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The Future Looks Bright: Energy-Efficient Lighting Technologies

New advances in controls, fixtures, lamps and more help reduce energy costs and environmental impact.

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Learning Objectives
After reading this article, you should be able to:

- Discuss recent green building initiatives related to lighting and energy efficiency
- List techniques and technologies for more energy-efficient lighting
- Explain how such products as LEDs and bi-level controls work
- Describe how the integration of daylighting and electrical lighting benefits building owners and occupants

The Future Looks Bright: Energy-Efficient Lighting Technologies

New advances in controls, fixtures, lamps and more help reduce energy costs and environmental impact.

By C.C. Sullivan

There's a revolution happening in lighting. While it has already been described as the "low hanging fruit" of energy-efficiency upgrades by more than one green building expert, today's new technologies, products and systems in the lighting industry are creating new opportunities to benefit the environment, end-users, and owner finances.

Private-sector interest in these advances has been buttressed by public policy, including more stringent energy codes. Reaffirming our government push for low-energy lighting, U.S. Department of Energy (DOE) Secretary Steven Chu recently announced more than $37 million from the American Recovery and Reinvestment Act to support high-efficiency, solid-state lighting (SSL) projects, such as light-emitting diodes (LEDs). Rebates and financial incentives have included the Commercial Buildings Tax Deduction, an Energy Policy Act of 2005 program of tax deductions capped at $1.80 per square foot, spurring interest and investment.

As energy prices continue to rise along with concerns about the environment, municipalities across the nation are investing millions to replace out-of-date lighting systems. In Anchorage, new LED streetlights draw 50 percent less energy than existing luminaires, saving the city $360,000 a year. By the time the lighting project is complete, the city's 15,700 replacement lamps will be saving Alaskans $1.7 million annually.

Another factor driving energy-efficient lighting is the need to relieve utility grids, which are operating at maximum capacity to meet ever-increasing demand — and not just during hot and cold months. On average, peak demand will increase by almost 15 percent by 2018, says a 2009 report by the North American Electric Reliability Corporation.

"The truth behind saving energy is to hold off on making more energy plants," says Tom Lueken, product manager with Kim Lighting. "You'll save money the day you start using an energy-efficient product, but the cost of energy will go up proportionately as the years go by."

On the consumption side, better lighting technology such as smart controls, LED and induction sources, and architectural luminaires are also driving new demand. "Much of the technology has existed for many years but has improved vastly and is now less expensive, such as dimming fluorescent fixtures or solutions that introduce daylighting into the space," says Lauri Maines, LC, president of Engineered Lighting Products, Inc. (ELP). Energy management systems more frequently tie into lighting, a fact reflected by the introduction of an intelligent buildings pavilion at Lightfair 2009. Even stand-alone fixture controls offer significant savings — up to 50 percent of total lighting power. Reduced run times also reduce maintenance needs, make lamp replacements less frequent, and extend product life span.

New LED fixtures with replaceable modules and large heat sinks areas, which extend the life of the light source, are being used in a variety of applications to save energy.
(Photo courtesy of Journée Lighting)

CODES FOR SMARTER BUILDINGS

Beyond today's flexible, easy-to-use control systems, energy codes are driving the adoption of intelligent lighting, says Pete J. Horton, vice president of market development with WattStopper. "Bi-level lighting, a requirement for California Title 24, EPACT 2005, and now part of ASHRAE 90.1-2010, provides for off, medium and high levels of lighting," he explains. In addition, ASHRAE 90.1-2010 will require automatic plug-load controls for 50 percent of receptacles, including those on modular partitions.

"State energy codes require efficient lighting sources measured in watts per square foot, automatic shutoff, usually an occupancy sensor or timer, manual on-off control, and multilevel lighting control," Horton adds. These measures also cut lighting costs from $0.40 to $0.60 per square foot to $0.15 to $0.25, depending on hours of use, occupancy and utility rates. A few municipalities even mandate daylighting: Seattle, for example, has stringent standards for natural light indoors under its 2009 Energy Code that require individual controls or daylight- or occupant-sensing automatic controls.

Lighting control system at the Department of Energy's Research Support Facility at the National Renewable Energy Laboratory
(Photo courtesy of RNL Design/Frank Ooms)

Other codes and standards driving the industry toward energy-efficient lighting and daylighting include the new LEED Version 3, which outlines a provision for lighting controls that enable occupant adjustments to meet both individual and group preferences. Title 24, California's energy code, now requires "Smart Grid" demand-response controls in retail stores of 50,000 square feet or more.

It's more than codes, of course, pushing project teams to focus on illumination. The main impetus? "Operating cost," says Scott Schuetter, energy engineer with the Energy Center of Wisconsin, Madison, WI. "Lighting comprises around 20 percent of a commercial building's energy use, and replacement is a cost-effective means of reducing energy usage, with paybacks of typically around a year."

APPLICATION IS EVERYTHING

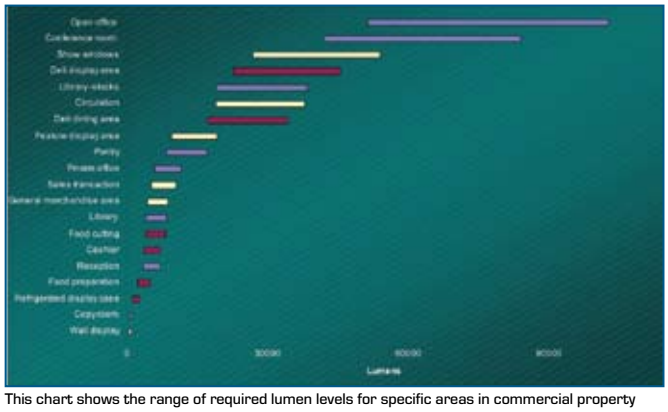
The big question is how to maximize resources, minimize upfront costs and optimize energy use. Because many aspects of design and application bear directly on system efficiency, careful attention to as many factors as possible will help assure success.

While general design rules — maximizing natural light, for example — can seem appealing, the most fundamental determinant of efficient lighting design strategy is project type. The chart at right shows the range of required lumen levels for specific areas in commercial property types, devised by Rensselaer Polytechnic Institute's Lighting Research Center as guidelines for architectural applications of LED devices. The lower end of each range, indicated by a bar, represents the ideal, where lighting operates at 100 percent efficiency; the high end of the range represents 50 percent efficiency.

The new Chandler, Arizona City Hall, designed by SmithGroup, was intended to provide effective daylighting, avoiding glare and solar heat gain.
(Photo courtesy of SmithGroup)

"The first step, without doubt, is to understand the needs of the client and the building. Inefficiencies in lighting energy use are related to systems that don't match how the building will be used," says Andrew Corney, sustainable design director with WSP Flack+Kurtz division Built Ecology, San Francisco, CA. "The second task is to understand the client's expectations: How do they expect to use and control their environment, and who is going to be making decisions about the quality of the light environment and its suitability?" The third task, Corney adds, is to select the products and approach that best meet the project needs.

Commercial — General Applications



This chart shows the range of required lumen levels for specific areas in commercial property types. A team at Rensselaer Polytechnic Institute devised this table as a guideline for architectural applications of LED devices.
(Source: Lighting Research Center, Rensselaer Polytechnic Institute)

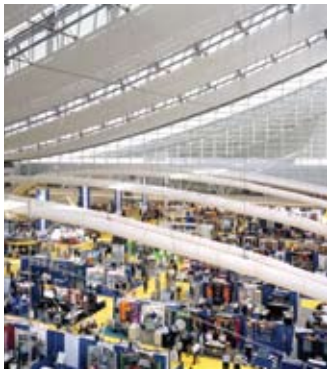
With technology changing quickly in this arena, many designers simply work with what they know. For that reason, Perkins+Will principal Joan Blumenfeld recommends working

with a lighting designer or consultant to stay on top of the latest improvements in lighting design. "Architects and designers tend to overlight space to build in a safety factor, whereas a lighting consultant will calculate exactly how much lighting is required, and no more," she explains. "Facilities managers may be concerned about installing too many fixture and lamp types, which means more to stock and replace. They often want to use what they know, which may not be the most efficient type."

Another mistake is swapping initial outlay during the construction phase for increased operational cost over the life of the building, when doing the opposite often pays for the increased first costs. Other important points for designing efficient lighting applications include:

• **Specify carefully for each application.** Tailor the lighting technique, system, source and fixture to the various spaces within the project to yield the highest performance and efficiency. For example, indirect lighting like cove lighting can provide warm accents at a low cost, using LED festoon and rope sources that help meet energy code requirements. According to ELP's Maines, novel cove fixtures include continuous, field-cuttable castings integral to the fixture, which reduce installation labor and costs.

• **Make use of natural light.** Daylighting has become key to efficient and sustainable design, but it's not always an appropriate choice. Depending on site positioning and climate, it can increase occupancy costs for cooling, for example. Corney recommends daylighting though the ceiling where possible, noting "It's significantly more effective, because glare and heat gain can be controlled much more easily."



The David L. Lawrence Convention Center in Pittsburgh uses a daylight harvesting system to cut energy consumption by 35%, an annual savings of about $500,000 per year. (Photos courtesy of Leviton)

• **Allow occupants to control illuminance.** Different times of day will call for more or less light, and efficient systems include dimming and other adjustability features controlled by the occupants. "Quite too often we exclude people — the human experience — from the equation," says Milena Simeonova, AIA, IES, LC, A IALD, a lighting consultant based in Riverdale, N.Y. "A new trend in design is the involvement of the end-users, so controls should be present and capable of adapting to the users' demands."

• **Rank efficiency among projects goals.** Reducing energy use is rarely the top priority. "Nor is our job just to meet the light levels designated in the *IESNA Lighting Handbook*," says Simeonova. "It's to understand the specific space, to role-play with the people who use the space, and to listen to what they need and like — and then push for creative and simpler solutions."

Controls Cut Lighting Energy by 40 Percent in Warehouse

Warehouses and distribution facilities tend to suffer from poor lighting quality, not to mention lost opportunities in energy savings. This was true for a 350,000-square-foot facility in Northern California operated by not-for-profit health plan giant, Kaiser Permanente.

To improve the situation, facility manager Marvin Cave oversaw a complete retrofit of the lighting system that added new, energy-saving controls. The upgrades, led by Concord, California-based Alamo Lighting vice president Robert Ofsevit, included several hundred occupancy sensors and time switches.

Prior to the upgrade, Kaiser Permanente's metal halide, high-pressure sodium and outdated fluorescent sources were powered on continuously from Sunday night through Friday afternoon. New systems would reduce those kilowatt-hours while improving the uniformity of light distribution to ease employee tasks.

The new system uses a single lamp type — a 5000 °Kelvin, 4-foot, long-life T8 fluorescent tube. In warehouse rack aisles, passive infrared (PIR) occupancy sensors are linked to individual six-lamp high-bay fixtures. Aisleway lenses sense workers approaching rack areas, powering on corresponding fixtures; otherwise, they remain off. Similar sensors control about half of the fixtures in packing areas and main aisles, where forklift traffic is high.

Under mezzanines, Ofsevit designed small task zones: About half the fixtures stay on, and the rest are operated by employees, as needed, via a digital time switch. Dual-relay wall switch sensors control bilevel lighting in private offices, switching automatically to 66 percent upon occupancy with an additional 33 percent available manually. In open office areas, lunchrooms and break rooms, ultrasonic sensors — which can sense around partitions — control illumination levels. A time clock takes care of secure storage rooms.

"The lighting upgrade has improved the quality of lighting in both the office area and warehouse, and saved a significant amount of energy and utility costs," says Cave. Proof is in the utility records, which show a 40 percent savings over the first year — enough to pay for the upgrades in only three years.

(Photo courtesy of WattStopper)

Suitability is a driving force for sustainable design, Simeonova adds. A properly lit space is a comfortable and healthy one — reducing eye strain, increasing productivity, boosting occupant satisfaction — which increases the building's usefulness and life span. The project team starts by balancing efficiency with a healthy regard for the needs and goals of the people who use the buildings.

Analyzing an LED Parking Luminaire

Energy savings are often accompanied by operational savings – and, occasionally, even first-cost reductions. All three advantages were seen when Boydston Engineering Associates of Auburn, AL, conducted an energy-use analysis for Greg Darden, development manager for Donald H. Allen Development's new North Park Parking Deck.

Using Illuminating Engineering Society (IES) recommended practice RP-20, principal Alan W. Boydston, P.E., calculated that 212 metal-halide fixtures at 150 watts each and 10 metal halide standards at 250 watts would consume 38,420 watts at night and 23,870 watts during the day. An alternative LED design with 214 LED fixtures at 75 watts each, along with 20 metal-halide entrance fixtures at 150 watts each and ten 150-watt standards totaled only 17,175 watts nightly, and 13,225 watts for the daytime.

These savings helped encourage the developer to choose LED for the $8 million parking deck. The long-life LEDs would also cut maintenance costs, and their unique design would reduce light trespass and control glare, making the facility safer for drivers, pedestrians and neighbors.

Darden also learned that LED lighting performs well in cold winter weather, which can degrade the performance of fluorescent systems. The LED sources, rated to last more than 50,000 hours — compared to 10,000 to 24,000 hours for comparable HID sources — also came with five-year warranties.

On top of that, the reduced energy loads allowed Darden to downsize electrical distribution and backup generators.

"I carefully considered fluorescent technology, which is getting a lot of attention now, and the industry standard is metal halide," he recalls. "But for a lot of reasons we went with LED, which offered a very promising cost-benefit curve."

Other green features of the 920-space hybrid precast and poured-in-place concrete deck include twin high-speed elevators, recharging stations for electric cars, covered bicycle parking, and an extensive digital security system.

(Photo courtesy of Kim Lighting)

LETTING DAYLIGHT IN

The sun is a plentiful natural resource, bringing with it abundant energy and light along with myriad health benefits. "Most projects, even basic tenant fit-outs, can benefit from utilizing natural lighting whenever possible instead of artificial sources," says Perkins+Will's Blumenfeld. A successful daylighting strategy can improve a building's life-cycle cost, reduce emissions and operating costs, and increase user productivity and satisfaction.

This last point is not conjecture. "Research has found that daylight is the 100 percent healthy package," says Simeonova. "Facts such as a 70 percent increase in work environment satisfaction and a 64 percent increase in work performance have been published by the Lighting Research Center, the National Institute of Building Sciences, and the Heschong Mahone Group. In hospitals, lighting and daylight in general are linked to overall health and faster patient recovery, as published by the Center for Health Design and the Robert Wood Johnson Foundation."

For new buildings, spaces to be sunlit can benefit from layouts that increase the structure's perimeter to maximize the usable daylighting area. To penetrate deeper into a space, clerestory windows and skylights are effective and also reduce the probability of disproportionate brightness. The design should also increase room brightness versus window brightness, for example through the use of light shelves, according to Southern California Edison's Gregg D. Ander, FAIA. Unintended side effects of daylighting, such as veiling reflections, glare and sharp contrasts, should be avoided.

While many lighting designs can be addressed through computer modeling, "There appears to be no software program or tool to help a designer who is not a mechanical engineer to understand both the lighting and energy impact of fenestration decisions," says Richard Keleher, founding co-chair of the Boston Building Enclosure Council. "While some programs exist, they are not benchmarked to U.S. standards." This is unfortunate, because the design team faces many challenges, solar heat gain chief among them.

SOURCES: SOMETHING OLD, SOMETHING NEW

Another challenge of daylighting is variable light quality, which can be addressed with proper selection of electric light sources and fixtures. In this arena, significant advances from the U.S. lighting industry are helping to push energy-efficiency levels. According to many lighting designers and engineers, many of those developments are decades old, with established track records.

Continues at ceu.construction.com

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Program title: **"The Future Looks Bright: Energy-Efficient Lighting Technologies" (09/10, page 93)**. AIA/CES Credit: This article will earn you one AIA/CES LU hour of health, safety, and welfare/sustainable design (HSW/SD) credit. (Valid for credit through September 2012). **Directions:** Refer to the Learning Objectives for this program. Select one answer for each question in the exam and fill in the box by the appropriate letter. A minimum score of 80% is required to earn credit. **To take this test online and avoid handling charge, go to ce.greensourcemag.com**

1. In addition to bi-level lighting, the energy standard ASHRAE 90.1-2010 will require:
- ❑ a. energy-efficient LED lighting for all new office buildings.
- ❑ b. photovoltaic systems connected to new lighting fixtures.
- ❑ c. automatic plug-load controls for 50 percent of receptacles.
- ❑ d. none of the above.

2. Some experts recommend daylighting though the ceiling where possible, because:
- ❑ a. integrated dimming technology only works that way.
- ❑ b. sunlight offers more healthful effects from a higher angle.
- ❑ c. other lighting sources are ceiling mounted.
- ❑ d. it is easier to control glare and heat gain.

3. What type of lighting has been credited with a 70 percent increase in work environment satisfaction and a 64 percent increase in work performance efficiency?
- ❑ a. Sunlight
- ❑ b. Metal halide lamps
- ❑ c. Solid-state lighting (SSL)
- ❑ d. Fluorescent biax lamps

4. T8 fluorescent lamps consume about 40 percent less energy than 1.5-inch-diameter T12 lamps. Last year, in the United States, what portion of fluorescent lighting products sold were the less efficient T12?
- ❑ a. About one-quarter
- ❑ b. About half
- ❑ c. One out of 100
- ❑ d. Almost none

5. LED and induction lighting systems share a number of advantages. Which of the following is NOT one of those advantages?
- ❑ a. They have a larger installed base than HID lamps.
- ❑ b. They are instant-on sources.
- ❑ c. They are dimmable from zero to 100 percent.
- ❑ d. They are rated for up to 100,00 hours of life.

6. Overheating degrades the performance of an LED light source. True or false: LEDs also produce fewer lumens per watt at lower temperatures, such as in a refrigerator.
- ❑ a. True
- ❑ b. False

7. While some LED sources are permanently attached to so-called "disposable luminaires," many new luminaires have replaceable light sources, called:
- ❑ a. R9 values.
- ❑ b. drivers.
- ❑ c. LED modules.
- ❑ d. bi-level controls.

8. A basic lighting control scheme provides for three lighting settings: off, medium and high. Occupants use the high setting about 20 percent of the time. This system is called:
- ❑ a. digital lighting management.
- ❑ b. plug-load control.
- ❑ c. tri-level control.
- ❑ d. bi-evel control.

9. California's Title 24 mandates the use of demand response (DR) using so-called "smart grid" systems for some end-users in the state. DR requires end-users to:
- ❑ a. turn off lights during specific times of the day.
- ❑ b. voluntarily reduce building energy loads.
- ❑ c. integrate lighting and daylighting controls.
- ❑ d. all of the above.

10. Education is seen as an important component of increasing lighting energy efficiency, because:
- ❑ a. owners prefer not to switch to lighting systems with which they are unfamiliar.
- ❑ b. there is limited awareness of new lighting technologies among corporate end-users.
- ❑ c. both of the above.
- ❑ d. none of the above.

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Material resources used: This article addresses issues concerning health and safety and sustainable design.

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"Ceramic metal halide is one of the most promising," says Gary Gordon, IES Fellow and principal of Gary Gordon Lighting, New York City, referring to a source that has been on the market for at least 15 years. "It's a mix of two older technologies from the 1960s, quartz metal halide and high-pressure sodium, which together offer excellent color rendering for low-energy uses."

A second source to consider, says Gordon, is halogen infrared, also known as halogen IR. "Many people are still using the same incandescent bulb that Edison deigned, and halogen IR is a drop-in replacement for existing fixtures that can slash energy use by one-third," he explains. A 60-watt halogen IR lamp, for example, yields the same amount of light as a 90-watt incandescent.

The Jewish Community Center on the Upper West Side in NYC, designed by Diamond and Schmitt Architects with the lighting designer Gary Gordon, features a range of energy-efficient lighting fixtures and lamps.
(Photo courtesy of Gary Gordon Lighting)

In addition, the Energy Center of Wisconsin's Schuetter notes that T8 fluorescent lamps are a workhorse of low-energy commercial lighting systems and will remain so for the foreseeable future. Yet the DOE estimates that of all 4-foot fluorescent fixtures and lamps sold in the United States last year, close to 50 percent were 1.5-inch-diameter T12s, which use more power.

"People are buying the older, less efficient technology!" exclaims DOE's Jim Brodrick, who oversees 71 research projects with a budget of $150 million in the Building Technologies Program. "You can save a good dose of energy by moving toward efficient T8s, with a whole new generation of ballasts." An F32T8 lamp, for example, consumes 19 watts less than the typical F34T12, which is typically rated for 44 watts — a savings of about 43 percent. (See chart below.)

Ballasts, needed to regulate the flow of energy through high-intensity discharge (HID) and fluorescent lamps, also consume wattage. Ballast factor (BF), also called relative light output (RLO), compares the lumens emitted from a ballasted lamp to the light output of the same lamp on a reference ballast at rated current and voltage. Ballast efficacy factor (BEF) — the ratio of the BF to input watts — describes the efficiency of the lamp/ballast system.

Efficiencies of Common Lighting Sources

Light Source	Typical Luminous Efficacy Range in lm/W (varies depending on wattage and lamp type)
Incandescent (no ballast)	10-18
Halogen (no ballast)	15-20
Compact fluorescent (CFL) (incl. ballast)	35-60
Linear fluorescent (incl. ballast)	50-100
Metal halide (incl. ballast)	50-90
Cool white LED >4000K (incl. driver)	60-92*
Warm white LED <4000K (incl. driver)	27-54*
*As of Spring 2009	

(Source: DOE EERE Building Technologies Program)

The most efficient ballasts are electronic, yet even those with the highest BEF use more power than *drivers*, which convert AC line voltage to DC for such lighting sources as LED and induction systems.

"LED and induction lighting systems bring other advantages over traditional HID sources," says April Ruedaflores, marketing manager with Kim Lighting, City of Industry, CA. "They're not just energy efficient, but both are rated for 100,000 hours life. And unlike HID lamps that are not instant-on sources, if power fails and a backup generator ignites, these fixtures will not skip a beat – no restrike delay. Also, Light Emitting Diode Systems (LEDs) hold their color temperature and other characteristics when dimmed, as opposed to many traditional sources that experience color shift."

LEDs have no mercury or lead, which are common in other lamp types. Another benefit, adds Ruedaflores, is that LED lighting systems are compatible with voltages from renewable energy systems. That means facilities can more easily go "off the grid" and use only energy produced on site by photovoltaic systems and the like.

LED PLUSES AND MINUSES

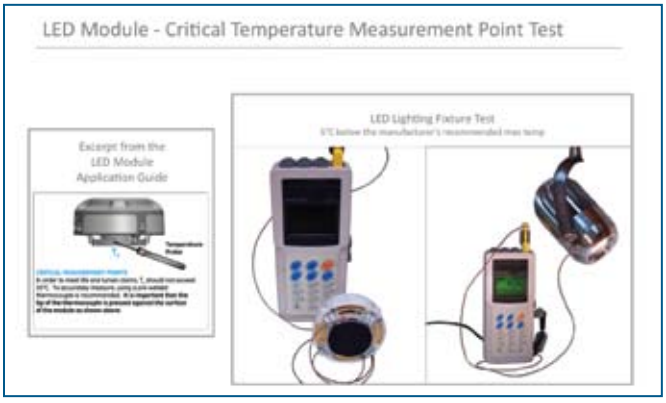
Of course, the primary draw of LED and induction systems are the jaw-dropping efficiency numbers, and these added features are improving their adoption in new building and retrofit projects. Yet, even though LED is considered to be one of the biggest technologies

Induction lighting sources, like this pole-mounted fixture, are instant-on sources, and many are rated up to 100,000 hours of life. (Photo courtesy of Kim Lighting)

revolutionizing the lighting design industry, the kinks are still being worked out as a number of sticky, technical issues remain. For example, while it's true that solid-state lighting (SSL) light output is "cool," its electrical mechanism is hardly so.

"LEDs generate quite a bit of heat at the point where the electric current is changed into light. The beam of light has very little heat, but there is heat generated at the LED chip, and this heat must be dealt with," cautions Avraham Mor, IALD, LEED AP, IESNA, Lightswitch Architectural, Chicago.

The effects of overheating are likely to be detrimental to the light output and operational life of the LED product, so careful research regarding the LED's thermal management capabilities is essential. "If the LED chip is not properly cooled, you do not get the published lamp life of the chip," says Clayton Alexander, founder and CEO of Journée Lighting, an LED fixture manufacturer. "The cooler that you keep the LED chip, via heat-sinking methods, the more lumens per watt you will get out of the LED. As an extreme example, if you put an operating LED in a refrigerator, the lumen output goes up. So thermal management is a very important part of the equation in LED luminaire design."



Heat-sinking is critical to LED fixture and luminaire design. If this fixture had a much smaller heat sink, the critical measurement point would read above 55°C, meaning that the lamp life and lumen output claims for the LED would not be met.
(Courtesy of Journée Lighting)

Lighting controls, including networked occupancy sensors, are being employed to directly control lighting energy use..
(Photo courtesy of WattStopper)

Alexander recommends that lighting specifiers look out for *under-heatsinking*, the effect of fixture designs without enough heat-dissipating surface area to properly cool the LED sources. "First, look at the fixture: Does the heat sink look a little small for the wattage?" As a point of reference, some new fixtures have 80 square inches of surface area within the heat sink to cool a 9-watt LED engine.

Performance documentation is the second line of defense, recommends Kevin Willmorth, a Wisconsin-based lighting consultant with Lumenique. "It is good practice to ask the manufacturer for independent test data showing the operating temperature of the LEDs when used as intended," he explains. "If the manufacturer cannot provide qualified data on the operating temperatures of the LEDs used and the electronic package behind them, it is better to pass than take a chance."

The key statistic for heat sinking is the *junction temperature* of the LED chip, says Alexander. "Ask the fixture manufacturer point-blank for the stabilized junction temperature of the chip with the fixture in a 25 °C ambient environment. Then you can compare that with the data sheet from the LED chip manufacturer," he says.

CONFIRMING SSL BENEFITS

As for the industry standard, Mor explains that the Illuminating Engineering Society's LM-80 testing procedure is the main evaluation of chip performance. However, it falls short of informing the specifier how that chip will perform once it's paired with a driver and installed in a luminaire. For that reason, Mor recommends reviewing the Energy Star label, which not only analyzes LM-80 data but also compares it against heat-testing of luminaires. In addition, savvy end-users should clarify the warranty details of what is considered a failure prior to purchase.

Circling back to another SSL benefit, reduced maintenance, manufacturers like to emphasize the technology's long life, often 10 years. As such, disposable luminaires have made their way into the marketplace. Because these units are unserviceable and meant for one-time, extended use, it becomes even more critical to have proper thermal management, protection from dust and dirt intrusion and shielding from incoming power spikes.

While this "no-maintenance" product does seem attractive — and could be a good choice for easily accessible outdoor applications such as landscape or roadway lighting — the industry's overall reaction has been mixed.

First of all, if the fixtures fail prematurely, replacement may require destructive measures such as cutting into a drywall ceiling, says Willmorth, which would be unacceptable. Replacement could also impact design integrity for the lighting systems. He adds, "If the products are replaced at end of life with no control over optical performance, how can a designer be sure that the space will remain as designed down the road? In some spaces, 50,000 hours is only seven years."

Most of all, throwing away the product — aluminum, glass, plastic and all — is far from sustainable. "What we need is better innovation of replaceable parts or better recycling by the luminaire manufacturers," says Mor.

Fortunately, some manufacturers have developed LED modules and chips that are easy to replace. "Today, there are field-replaceable modules that are end-user and consumer-friendly," contends Journée Lighting's Alexander. "Some modules have all the electronics inside the module including the LED driver circuit, meaning that the fixture itself does not have any components onboard which can fail over time." One module, he adds, has a thumb switch to change the fixture wattage, from six to eight to 10 watts.

Moving on to another key technical issue, color rendering index or CRI — and, in some cases, its R9 value, a measure of rendering deep red colors — requires attention. While a CRI of greater than 80 is usually acceptable in general settings, for retail and critical color applications, at least 85 and perhaps as high as 92 is required. Meanwhile, levels for R9 — oftentimes weaker with LEDs — should be at least 90 for critical color settings, advises Willmorth.

When investigating color rendering, Mor cautions that manufacturers may misrepresent this data, so it's important to review the company's "color constancy" policy. "I want to make sure that luminaire is going to have constant color when I order it today, and in three years," he says.

CONTROLS: REDUCING ENERGY USE

Another very significant approach to reducing lighting energy use is by integrating lighting controls in new and existing projects. Whether it's a straightforward bi-level switching set-up or the use of occupancy sensors or multiple illumination levels — or a more advanced daylighting harvesting or building-automation system (BAS)-integrated scheme — energy savings are there for the taking.

"A researcher at the CLTC, the California Lighting Technology Center, captured the opportunity in 2008, saying, 'If commercial buildings used existing lighting control technologies, they could see an immediate and sustainable savings of 50 to 60 percent,'" recalls WattStopper's Horton.

The simplest approach is priming occupants to use controls properly, says the lighting designer Gordon. "The most effective control in America today is a toggle switch," he says. "If you just turn off the light when you're not using it, we would save enormous amounts of energy." The next step up is bi-level lighting, Horton explains, a requirement for California Title 24, EPACT 2005, and now part of ASHRAE 90.1-2010. "This allows spaces to operate at a medium lighting level most of the day while occupants are on the phones or working with their computers," he says. "When an occupant needs a higher level of lighting, which occurs about 20 percent of the time, the occupant can raise the light levels to meet the task requirements."

Another low-tech, low-hanging opportunity is found in controlling *plug loads*, which includes not only task lighting but also computer monitors, coffee makers, printers and other nonessential plug-in devices. "If we could leverage the control system that turns off the lights to also control these nonessential loads, we'd get significant energy savings with very little incremental capital investment," says Horton.

DIGITAL ADVANCES IN CONTROLS

For major lighting installations and retrofits, project teams should look for advanced digital control strategies and systems, which offer distinct advantages over older, analog systems. "Digital control systems enable ladderless and toolless startup, calibration and commissioning," says Craig DiLouie, education director with the Lighting Controls Association, Rosslyn, VA. "They can consolidate the power switches for a load to a single relay that, in turn, is controlled by a programmable or adjustable control/logic card. This allows easy, simplified and cost-effective integration of multiple control inputs."

Some systems even enable configuration via handheld tools on site, while others work with an Internet connection and some even configure themselves, albeit to varying degrees of accuracy. Many of the packages are able to self-configure the entire lighting system, says Horton, including all the system controllers, occupancy sensors, switches, daylighting sensors, plug-load controls, lighting-control panels, interfaces and accessories. Lighting designers like Mor encourages clients to run automatic configuration programs but also to fine-tune settings during commissioning.

The fact remains that lighting systems, especially large ones, can be extremely complex, involving literally thousands of digital addresses. The cost of commissioning such a monster can be very steep and time-intensive, not to mention future changes to the lighter loads. "Manually, this can become unmanageable, as the complexity of the system becomes impossible to comprehend, and the manually mapped documentation becomes confused or lost," says Willmorth.

Faithfully addressing this technical nightmare, "automatic" systems can do much to simplify this process as this complex data is embedded into the system's architecture. Consequently, setting the levels becomes a matter of pointing and clicking. And when a luminaire burns out, the system will automatically assign the same control association with the new bulb, so there's potentially no commissioning impact.

However, one drawback is the lack of replacement parts currently available for these advanced systems. "This means that some lighting systems end up a hybrid of the manual and automatic, which can be a little messy," cautions Willmorth.

Unfortunately, a similar limiting-type situation applies to the Digital Addressable Lighting Interface. While the original goal was to create an open protocol, says DiLouie, "The standard suffered

National Parks Service Chooses LED Track Lighting

Lassen Volcanic National Park has long offered beautiful views and scenery 160 miles west of Reno, Nevada, but until recently it never had a visitor facility. After a 92-year wait since opening, the park now has the Kohm Yah-mah-nee Visitor Center at its Southwest entrance.

The U.S. National Park Service (NPS) elected to make the facility LEED Platinum, and included integrated daylighting and electrical lighting systems as well as a novel LED track lighting system supported on a field-bendable monorail.

The LED track system employs 50 luminaires to illuminate roughly 1,500 square feet of displays, kiosks and historic photos. "Through the use of this new LED-based track lighting system, the visitor center exhibits will be using less than half of the energy required by similar halogen-based lighting systems," says Ric Alesch, NPS project manager.

The track system is controlled by a digital dimming system that adjusts light levels in the exhibit based on the amount of natural daylight entering the space through picture windows on the facility's north façade. According to Journée Lighting, which manufactures the track system, the LED-based light fixtures comply with California's energy-conscious Title 24 code as well as U.S. Green Building Council LEED standards being adopted nationwide.

Before using the LED track fixtures for the exhibit area, NPS officials monitored the same system's performance at the agency's Harpers Ferry Center in West Virginia. An exhibit lighting consultant confirmed that the fixtures drew only 16 watts while producing luminance equivalent to a 40-watt incandescent bulb. In addition, unlike other high-efficiency light sources such as compact fluorescent and metal halide, the LED sources contain no mercury or lead and offered a long rated lamp life of about 40,000 hours.

The product evaluation also showed that the luminaires would help the Visitor Center meet or exceed platinum LEED certification.

(Photo courtesy of Journée Lighting)

from complex commissioning requirements, lack of definition for communication between controls and relatively slow data transmission speed. As a result, manufacturers have moved ahead on their own and now offer packaged, proprietary-protocol systems," explains DiLouie.

Consequently, users often find themselves locked into a single manufacturer for technical support and future component replacements. For this reason, some designers, such as Brett Lorenzen, a LEED-accredited electrical engineer-in-training with SmithGroup in Phoenix, prefer nonproprietary digital distributed-control systems.

DEMAND AND DAYLIGHT

Whatever the case may be, control systems are expected to continue proliferating, driven by the LEED guidelines and energy codes. For example, California's Title 24 mandates strict guidelines for dual switching, the use of occupancy and vacancy sensors, mandatory daylighting harvesting and, for some applications, *demand response* (DR) using so-called "smart grid" systems.

For DR, the end-user voluntarily reduces load or helps generate power to return to the gird, delivering significant savings and shaving peak loads for utility-wide benefits. Research shows that users can tolerate quick, steep reductions in lighting on a temporary basis, relates DiLouie, making it a good candidate for DR integration.

Regional utility rates and the availability of incentives determine whether DR is a viable option. In California, where peak demand rates can reach as high as $0.55 per kWh, DR is seen as the key to a reliable power grid. In the West North and Central regions, however, where the Energy Information Administration reports much lower rates, it really doesn't make sense.

Where it does, a facility's lighting system can be set up to initiate a load-reduction protocol at peak demand times. "This programming sequence, for example, would dim all lighting fixtures to an unnoticeable 80 percent of their maximum output over a period of five minutes, leading to significant savings," says Lorenzen. Such schemes require a capital investment in hardware and software, so many end-users will only participate if it is mandated by energy codes or induced by powerful utility incentives — or if they plan to use ballasts and controls already, notes DiLouie.

"That said, DR and smart-grid solutions remain very regional in nature, so are unlikely to have a large impact on the overall specification market," Willmorth concludes.

Noteworthy for lighting specifiers in all markets, however, are several up-and-coming integral daylighting/lighting control products. DiLouie is particularly interested in dual-loop technology, now under development at the California Lighting Technology Center and also marketed by a few manufacturers. Essentially, the technology solves the shortcomings of open-loop and closed-loop daylight harvesting strategies by rolling both technologies into a single, self-commissioning unit.

"Another valuable development is called dynamic façades, utilizing motorized window treatments controlled by intelligent systems that calculate sun's position, to reduce HVAC costs," says Susan Hakkarainen, chief creative officer of Ivalo Lighting

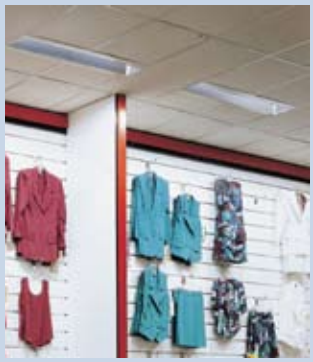
Merchandising with a Miserly Touch

Last year, the apparel stores owned by JCPenney — many featuring energy-miser lighting systems — helped their Plano, Texas-based owner become the first retailer to earn an ENERGY STAR Award for Sustained Excellence. This year, they repeated the win, too.

To earn the honors, JCPenney drafted a five-year energy strategy and cut their energy use by 5 percent over a 12-month period. About 10 new stores were built to meet ENERGY STAR guidelines, and another 20 existing stores were upgraded to that status.

In terms of lighting, retailers are focused on visibility, color rendering and intangible benefits such as "sparkle." To achieve those qualities while still reducing energy loads was a challenge.

Working with Wojno Construction and the lighting manufacturer, JCPenney was able to enhance merchandise displays while cutting power loads and maintenance costs at several stores.



(Photos courtesy of Robin A. Higgin)

For some merchandise displays, JCPenney replaced their incandescent track fixtures with state-of-the-art wall-wash fixtures, using two 40-watt biax fluorescent lamps. The light sources are shielded from normal viewing angles, yet the rectangular fixture with aluminum reflectors is shallow (3.5 inches) to fit in a small ceiling space.

This resulted in superior lighting on the merchandise: an even, unscalloped wash of bright light with excellent color rendering. Just as important for JCPenney, the fixtures garnered 72 percent savings in energy (see Fixture Comparison Chart below) and need to be relamped once every four years.

Fixture Comparison

COMPARISON	BEFORE	AFTER
Fixtures	12	12
Total Watts	1,080	12
Total Lumens	15,240	12
Lamp Life	2,500	12
Annual Operation Cost*	$566.09	12

*Based on annual use of 3,744 hours @ 10 cents per KWH plus the annual lamp cost.

A comparison of JCPenney's incandescent track fixtures versus their energy-efficient replacement: high-color-rendering fluorescent wall-washers.
Courtesy Engineered Lighting Products

thought out way, such as reducing light levels without sacrificing visual comfort."

Meanwhile, Mor sees much potential for BAS-linked daylighting and electrical lighting, although he and other lighting designers see the industry as being a few years away from a seamless BAS-integrated lighting system. A few forward-looking projects have also used weather monitors and tracking mirrors, but these have also been rare. "Those seem more suitable for warehouses and big-box applications where vertical footcandles are important," suggests John Hall, a senior associate with EYP Architecture & Engineering, Albany, NY. "Also, this type of technology in an office environment may increase cooling requirements and reduce the ability for occupants to select appropriate lighting levels."

Instead, Rachel Petro, IESNA, A IALD, LC, LEED AP, lighting designer, associate, RNL Design, Denver, relies upon the data for penetrating light levels and shading from daylight studies to inform the daylight harvesting system design. As such, the specification is based upon "the architecture, site location and orientation, and the system ultimately utilizes a combination of interior and exterior photosensors to determine the real-time light levels at the site."

DESIGN TOOLS FOR BETTER EFFICIENCIES

Project teams have a host of issues to sort out when designing and implementing a successful lighting system, including cost, performance and maintenance considerations. Over the past few years there has been a surge in lighting design tools meant to help ease those challenges, addressing energy-cost benefits, light-level and performance requirements, and the relative benefits of control schemes.

Several new, easy-to-use software programs help designers estimate energy savings, calculate watts per square foot, needed fixture counts and the like in the pre-planning and schematic design phases. Importantly, these tools also give designers a starting point on equipment and operational needs. These tools can perform assessments for multiple projects and retain data for future reference, and reports can be personalized for use in submittal packages and proposals. Among the most current:

- **Commercial Lighting Solutions** (CLS) is an interactive online tool created by DOE to help commercial buildings improve lighting efficiency by at least 30 percent over ASHRAE 90.1-2004. Developed in partnership with lighting designers, architects, and commercial end-users, CLS provides energy savings projections based on user input and selections. The solutions are designed to meet or exceed energy savings levels needed to qualify for tax incentives established by the Energy Policy Act of 2005.
- **Advanced Lighting Guidelines** will be published by the New Buildings Institute (NBI) this fall, with updated content on the importance of daylighting, evolution and new technologies of lighting controls, and integration of lighting design with other green building practices.
- **Plug-Load Calculation Tools** enable users to calculate energy savings opportunities as well as return on investment (ROI) by automatically controlling office equipment and other plug loads. "Many office workers leave equipment plugged in and on 24/7,"

says Jeff Park, LEED AP, CLEP, manager of sustainable market development for WattStopper, which created one such tool. "That's 8,760 hours per year of electrical consumption for task lighting, computer monitors, personal charging devices and more." Mobile versions are available for use on laptops and PDAs.

• **Other software programs**, such as EcoLumen, DIALux and Radiance, prove to be useful software for lighting designers and facility managers. Each program is slightly different and all have pros and cons — one program that can't do daylight calculations, for example — but essentially users enter basic information such as room dimensions and colors and space usage patterns, as well as fixture choices, and the software spits out recommended illumination levels and lamping options.

• **Energy-modeling software**, in addition to pure lighting programs, is also critical to designing of efficient commercial buildings that hold their value over time. Modeling assists architects and engineers in quickly identifying the most cost-effective and energy-saving measures for heating, cooling, lighting, water and other energy flows in buildings. EnergyPlus, OpenStudio and Energy-10 are just a few of the programs available online for use.

BIG CHALLENGES REMAIN

In spite of the technology solutions and the market pressures facing building owners, there are far fewer projects employing truly cutting-edge lighting systems. That means that across the country, we are still wasting energy where it isn't necessary.

The answer? "Education," says the Energy Center of Wisconsin's Schuetter. "People have trouble switching from the system types that they know and are comfortable with. More education will relieve this anxiety and allow for more widespread implementation." Gary Gordon agrees that there is a "huge lack of knowledge and awareness among corporate end-users."

"Another barrier is the economy and the worries of the future," according to Kim Lighting's Lueken. "All projects are taking a cautious approach and buying smaller quantities to appraise the application. By the time the appraisal is done, the product has improved and the analysis is outdated."

Other lighting designers, like Simeonova, are more optimistic. "I don't see any barriers. Energy-efficient lighting is favored initiative by government, politicians, Wall Street, academia, business, and the public. The challenge I see is to avoid focusing predominantly on numbers and issues, at the exclusion of people."