Upgrading Troffer Luminaires to LED

Lighting accounts for roughly 20% of the electricity use in a typical commercial building, and the workhorse in these indoor applications has been the linear fluorescent lamp. In 2010, lighting systems using linear fluorescent lamps accounted for over 75% of the lighting service in commercial buildings. Recessed troffer luminaires, commonly available in 1' × 4', 2' × 4', and 2' × 2' sizes, provide the majority of this lighting. The total installed stock of common linear fluorescent luminaires in the United States is estimated to be over 960 million luminaires.[1]

Although the installation of LED troffer-style luminaires jumped from an estimated 40,000 units in 2010 to nearly 700,000 units in 2012, LED luminaires still represent less than 0.1% of the troffer luminaires installed in commercial buildings. It may be possible to achieve over 25% energy savings on a national level if LED technology reaches its projected market penetration in troffer luminaires of over 65% by 2030. The energy savings on an individual project can be much greater than 25%. The related economic and environmental benefits are substantial.[2]

Introduction

Three primary LED options exist for upgrading lighting systems that use fluorescent troffers: replacing the fluorescent lamps with LED replacement lamps, replacing the fluorescent lamps and other luminaire components with an LED retrofit kit, and replacing the fluorescent luminaires with new luminaires designed for LED light sources. Selecting the best option for an installation depends on the current lamp and ballast types and the condition of the fluorescent troffer luminaires, the desired photometric properties of the upgraded lighting system, the accessibility of the ceiling plenum, and the initial and ongoing economic goals for the upgrade. This fact sheet provides guidance on the various factors to consider when deciding on an LED upgrade for a fluorescent system.

System Factors to Consider

An evaluation of LED upgrade options includes assessing the system costs and the impacts on the lighting system performance. Table 1 summarizes a number of the key factors, and the accompanying text explains those factors. The column heading *Lamps* refers to LED replacement lamps; the heading *Kits* refers to LED retrofit kits; and the heading *Luminaires* refers to new LED luminaires. For each of the three LED upgrade options, the table provides a color-coded identification of whether a factor is favorable for the related LED option (green circle), whether there may be reasons to exercise caution based on this factor (yellow triangle), or whether there may be significant barriers to implementing the related LED option based on this factor (red square). *Note that the performance of the products available within each of the LED options varies and each individual product must be evaluated on its own merits.*

[1] *"Energy Savings Potential of Solid-State Lighting in General Illumination Applications", Navigant, January 2012, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/ssl_energy-savings-report_jan-2012.pdf.*

[2] *"Adoption of Light-Emitting Diodes in Common Lighting Applications", Navigant, April 2013, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led-adoption-report_2013.pdf.*

Initial Costs

Equipment Purchase Costs

LED replacement lamps often provide the lowest cost option in terms of purchasing the LED components. The cost of LED retrofit kits is usually more than replacement lamps, and purchasing new LED luminaires usually is the highest cost.

Installation Labor Costs

Replacement lamps that simply snap into the existing fluorescent lamp sockets provide the lowest labor costs for installation. However, most products marketed as replacement lamps require further modifications to the luminaire, and will have labor costs similar to products marketed as retrofit kits. Labor costs for installing retrofit kits are generally higher than those for replacement lamps, and depending on the extent of the luminaire modifications required, may approach or even exceed the labor

Table 1. System factors to consider for LED upgrades.

SYSTEM FACTORS TO CONSIDER	DESCRIPTION	LAMPS	KITS	LUMINAIRES
Initial costs	Equipment purchase costs	●	▲	■
	Installation labor costs	●	▲	■
	Safety certification costs	▲	▲	●
Operating costs	Energy costs for equal light output	■	▲	●
	Replacement costs over system life	▲	▲	▲
Current light levels	Acceptable; should not be reduced at all	▲	▲	▲
	Reductions of 10% or more are okay	●	●	●
Dimming required	No, dimming is not required	●	●	●
	Yes, dimming is required	■	▲	▲

costs for installing new LED luminaires. Labor costs for replacement lamps and retrofit kits are sometimes underestimated, such as when the electrician must perform additional wiring modifications and component removal. Some older systems have ballasts that contain PCBs, a hazardous substance that requires proper handling and disposal,[3] which can add to the installation costs.

Safety Certification Costs

New luminaires should already have required safety certifications (UL, CSA, ETL) and the cost of those certifications is included in the purchase price of the luminaire. With replacement lamps and retrofit kits, the original safety certification and warranty for the luminaire may no longer be valid, depending on the specific details of the product and modifications to the luminaire. A recent CALiPER project found that more than 50% of the replacement lamp and retrofit kit products evaluated could have been rejected by a local inspector due to issues with the certifications.[4] An on-site inspection and certification would then be required, at additional cost. (See the sidebar for further details on safety certifications.)

Operating Costs

Energy Costs

For retrofit projects that retain the existing number of luminaires and control scheme, energy costs depend on the wattage of the luminaire with the new components installed relative to the existing luminaire. But in some cases, the retrofit products offering the greatest wattage reductions also deliver much less light than the existing system. This may be acceptable—see the discussion on light levels below—but to compare across the categories of LED options, Table 1 assesses energy costs for equal luminaire output. In the CALiPER study cited previously, a few LED replacement lamp products provided little to no reduction in wattage; in fact, at least one product increased the system wattage. Based on efficacy data from CALiPER, LED Lighting Facts,[5] and other programs, new LED luminaires generally provide the greatest energy savings for equal luminaire output, followed by LED retrofit kits.

Replacement Costs

Ongoing replacement costs depend on the product and labor costs and frequency for replacing the light sources (fluorescent or LED) and the related auxiliary equipment (ballasts or drivers). Because the expected replacement frequency and costs require careful assessment for each application, the LED options are shown as yellow in Table 1 for this item.

Current Light Levels

Some LED products reduce the light output as well as input power, based on the assumption that many installed fluorescent systems provide more light than current standards require. Selecting an appropriate LED option depends on an assessment of current light levels and the extent to which they may be reduced. In cases where the existing light levels must be maintained, LED options require a full evaluation of their impact on the light levels. In cases where the light level can be reduced, the greatest savings may result from reconfiguring the layout to use fewer luminaires. The light distribution also needs to be evaluated, since many of the LED options produce different distribution characteristics than typical fluorescent troffers. In addition to increasing the chance for glare from the luminaire, this altered distribution also may result in uneven light levels in task areas and reduced light on the walls. Detailed calculations or measurements of a mock-up installation are needed to assess the light levels beneath and between luminaires.

Dimming

LED options are available for lighting systems requiring dimming capability, although dimmable products in the replacement lamp category were very rare at the time of this publication. Some combinations of LEDs, drivers, and dimmers can produce noticeable flicker, so retrofit kit and new luminaire options have been designated yellow in Table 1. Product samples of the exact configuration desired should be evaluated throughout the dimming range to assess the possibility of flicker and color shift.[6]

[3] *"Proper Maintenance, Removal, and Disposal of PCB-Containing Fluorescent Light Ballasts", EPA, http://www.epa.gov/epawaste/hazard/tsd/pcbs/pubs/ballasts.htm.*

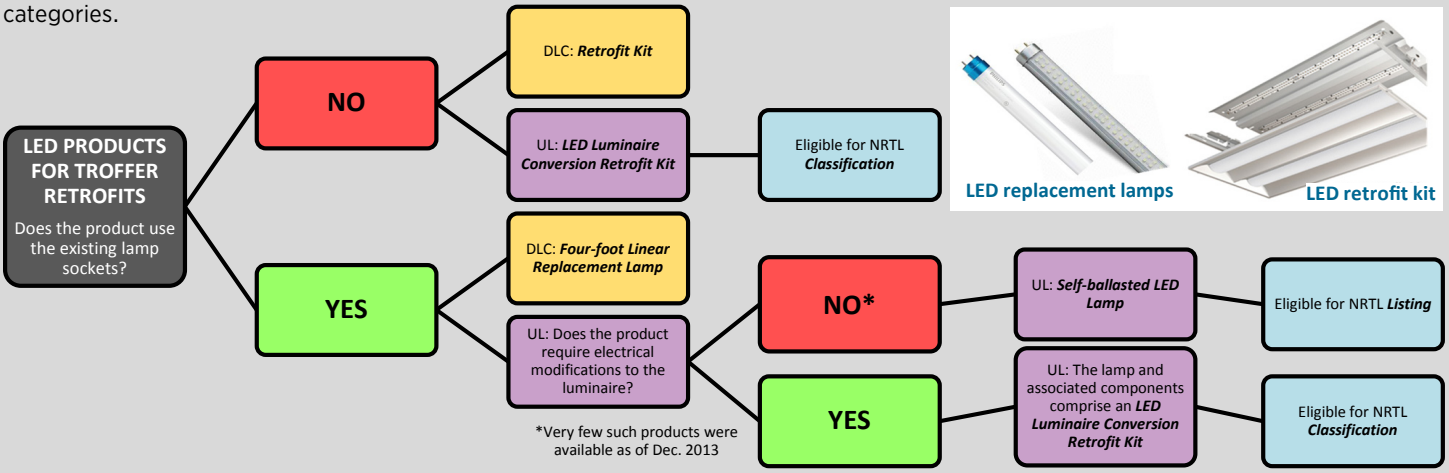
[4] *"Exploratory Study on Recessed Troffer Lighting", March 2013 (revised June 2013), http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/caliper_recessed-troffer_2013.pdf.*

[5] *http://www.lightingfacts.com/*

[6] *M. Poplawski, "Dimming LEDs: What You Need to Know", December 2012, http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/dimming_webcast_12-10-2012.pdf.*

LED Retrofit Options : Terminology and Safety Certifications

What is the difference between an LED replacement lamp and an LED retrofit kit? Various groups have differing definitions so the terminology used can be confusing. The LED Lighting Facts program allows manufacturers to self-classify their product as a Luminaire, Lamp, or Retrofit Kit; the definition is at the discretion of the manufacturer. The DesignLights Consortium (DLC) and Underwriters Laboratories (UL) differ in their categorization of these products. The chart below illustrates the differences between these groups, and the Safety Certification sidebar provides further details on the UL categories. This Fact Sheet groups products in a manner similar to the DLC categories.



Color Quality

Although not included in Table 1, the color quality of the LED upgrade is an important consideration. All of the LED categories offer products with a selection of correlated color temperatures (CCT), and all offer products with color rendering index (CRI) values in the 80s and higher, similar to fluorescent lamps. Still, LED products with poor color quality are available, often at low cost, so CCT and CRI ratings should be evaluated and product samples should be compared visually to the existing fluorescent products to assess any noticeable differences in color quality. Although CCT is not an indication of quality, it needs to be evaluated visually to avoid unpleasant surprises.

Existing Conditions to Consider

Lighting systems change over time. Many of these changes degrade the performance of the system, usually resulting in a reduction in light output. Some of these light losses are recovered through routine maintenance. For example, the light output of fluorescent lamps decreases over their lifetime, but is restored to the initial levels when the lamps are replaced. Similarly, the light output from the luminaire will be reduced by the normal accumulation of dust and particulates on the luminaire; these light losses can be restored through simple cleaning.

Table 2. Existing conditions to consider for LED upgrades.

EXISTING CONDITIONS TO CONSIDER	DESCRIPTION	LAMPS	KITS	LUMINAIRES
Condition of sockets	Look like new	●	●	●
	Some wear but no major cracks	▲	●	●
	Look old, blackened, cracks apparent	■	●	●
Condition of interior surfaces	Nice and white	●	●	●
	Slightly worn but no major scratches or peeling paint	▲	▲	●
	Very worn, scratches in paint, some peeling paint	■	▲	●
Condition of lens or louvers	Looks new; very little wear apparent	●	●	●
	Some minor color variations or scratches in surface	▲	▲	●
	Looks old, obvious cracks or yellowing	■	■	●
Ceiling access	No concerns with working above the ceiling; easy access	●	●	●
	Some concerns about working above the ceiling; limited access	●	●	▲
	Working above the ceiling should be avoided	●	▲	■

Safety Certifications

Manufacturers typically have their luminaires certified for electrical safety by a Nationally Recognized Testing Laboratory (NRTL) such as Underwriters Laboratories Inc. (UL), Canadian Standards Association (CSA), or ETL. If the NRTL determines that the luminaire meets the relevant safety requirements,[7] the luminaire is *Listed* by the NRTL. The manufacturer acquires and affixes the NRTL Mark to each luminaire, according to the requirements of the listing. LED replacement lamps that replace a fluorescent lamp without making any modifications to the luminaire are eligible for *Listing* as Self-Ballasted LED Lamps,[8] even those that do not have an integral driver but operate on the fluorescent lamp ballast. Products in this category can be used in a *Listed* luminaire without requiring further investigation. Very few products existed in this category as of December 2013.

When the electrical or thermal characteristics of a *Listed* luminaire are modified in the field, it is uncertain whether the modified luminaire continues to meet the relevant safety requirements unless the field modifications are investigated by a NRTL. Many tube-style LED replacement lamps require modifications such as installation of a driver and/or rewiring of the lamp sockets; the lamps and other components are categorized by UL as "LED Luminaire Conversion Retrofit Kits." (The LED retrofit kits discussed in this Fact Sheet also fall in this UL category.) LED luminaire conversion retrofit kits are eligible for NRTL *Classification*.[9] When a luminaire modification is performed using a NRTL *Classified* LED Conversion Retrofit Kit, the modified luminaire is considered to meet the same level of safety that was present prior to retrofit, without requiring an in-field investigation.

As part of the retrofit using a NRTL *Classified* LED luminaire conversion retrofit kit, the luminaire must be labeled indicating that the luminaire has been modified from its original condition and that it will no longer support operation from a light source other than the specific tube-style LED replacement lamp with which it has been fitted. The label must be prominent and the information on the label must match corresponding information on the installation instructions and other documents. If the labels are missing or do not match other documentation, or if the LED product used is not NRTL *Classified*, the local inspector can reject the installation as non-compliant with electrical safety requirements. A rejected installation usually requires an on-site inspection and field safety certification by an NRTL.

So, when evaluating LED upgrades to fluorescent lamp troffers, remember than an in-field safety investigation should not be needed for:

- A replacement lamp that requires no further electrical modifications to the luminaire and is NRTL Listed;
- A replacement lamp that requires electrical modifications to the luminaire such as installing a driver, and that is part of a properly installed NRTL Classified LED luminaire conversion retrofit kit; or
- A properly installed retrofit kit that is NRTL Classified.

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7 *"LED Equipment for Use in Lighting Products," UL 8750, http://ulstandardsinfonet.ul.com/scopes/scopes.asp?fn=8750.html.*

8 *"Self-Ballasted Lamps and Lamp Adapters," UL 1993, http://ulstandardsinfonet.ul.com/scopes/scopes.asp?fn=1993.html.*

9 *"LED Retrofit Luminaire Conversion Kits," UL 1598C, http://ulstandardsinfonet.ul.com/outscope/outscope.asp?fn=1598C.html.*

Other factors that may degrade lighting system performance over time cannot be addressed through routine maintenance. Mechanical degradation of reflector, lens and louver surfaces may result in a reduction in the amount of light being reflected or transmitted. This is sometimes accompanied by a yellowing of the materials or by painted surfaces becoming scratched or peeling. Electrical components such as lamp sockets and wiring also degrade, in some cases affecting the long-term performance of the lighting system. Normal replacement of lamps and cleaning of fixtures does not address these long-term degradations in system performance.

In addition to the system factors shown in Table 1, the existing conditions of the installed lighting system can affect which LED upgrade option may be most suitable. Table 2 identifies some of the important parameters, and uses the same column headings and color-coding scheme described for Table 1. *Note that the performance of the products available within each of the LED options varies and each individual product must be evaluated on its own merits.*

Condition of Sockets

Many replacement lamp products are designed to be installed in the existing fluorescent sockets, which may or may not be in suitable condition for those lamps. If the condition of the sockets cause any doubt about using replacement lamps, a visual inspection of the sockets by an electrician often is sufficient to determine whether socket replacements or other modifications are necessary as part of the upgrade.

Condition of Interior Surfaces

The interior painted surfaces of older luminaires may have significantly degraded or been damaged over time, and some LED upgrade options will not correct those issues. LED replacement lamps may be viable as a short-term solution if the interior degradation is not severe, but with significant degradation replacement lamps are not recommended. Some LED retrofit kits provide new reflector surfaces that mostly or completely cover the existing surfaces; the yellow designation in Table 2 indicates that a sample should be evaluated to ensure that the new reflector completely covers the degraded surfaces. The costs of any additional components need to be included in the economic analyses for the system. Again, a visual inspection of the luminaires can usually determine the extent of the modifications needed.

Condition of Lenses or Louvers

Similar to the interior surfaces of the existing luminaires, optical media such as lenses or louvers also may degrade or be damaged over time. Some of these materials turn yellow after years of use; some specular materials show color separation and variations in specularity; some materials become scratched from improper cleaning techniques or from handling during relamping. If the degradation is minor, consider replacing or removing these components as part of an installation of replacement lamps or retrofit kits, if new components are not included as a standard part of the upgrade. With more significant deterioration, replacement lamps or retrofit kits are only viable if the degraded components are also replaced. The costs of these additional components need to be included in the economic analyses for the system.

Ceiling Plenum Access

In some existing buildings, lighting system upgrades that require access into the ceiling plenum raise a number of concerns, from convenience and ease of access to health concerns related to potentially harmful materials that may be present. In these cases, replacement lamp and retrofit kit solutions that can be installed completely from below the fixture may be suitable, while installing new luminaires may be difficult if the above-ceiling access is restricted. In cases where any access or disturbance of the existing ceiling is prohibited, new luminaires are unlikely to be viable. Installation instructions for the upgrade options being evaluated should be reviewed to determine the extent of access that may be required.

Troffer Performance Criteria

Several groups establish performance criteria for troffer luminaires that use LED technology. The Better Buildings Alliance, a collaborative effort between the U.S. Department of Energy and owners, operators and managers of commercial buildings, provides fact sheets, specifications, and webinars related to high efficiency troffer lighting and other building energy products. The DesignLights Consortium (DLC) develops specifications for high efficiency, high quality commercial lighting solutions and maintains listings of qualified products that satisfy the specification requirements.

The DLC Technical Requirements Table (V 2.1) and the Better Building Alliance's Model Technical Specification for High Efficiency Troffers (V 4.0) establish the following performance criteria:

- Warranty of at least five years;
- Minimum luminaire efficacy of 85 lm/W;
- Minimum CRI of 80 (the BBA Specification also requires a minimum R_9 of 0); and
- Minimum of 50,000 operating hours with lumen maintenance greater than 70% of initial lumens.

Both groups also establish minimum lumen output levels for different size troffers. In addition, the BBA Specification[10] sets distribution goals in terms of the spacing criterion to help assure uniformity of lighting. The DLC[11] uses the same performance criteria whether the product is a dedicated LED luminaire, a fluorescent luminaire with an LED retrofit kit installed, or a fluorescent luminaire with LED replacement lamps installed. For LED replacement lamps, the DLC also requires a minimum bare lamp efficacy of 100 lm/W.

10 The BBA specification may be accessed at: http://www4.eere.energy.gov/alliance/activities/technology-solutions-teams/lighting-electrical.

11 The DLC Technical Requirements and related qualified product lists may be accessed at: http://www.designlights.org/.

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