple as possible may sacrifice some portion of potential savings, but simple systems are more likely to work properly. Typically, "simple" implies using fewer sensors, choosing open-loop rather than closed-loop controls, and sometimes using on/off switching rather than dimming. Open-loop systems monitor the incoming daylight but not the electric lights that are adjusted in response to the daylight signal. In a closed-loop system, photosensors monitor both daylight and electric light, and the signals from the sensors are used to adjust the electric lights.

- *Coordinate the efforts of all design professionals*. All members of the design team—architects, interior designers, mechanical engineers, and commissioning agents—need to coordinate their efforts. For example, if the interior designer isn't on the team, you may wind up with interior furnishings that are too dark for the planned daylighting system. If mechanical and electrical specialists aren't aware of the benefits of a planned daylighting system, the HVAC equipment may not be sized to take advantage of the reduced cooling loads and the controls are less likely to work properly.

- *Work closely with occupants*. The more the design team knows about the needs of the occupants, and the better informed occupants are about the daylighting system, the more likely occupants are to support the system and use it properly.

- *Supplement daylighting with task lighting*. Strategic use of task lighting can enable deeper dimming of ambient lighting.

- *Work closely with manufacturers, building operators, and contractors*. The Weidt Group's Vaidya has repeatedly found that controls have not been fully

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explained to building operators, who therefore give up on daylighting systems installed at their facilities.

- *Demand better controls documentation.* Vaidya reports that one of the major conclusions The Weidt Group has drawn from its studies is that controls documentation is often inadequate. As part of the solution, he suggests that lighting designers review construction documents, require and check shop drawings, create instructions for occupants and building operators, and develop a daylighting controls narrative to inform all of the building design teams.

Linear Fluorescent Lamps

I've already done a retrofit with T8 lamps and electronic ballasts; are the new T8s much better? The short answer is "Yes!" The most recent T8 technology, called "higher lumen" or "super T8," offers higher efficacy, longer life, and better color quality than earlier generations of T8 lamps (see **Table 1**).[5]

Savings from using super-T8 technology can be significant—the efficacy of a super-T8 system is roughly 70 percent better than that of a T12/magnetic ballast system, more than 20 percent better than the 700-series T8, and more than 10 percent better than the 800-series T8.

The costs of super T8 technology are also still high, although prices have come down as volume has increased. Still, according to a recent study by the Consortium for Energy Efficiency, the cost of a super-T8 or higher-lumen system is roughly 40 to 50 percent greater than that of a T12 system and 25 to 30 percent greater than a standard 700-series T8 system (see **Table 2**).[6] Payback periods for the super-T8 fluorescent lamps compared with other options will depend on local utility rates, system usage, and a series of interactions among lighting and other building systems.

Are low-wattage T8 lamps a good option to reduce lighting energy use? Low-wattage T8 lamps are an easy way to save energy in a retrofit situation, but they do have some limitations and are not the best choice for new construction. The three major lamp manufacturers—Philips, GE, and Osram Sylvania—now offer T8 lamps at lower wattages than the conventional 32-watt (W) T8s. Depending on the manufacturer, products are available with ratings of 25, 28, or 30 W. The lighting companies are pushing the low-wattage technology very hard, and, as a result, there seems to be a lot of demand.

Table 1: The evolving T8 family

Current T8 technology offers higher efficacy and better color than earlier generations of T8 lamps.

Lamp type	Nominal power (W)	CRI	Efficacy (initial lm/W)
700 series	32	70s	<85
800 series	32	Low 80s	87–94
Super T8 (higher lumen)	32	High 80s	94–100
Energy saver	30	High 80s	94–100
Reduced wattage	28	High 80s	94–100
Reduced wattage	25	High 80s	94–100

Note: CRI = color rendering index; lm = lumen; W = watt.

Source: E SOURCE; data from Consortium for Energy Efficiency [5]

Table 2: Incremental costs for T8 systems

The more-efficient fluorescent technologies carry a cost increment over the earlier T12 and 700-series T8 systems.

	Cost increment over T12 energy saver ($)		Cost increment over T8 700 series ($)	
	T8 800 series	Super T8 (higher lumen)	T8 800 series	Super T8 (higher lumen)
Lamp	1.50–2.00	2.00–2.50	1.00–2.50	1.50–2.00
Ballast	4.00–5.00	7.00–8.00	2.00–3.00	5.00–6.00

Source: E SOURCE; data from Consortium for Energy Efficiency [6]

However, we recommend proceeding with caution—the lamps do have several drawbacks:

- They are sensitive to cold temperatures and are therefore only suitable for use in conditioned spaces.
- It takes about 10 minutes for the light output to stabilize.
- The lamps work almost exclusively with instant-start ballasts, so they have no dimming capabilities and don't work with low–ballast factor ballasts or programmed-start ballasts. This feature makes the low-wattage lamps inappropriate for use with daylighting or occupancy controls.

Overall, that adds up to less flexibility in design and application. In addition, there is a feeling among some lighting experts that the introduction of all these low-wattage options confuses the market and makes it harder for people to identify the most-efficient alternatives.

There is also some concern about the permanence of savings, often referred to as "snapback"—when a low-wattage lamp burns out, it could easily be replaced with a 32-W lamp, which would wipe out any demand savings that had been achieved. That possibility could be minimized if a facility used, say, all 28-W lamps, as was done in a recent lighting retrofit at the campus of Northeastern University in Boston. Taking that step would also mitigate the problem of having to keep too many lamp types in inventory, but it might be hard to limit the number of lamp types that you need if you want to have dimming or occupancy sensors in some areas.

What about T5 fluorescent lamps? T5 and T5 high-output (HO) lamps are available only in metric lengths and use different sockets than T12 and T8 lamps, so they are not a good retrofit option. But they can be an effective choice in new construction or major renovations. The most common applications for T5 lamps are indirect lighting fixtures and fixtures for high-bay lighting. The efficacy of a standard-output T5 is similar to that of a super T8 lamp, but the T5's smaller size affords better optical control. The efficacy of a T5 HO is about 10 percent less than that of a standard output T5. The T5 lamp is designed for operation only on high-frequency, rapid-start, or programmed rapid-start electronic ballasts. T5 lamps also offer high lumen maintenance, putting out as much as 97 percent of their original light output at 40 percent of rated life. And T5 lamps are designed for a high optimal operating temperature, which improves performance in enclosed fixtures and warm spaces.

The introduction of T5 fluorescent lamps, which are thinner and offer a higher intensity of light output than T8s, has widened the applicability of indirect lighting. Indirect lighting minimizes glare and creates a soft, inviting environment for concentrated work. The high light output of T5 HO lamps means that rows of indirect fixtures can be placed as much as 12 to 15 feet (ft) apart on ceilings as low as 9 ft (some manufacturers claim that the fixtures can be used on ceilings as low as 8 ft, 6 inches) and still provide uniform ceiling illumination levels. Wider spacing means that fewer fixtures need to be used in a given space, and the overall cost for an installation can be reduced accordingly. By the end of 2006, at least one manufacturer may be offering very high output (VHO) T5 lamps, providing 7,000 to 8,000 lumens (lm), compared with 5,000 lm from T5 HO lamps. That development could open up more applications for the T5.

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LEDs

I've heard a lot of talk about LEDs—are they a good source for general lighting? LEDs are solid-state electronic devices that create light. They offer several advantages over conventional light sources, including long life and vibration resistance. The small sizes of LED sources and the directional nature of LED output are also advantages in some cases. These characteristics have enabled LEDs to replace incandescent lamps in some applications, but efficiency still needs to improve significantly and costs need to decrease before LEDs can become a cost-effective replacement for higher-efficiency sources such as fluorescent lamps.

The most successful early applications for LEDs have been those, such as traffic signals and exit signs, where LEDs replace filtered incandescent bulbs. That's because the filtering of emitted light makes an already inefficient source even less efficient. The efficacy of incandescent lamps is relatively low: about 17 lm/W for a conventional 100-W bulb. When incandescent lamps are used to produce colored light, an absorptive filter is placed in front of the white light source to absorb all colors except those that are required for the application. When red light is needed for, say, a traffic signal or an automotive brake lamp, this absorptive filter reduces the efficacy of the incandescent lamp-plus-filter combination to 1 to 5 lm/W. LEDs, on the other hand, are naturally narrow-band sources, and the color of the light they generate is based on the materials used to construct the LED instead of a filter that absorbs colors of light not needed for the application. Modern, high-brightness red LEDs operate with an efficacy of 15 to 30 lm/W, which makes them much more efficient sources of red light than filtered incandescent lamps. The other area where high-brightness LEDs have replaced other light sources is large outdoor displays.

For general illumination, LEDs still have a long way to go. As of 2005, the most efficient white LEDs available offered an efficacy of about 25 lm/W at ideal operating conditions and less than 20 lm/W at real-world conditions—not much more than a typical incandescent lamp. Producing white light with LEDs also still costs far more than it does with other light sources (**Table 3**).[7]

Table 3: Cost of light sources

It costs far more to produce 1,000 lumens of light with an LED than it does with other light sources.

Light source	Cost ($/klm)
Incandescent, 40 W	25
Fluorescent, F32T8	1
Metal halide, 175 W	2
CFL, self-ballasted	20
LED	150

Notes: CFL = compact fluorescent lamp; klm = thousand lumens; LED = light-emitting diode; W=watt. Includes replacement costs over 20,000 operating hours; does not include costs of energy.

Source: E SOURCE; data from Vic Roberts [7]

IN BRIEF

ACEEE Provides Resources on the Energy Performance of Commercial Buildings

The American Council for an Energy-Efficient Economy (ACEEE) has recently announced the release of two resources that provide information on improving the energy performance of commercial buildings.

The first, a web site entitled "Commercial Building Performance Resources," provides resources for improving the energy performance of building operations and maintenance (O&M). It has been shown that improved O&M practices can reduce energy use by 5 to 10 percent or more.

Resources found on the web site include building-performance program materials, technical resources, research reports, case studies and contacts.

The second, a report entitled "Comprehensive Commercial Retrofit Programs: A Review of Activity and Opportunities," discusses the experience and effectiveness of equipment retrofit programs and provides recommendations for retrofit improvements. According to the report, "A 15 to 40 percent reduction in energy use can result from a comprehensive retrofit." Programs examined include comprehensive retrofit programs for individual buildings as well as building systems.

To access the "Commercial Building Performance Resources" web site, please visit http://aceee.org/buildingperformance. To download a free copy of the report, "Comprehensive Commercial Retrofit Programs: A Review of Activity and Opportunities," please visit ACEEE's web site at http://aceee.org/pubs/a052.htm.

New Study: Energy Efficiency Could Reduce Natural Gas Prices

The American Council for an Energy-Efficient Economy has released a report entitled "Impacts of Energy Efficiency and Renewable Energy on Natural Gas Markets: Updated and Expanded Analysis." This report updates ACEEE's December 2003 analysis of the effects of renewable energy investments and energy efficiency on natural gas prices.

The study reveals that increased investment in energy efficiency and renewable energy could result in a 1 percent reduction in total energy consumption, translating into a 37 percent reduction in natural gas prices over the next 12 months. Projecting into 2010, gas savings of 4 percent or more could reduce natural gas prices by 20 percent. A section of the study analyzes the consumption and price effects of investment in energy efficiency in eight midwestern states and shows that modest savings can result in significant reductions in natural gas prices. This report also provides information on the eight state and federal energy-efficiency policies that have been proposed.

To access a free copy of this report, please visit ACEEE's web site at http://aceee.org/pubs/e052.htm. ACEEE's analysis from December 2003 has also been updated and can be located at http://aceee.org/energy/efnatgas-study.htm.

New Handbook on Energy Management Information Systems

The Office of Energy Efficiency of Natural Resources Canada (OEE-NRCAN) has published a handbook entitled "Energy Management Information Systems: Achieving Improved Energy Efficiency—A Handbook for Managers, Engineers and Operational Staff." This publication provides a structured understanding of energy management information systems (EMISs) and serves as a guide for implementation. The handbook is organized so that each level of operational staff may refer to pertinent sections.

Aspects of EMISs covered in this handbook include elements of a successful EMIS, cost-benefit analyses, EMIS design, reporting, data collection, data analysis, and metering. The handbook concludes with a checklist to ensure that readers choose effective EMISs.

To access a free copy of this handbook, please visit OEE-NRCAN's web site at http://oee.nrcan.gc.ca/cipec/ieep/newscentre/guides.cfm#EMIS.

Notes

1 Heschong-Mahone Group (HMG), "Skylighting and Retail Sales" and "Daylighting in Schools," prepared for Pacific Gas & Electric (August 20, 1999), from www.h-m-g.com (accessed February 12, 2005).

2 HMG, "Daylight and Retail Sales," prepared for the California Energy Commission's Public Interest Energy Research Program (2003), from www.newbuildings.org (accessed February 14, 2005).

3 Brian Libby, "Beyond the Bulbs: In Praise of Natural Light," *New York Times* (June 17, 2003), from www.daylightinglab.com/daylighting/articles/nyt_beyond_bulbs/Premium%20Archive.htm (accessed February 22, 2005).

4 Prasad Vaidya et al., "What's Wrong with Daylighting? Where It Goes Wrong and How Users Respond to Failure," presented at the American Council for an Energy-Efficient Economy's Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA (August 2004), The Weidt Group, Minnetonka, MN, www.twgenergy.com.

5 Afroz Khan (March 24, 2005), Commercial Program Manager, Consortium for Energy Efficiency (CEE), Boston, MA, 617-589-3949, akhan@cee1.org.

6 CEE, "High Performance Commercial Lighting Systems Initiative" (November 2004), from www.cee1.org/com/com-lt/com-lt-id.pdf (accessed June 14, 2005).

7 Vic Roberts, "Solid State Lighting: Status and Future Directions," presentation to E SOURCE Forum, Colorado Springs, CO (November 12, 2004), Principal, Roberts Research & Consulting Inc., Burnt Hills, NY.