SEPTEMBER 2012

CONSULTING - SPECIFYING

engineer®

www.csemag.com

SAVING ENERGY THROUGH

Lighting retrofits

page 24

INSIDE:

Building energy modeling tools
page 32

CONSULTING - SPECIFYING engineer 2012 PRODUCT OF THE YEAR

Winners on
page 49

CFE Media®

CONSULTING – SPECIFYING
engineer
SEPTEMBER 2012

ON THE COVER: *The Hannah V. McCauley Library at Ohio University's Lancaster regional campus was remodeled recently and included lighting retrofits with a mixture of fluorescent T8 linear lamps, CFLs, and LED light sources. Metro CD Engineering performed the lighting design and provided construction administration services. Courtesy: Matthew Carbone*

COVER STORY

FEATURES

DEPARTMENTS

KEY

- AUTOMATION & CONTROLS
- COMMUNICATIONS
- ELECTRICAL
- FIRE, SECURITY & LIFE SAFETY
- HVAC
- LIGHTING
- PLUMBING

CONSULTING-SPECIFYING ENGINEER (ISSN 0892-5046, Vol. 49, No. 8, GST #123397457) is published 11x per year, monthly except in February, by CFE Media, LLC, 1111 W. 22nd Street, Suite #250, Oak Brook, IL 60523. Jim Langhenry, Group Publisher /Co-Founder; Steve Rourke CEO/COO/Co-Founder. Periodicals postage paid at Oak Brook, IL 60523 and additional mailing offices. Circulation records are maintained at CFE Media, LLC, 1111 W. 22nd Street, Suite #250, Oak Brook, IL 60523. Telephone: 630/571-4070 x2220. E-mail: customerservice@cfemedia.com. **Postmaster: send address changes to CONSULTING-SPECIFYING ENGINEER, 1111 W. 22nd Street, Suite #250, Oak Brook, IL 60523. Publications Mail Agreement No. 40685520. Return undeliverable Canadian addresses to: 1111 W. 22nd Street, Suite #250, Oak Brook, IL 60523. Email: customerservice@cfemedia.com.** Rates for nonqualified subscriptions, including all issues: USA, $ 145/yr; Canada, $ 180/yr (includes 7% GST, GST#123397457); Mexico, $ 172/yr; International air delivery $318/yr. Except for special issues where price changes are indicated, single copies are available for $20.00 US and $25.00 foreign. Please address all subscription mail to CONSULTING-SPECIFYING ENGINEER, 1111 W. 22nd Street, Suite #250, Oak Brook, IL 60523. Printed in the USA. CFE Media, LLC does not assume and hereby disclaims any liability to any person for any loss or damage caused by errors or omissions in the material contained herein, regardless of whether such errors result from negligence, accident or any other cause whatsoever.

Engineering a successful lighting retrofit

A lighting retrofit can be one of the easiest and most cost-effective methods to reduce a facility's energy consumption.

BY MICHAEL CHOW, PE, LEED AP BD+C, *Metro CD Engineering LLC, Dublin, Ohio*

Lighting retrofits can provide a flexible, maintainable long-term system in any type of building. Building owners can offer their occupants better light quality, improving working conditions and benefitting occupants as a whole.

A recent lighting retrofit project included upgrading existing lighting fixtures with T12 lamps to more energy-efficient T8 lamps and electronic ballasts. In this example, 40-W T12 lamps and magnetic ballasts were being phased out of production in July 2012, making replacement parts difficult to find. Consult GE Lighting's online document that covers this phase-out.

According to the U.S. Dept. of Energy's (DOE) 2010 U.S. Lighting Market Characterization report published in January 2012, at the end of 2010 there were approximately 941 million T12 lamps in use. Nearly 766 million of these were 48-in. T12 lamps, with 410.5 million in commercial buildings. The approximate savings in energy per year in retrofitting all the commercial T12 lamp fixtures (assuming 40-W T12 lamps) with T8 lamps and ballasts is $1.52 billion per year (see Figure 1). As shown in Figure 1, an existing facility with T12 lamps is a great candidate for a T8 lamp and ballast lighting retrofit. This retrofit could result in energy and cost savings of approximately 30%.

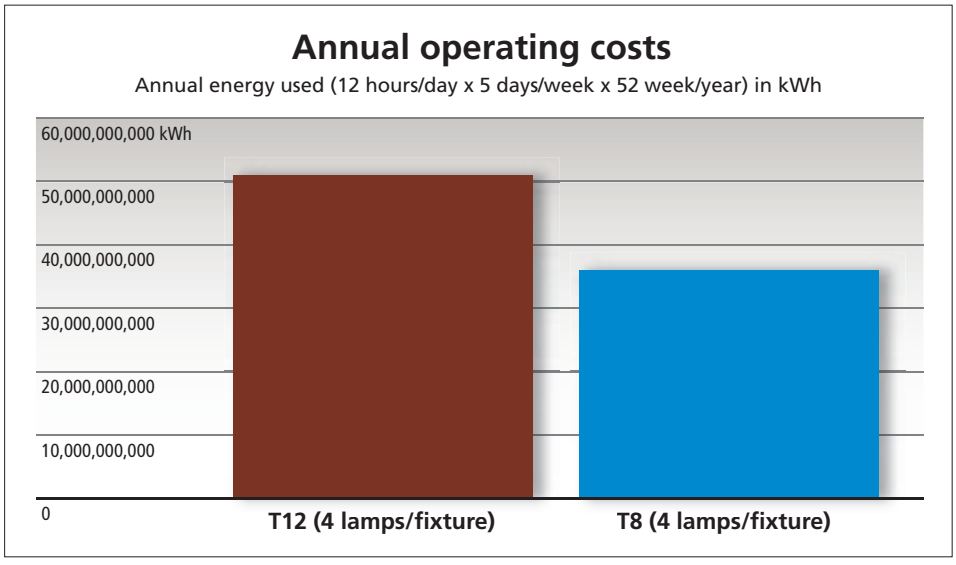

Figure 1: Data are based upon $0.10/kWh with lamps being used 10 hours/day, 5 days a week, 52 weeks per year; based upon all T12 lamps in comparison installed with 40-W T12 4-lamp lighting fixtures with 40-W lamps and 1.00 ballast factor with retrofits using four 32-W T8 replacement lamps with a replacement electronic ballast with a 0.88 ballast factor. Courtesy: GE Lighting

Standard T8 lamps are the same length (48 in.) as standard T12 lamps and can fit in most T12 lampholders. The existing lampholders should be checked and replaced as needed during retrofits. Standard T5 lamps are shorter in length (46 in.) than T12 lamps (48 in.) and in most instances are not as easy to retrofit in existing fixtures as T8 lamps.

Considerations and evaluations

What are some of the considerations when retrofitting from T12 lamps to T8 lamps? In many cases the original lighting fixture was UL listed with a T12 lamp

Figure 2: The Hannah V. McCauley Library is located at Ohio University's Lancaster (Ohio) regional campus. The recent lighting retrofits included a mix of fluorescent T8 linear lamps, CFLs, and LED light sources. Courtesy: Matthew Carbone

and magnetic ballast. What happens to the UL listing of these fixtures when the existing lamps/ballasts are replaced with a more energy-efficient T8 lamp/ballast combination?

In an online document, UL implies that modifying a fixture by replacing the existing lamps and ballasts in the field might negate the UL listing. UL offers a "field evaluation" service that provides for a UL inspector to visit a facility and evaluate its retrofits.

A luminaire conversion retrofit kit is an alternative to the field evaluation for a UL classification with lamp/ballast retrofits. This kit would be UL classified under the product category Luminaire Conversions, Retrofit (IEUQ). According to UL, "these products have been investigated to determine that, when used in accordance with the manufacturer's instructions, they do not adversely affect the operation of the complete unit." A database of IEUQ products can be found at www.ul.com/database.

Tubular lamps using multiple integral LED light sources can replace existing standard T8/T12 lamps and ballasts. LED light sources have a long life compared to other light sources. However, as was true when fluorescent lamps were in their infancy, the specifications for LED light sources might not be entirely accurate.

Learning objectives

- Understand the benefits of swapping out one light fixture to replace another
- Learn which lighting sources are best in each application
- Know how to evaluate an LED light source

An engineer has many items to consider when evaluating LED light sources, including reputation of the manufacturer, the warranty period, and review of the specifications including testing data that conforms to Illuminating Engineering Society (IES) procedures.

The following IES documents should be referenced with a LED light source: LM-79-08 Electrical and Photometric Measurements of Solid-State Lighting Products, LM-80-08 Measuring Lumen Maintenance of LED Light Sources, and TM-21-11 Projecting Long Term Lumen Maintenance of LED Light Sources. These documents can be purchased and downloaded from the IES website at www.iesna.org.

Tubular lamps

An important consideration when using a tubular lamp with LED light sources is the distribution of the light. Tubular lamps using LEDs have multiple light sources, and the light distribution differs from that of a fluorescent lamp. LEDs are directional light sources whereas fluorescent lamps are omnidirectional. For example, an existing lighting fixture that uses T12 lamps and has parabolic louvers could have significant light distribution and glare problems if retrofitted with tubular lamps with LEDs.

Another consideration when using tubular lamps with integral LEDs is whether to install a frosted lens or a clear lens. A clear lens may not be a good retrofit option when the lamps are exposed and visible to the building's occupants

For lamp and ballast retrofits, the AHJ should be contacted early in the design process to determine what is required for the permit and inspection process.

because the occupants may experience glare and eye strain.

Retrofits with tubular lamps with LEDs require removal of the existing ballast for the fluorescent lamps. An LED power supply (driver) is required that will be wired to the lampholders. The IEUQ database should be consulted to ensure the proposed installation will be a UL-classified retrofit.

The DOE has two references available online:

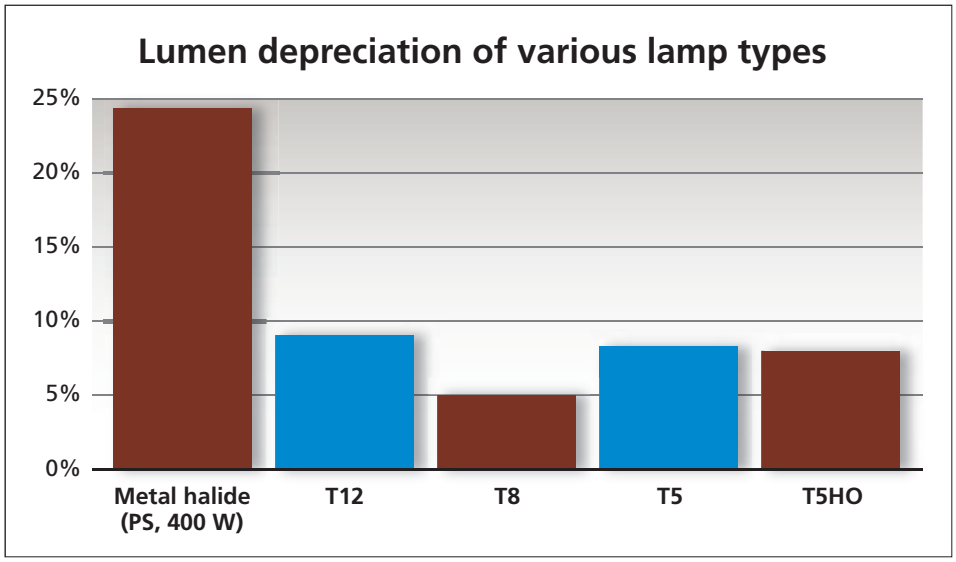

Figure 3: Data are from the GE Lighting catalog: fluorescent rated life is for 3 hr/start; metal halide pulse start lamp part #MVR400/VBU/HO/PA; T12 lamp part #F40/SP35/ECO; T8 lamp number #F32T8/SP35/ECO; T5 lamp number #F28W/T5/835/ECO; T5HO lamp number #F54W/T5/835/ECO. Courtesy: GE Lighting

- LED Performance Specification Series: T8 Replacement Lamps
- Performance of T12 and T8 Fluorescent Lamps and Troffers and LED Linear Replacement Lamps.

The DOE's 2010 U.S. Lighting Market Characterization report states that tubular LED lamps are two to three times less efficient than T8 lamps. The median efficacy for the testing done for the publications was 44 lumens/W. The highest LED tubular lamp efficacy was 70 lumens/W. The report also states that the LED tubular lamp manufacturer claims of 40,000+ hour life could not be verified.

Older warehouses and facilities with high-bay ceilings (higher than 15 ft) typically have lighting fixtures with high-intensity discharge (HID) lamps. These buildings can save energy by replacing the existing HID lamps with fluorescent or LED lighting. See the October 2011 DOE Industrial Technologies Program document on high-bay lighting retrofits for additional information.

According to GE Lighting's catalog, pulse-start metal halide lamps have a lumen depreciation (decrease of light output) around 25% of initial lumens at 8,000 hours of the 20,000-hour rated life. Fluorescent lamps have better lumen maintenance compared with standard pulse start metal halide lamps. Lumen depreciation for fluorescent lamps is measured at 40% of their rated life; this comes out to 8,000 hours with a 20,000-hour rated life lamp.

T8 lamps maintain their light output very well and have a lumen depreciation of 5%, according to the GE lighting catalog. T5 and T5HO fluorescent lamps have a lumen depreciation of 8% of initial lumens. The smaller size of T5 and T5HO lamps makes them attractive when a slim/narrow profile is desired. Standard T5 and T5HO lamps also have a longer life than standard T8 lamps—30,000 hours compared to 20,000 hours (see Figure 3).

The October 2011 DOE Industrial Technologies Program document examined replacing fixtures using pulse start metal halide lamps in high-bay applications with fixtures using fluorescent lamps and LED luminaires. The study reported that LED luminaires are available with slightly higher efficacy (80 lumens/W) than the benchmark four-lamp 32-W T8 fixture (79 lumens/W).

A design engineer should take into account the height of the lighting fixture in deciding what light source to use. For example, fixtures with T5HO lamps with the bare lamps exposed (e.g., without a louver or without a lens) generally should be mounted 14 ft or higher above the floor due to the high bulb brightness.

Ambient temperatures also should be considered when choosing a light source. Generally T8 lamps are designed for maximum light output at an ambient temperature around 77 F. T5 and T5HO lamps are designed for maximum light output at 95 F. Special lamps and ballasts designed for cold temperatures (rated to start at -22 F) should be used when the ambient temperatures drop below 60 F. These cold temperature lamps and ballasts will maintain lumen output at colder temperatures more effectively than standard lamps and ballasts.

For lamp and ballast retrofits, the authority having jurisdiction (AHJ) should be contacted early in the design process to determine what is required for the permit and inspection process. Many AHJs do not consider a lamp and ballast replacement a maintenance procedure and require a permit. Also, engineers should consider all applicable energy codes and check with the AHJ to see if the retrofit project is required to meet the energy codes.

Lamp recycling

Retrofitting existing fluorescent lamps and their ballasts requires proper recycling/disposal procedures as t items contain mercury, lead, and possibly PCBs.

Lifecycle cost analysis plays an important role in determining the best bang-for-the-buck with lighting retrofits.

Lamp recycling may be required by some states and local codes. Older ballasts (manufactured prior to 1979) may contain hazardous chemical PCBs, and many jurisdictions require such ballasts to be recycled. Details can be found at http://lamprecycle.org and www.almr.org (Assn. of Lighting and Mercury Recyclers).

Retrofits with fluorescent lamps should use lamps that contain low amounts of the hazardous chemical mercury. LEDs do not contain hazardous chemicals, making them easier to dispose of than fluorescent lamps.

Lumen output of the retrofitted lighting fixture with the new lamp/ballast combination should be comparable to the original configuration. Occupants should be surveyed to determine if they feel the pre-retrofitted lighting levels are adequate. A photometric point-by-point study should be done for both the existing and proposed lighting levels. The IES Lighting Handbook HB-10-11 can be consulted as a reference to determine the proper lighting foot-candle levels for each room/area.

Engineers should keep in mind when designing retrofits that mean lumens, the average light output over a lamp's rated life (usually at 40% of the rated life for fluorescent lamps according to the GE Lighting catalog), will be lower than initial lumens (light produced once the lamp has stabilized; for fluorescent lamps this is around 100 hours).

Lifecycle cost analysis

Lifecycle cost analysis plays an important role in determining the best bang-for-the-buck with lighting retrofits. Upfront material and labor costs are to be included in the analysis as well as the operational maintenance requirements of the new luminaires.

The life of the light source should be considered with the lifecycle cost analysis. Most standard fluorescent T8 lamps have a 20,000-hour rated life. There are now T5, T5HO, and T8 lamps that have a rated life of 30,000 hours or more. The incremental cost difference between a 30,000-hour lamp and a 20,000-hour lamp may be attractive considering the costs (labor and material) to change out lamps at a percentage of their rated life (usually at the 70% of rated life time frame for fluorescent lamps).

Fluorescent lamps and many white LEDs use rare-earth phosphors. Most of the world's supply of these phosphors comes from China. Recently, the export of rare-earth phosphors has been greatly limited by the Chinese government. This has resulted in a significant price increase for fluorescent lamps. White LEDs use a small amount of the phosphors compared to fluorescent lamps, so the white LED prices have not been impacted as much as fluorescent lamp prices have.

Due to the shortage of rare-earth phosphors, engineers should get up-to-date pricing and availability for fluorescent lamps when calculating the lifecycle costs for retrofits. Engineers should also consider fluorescent lamps with a long life (e.g., a 30,000+ hour rated life T8) to help offset the rising cost of the phosphors.

More saving can be realized with lighting retrofits by analyzing the efficacy (lumens/W) of the lamp and ballast combination. For example, the IES publication LEM-3-07 Guidelines for Upgrading Lighting Systems in Commercial and Institutional Spaces lists the mean lumens/W for various fluorescent lamp and ballast types. An engineer can use the data in this publication to help determine the most cost-effective strategies for lighting retrofits. An example of the use of the data is shown in Figure 4.

Super T8 lamps with low ballast factors (0.77 and below), also known as high-performance T8 systems, are a new technology that can reduce energy by 15% to 20% compared to standard T8 lamps and normal ballast factors.

Low-wattage fluorescent lamps (e.g., a 28 W T8 lamp compared to a standard 32 W T8 lamp) are available that consume less energy but produce about the same lumens as a standard wattage lamp. (According to the GE Lighting e-catalog, a 28 W T8 lamp has 2585 mean lumens; a 32 W standard T8 lamp has 2660 lumens). These low-wattage lamps have a greater incremental cost, but the return on investment can be worthwhile in the long run (see Figure 4).

A lifecycle costs analysis using LED light sources for retrofits should also be

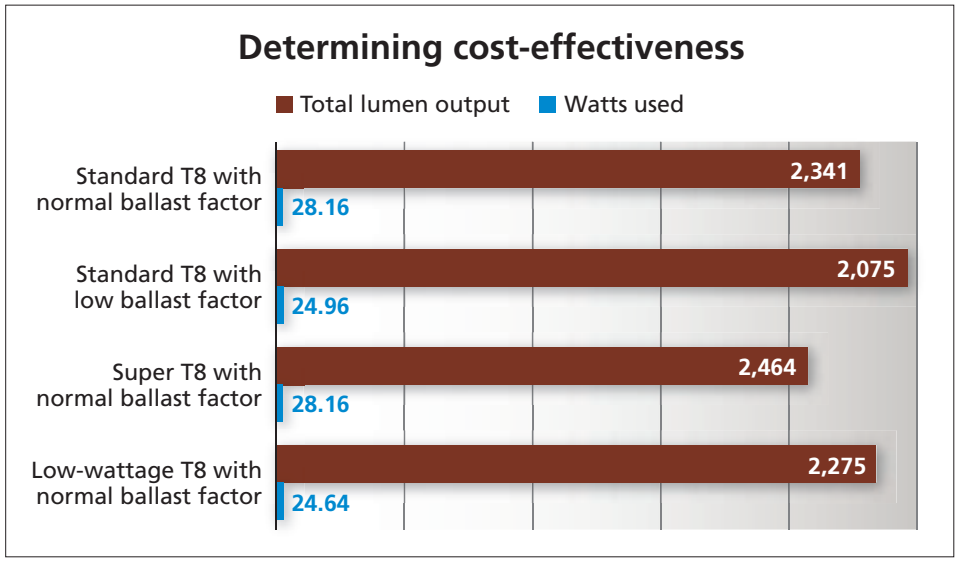

Figure 4: Data are from GE Lighting catalog; standard T8 lamp number #F32T8/SP35/ECO; super T8 lamp part number #F32T8/SPX35/ECO; low-wattage T8 lamp part number #F28T8/SP35.UMX/ECO; normal ballast factor: 0.88; low ballast factor: 0.78. Courtesy: GE Lighting

The efficacy of LED light sources has been increasing; some LED light sources have efficacies greater than those for fluorescent lamps.

considered. Many LED light sources have a projected life of 50,000 hours and have no hazardous chemicals to recycle. The relative high initial costs of LED light sources also may be offset by the savings realized by operational maintenance upkeep compared to standard fluorescent lamps. The efficacy of LED light sources has been increasing; some LED light sources have efficacies greater than those for fluorescent lamps.

Installation of lighting controls also can help reduce energy and maintenance costs. For example, time-of-day controls can turn off lighting at a preset time and turn it back on at another preset time. Temporary manual overrides should be allowed for users to turn on the lighting for a limited amount of time. Engineers should check with the energy code for their project to ensure the override time period does not exceed the time allowed by the code. Dimming or turning off lights when not needed extends the light source's life, reducing energy costs.

Other types of energy-saving lighting controls include occupancy/vacancy sensors, light sensors, and daylight harvesting.

In addition, cleaning of lenses should be factored into the maintenance schedule. When light is not able to pass through accumulated dirt and dust on lenses, system efficiency is reduced.

Group relamping of light sources is recommended versus spot relamping. A good strategy is to replace all lamps when the average lamp reaches a predetermined period of its performance life (e.g., 70%).

Color quality and dimming

Building occupants can benefit quickly from lighting retrofits. Good color quality, the right color temperature, and lighting controls are some of the advantages of a quality retrofit. Color quality typically is measured by the color rendering index (CRI) value, where 100 is the maximum CRI value. High CRIs may be important in certain applications such as retail and grocery stores.

Correlated color temperature is the color of the light produced by the light source. Choosing the correct color temperature for an application is important. Homes, restaurants, retail stores, and hotel lobbies generally use warm color temperatures (2700 to 3000 K) while offices have a neutral white color temperature (3000 to 4000 K). Museums and hospitals usually have cooler color temperatures, with lights at 3200 K and 3500 K, respectively; temperatures may go up to 5000 K or higher in some cases. To put this into perspective, an incandescent lamp has a warm white light and a color temperature of 2700 K at full intensity.

Retrofits of lighting fixtures with T12 lamps and ballasts with T8 lamps and electronic ballasts may provide flicker-free operation. The elimination of flicker is another benefit to occupants with this type of retrofit.

Lighting controls such as dimmers and bilevel switching can improve occupant comfort. Dimming controls can be installed with most lamps, including fluorescent lamps and LED light sources, provided dimming ballasts or drivers are also installed. Continuous dimming control allows occupants to manually adjust the amount of light to suit their needs. Another option is to install a daylight sensor with a continuous dimming system to automatically dim the lighting levels when there is adequate daylighting.

Bi-level switching or step-dimming can reduce energy costs and improve occupant comfort and control. For example, one use of bi-level switching would allow an occupant to turn off 50% of the lamps in each lighting fixture. Step-dimming generally provides two lighting levels (low and high) for the occupants. Keep in mind that step dimming or bi-level switching should be confirmed as acceptable to the AHJ and the applicable energy codes.

Dimming and bi-level switching for fluorescent lamps and LED light sources will add cost to retrofit projects. With continuous dimming, for example, fluorescent lamps require a dimming ballast and a compatible dimmer control. The design engineer should evaluate these costs when designing the retrofit.

Installation of occupancy sensors during a retrofit can save energy. Occupancy sensors should be installed in offices, conference rooms, restrooms, employee lunch/break rooms, copy rooms, file rooms, and so on. Occupancy sensors should not be installed in mechanical/electrical rooms and in areas where lighting is required for security purposes. Please check with the AHJ and the applicable energy codes when deciding where to use occupancy sensors.

Vacancy sensors can be installed instead of occupancy sensors to reduce energy costs. Vacancy sensors require a user to manually "switch on" the lamps. (Occupancy sensors automatically turn on the lights when someone enters a room.) Occupants can choose to leave the lights off and save energy. Vacancy sensors also help keep the lights off when someone enters a room momentarily.

There are incentives for lighting retrofits. One incentive is the federal Energy Policy Act of 2005 (EPAct05). To find incentives on a state-by-state basis, visit www.dsireusa.org.

There also are several other technologies to consider when designing a lighting retrofit system. These include Spectrally Enhanced Lighting, High Performance T8 Systems (HPT8), and other light sources such as Super T8 lamps and induction lamps.

Lighting retrofits performed correctly can save a lot of energy with a fast payback. Maintenance costs can be reduced by installing long-life light sources. Building occupants can also benefit from retrofits with better light quality and controls. cse

Michael Chow is the founder and owner of Metro CD Engineering. He is an accomplished electrical engineer and entrepreneur and is a member of the Consulting-Specifying Engineer *editorial advisory board and a 2009 Consulting-Specifying Engineer 40 Under 40 winner.*