LED Retrofit Kits, TLEDs, and Lighting Controls: An Application Guide

Lighting use constitutes between 10 and 20% of the total source electricity consumption in commercial buildings.[1] The vast majority of lighting in U.S. commercial buildings is provided by fluorescent troffer ceiling fixtures. Retrofitting these fluorescent troffers to light-emitting diode (LED) sources offers the potential for enormous energy savings. At a project level, retrofitting or replacing fluorescent troffers with LEDs can result in energy savings of 20 to 60% and help agencies meet energy-efficiency goals.

In a lighting upgrade of the New Carrollton Federal Building in Lanham, Maryland, the U.S. General Services Administration cut energy use by 82% and trimmed an annual lighting bill from $291,000 to $53,500 by replacing 11,800 fluorescent troffers with LED fixtures and controls. Photo source: GSA.

Troffer Lighting at a Glance

The term "troffer" is a combination of two different architectural elements: a "trough" and a "coffer." A troffer is a square or rectangular light fixture designed to fit into a modular dropped ceiling grid. Fluorescent tubes were introduced to the market in 1938, and ceiling troffer fixtures were soon designed to accommodate standard linear fluorescent lamp sizes (T12s, T8s, and T5s). Troffers are typically available in standard sizes of 1 × 4 ft, 2 × 4 ft, and 2 × 2 ft. There are hundreds of millions of fluorescent-based troffers in use in the United States; nearly every commercial building has them. Around 2010, LEDs began gaining popularity for interior lighting, and lighting manufacturers started designing troffer models with integral LED sources. Most LED troffer luminaires sold today are still designed in the traditional 1 × 4 ft, 2 × 4 ft, and 2 × 2 ft rectangular troffer shapes, although that may change for new buildings as architects and lighting designers realize they are free from the design constraints dictated by the size and shape of linear fluorescent troffers. Recognizing the preponderance of fluorescent troffers in existing buildings, lighting manufacturers also began marketing tubular LED (TLED) lamps and LED retrofit kits that replace the fluorescent light sources in existing troffers to provide the same light levels with longer-lasting LED solutions that use less energy.

Retrofit Options

This document provides guidance for retrofitting existing fluorescent troffer fixtures with LEDs. Information about lighting controls is also provided.

There are three retrofit options:

1. Lamp – Replace the lamp only with TLEDs.
2. Retrofit Kit – Replace the fluorescent lamps and other luminaire components with an LED retrofit kit.
3. Luminaire – Replace the entire fluorescent luminaire, including the housing, with a new LED luminaire.

Table 1 summarizes the pros and cons of each option, which agencies approve or have criteria for an option's use, and an approximate sense of installation time, energy savings, and first cost.

Figure 1 is a decision tree to guide decision makers in choosing the best option for their facility.

Tubular LEDs

TLEDs are LEDs that match the form factor (diameter, length, and base) of fluorescent tubes so they can plug into the existing sockets in a fluorescent troffer. There are three types of TLEDs:

1. UL Type A – This TLED uses the existing fluorescent ballast and also has an internal driver.

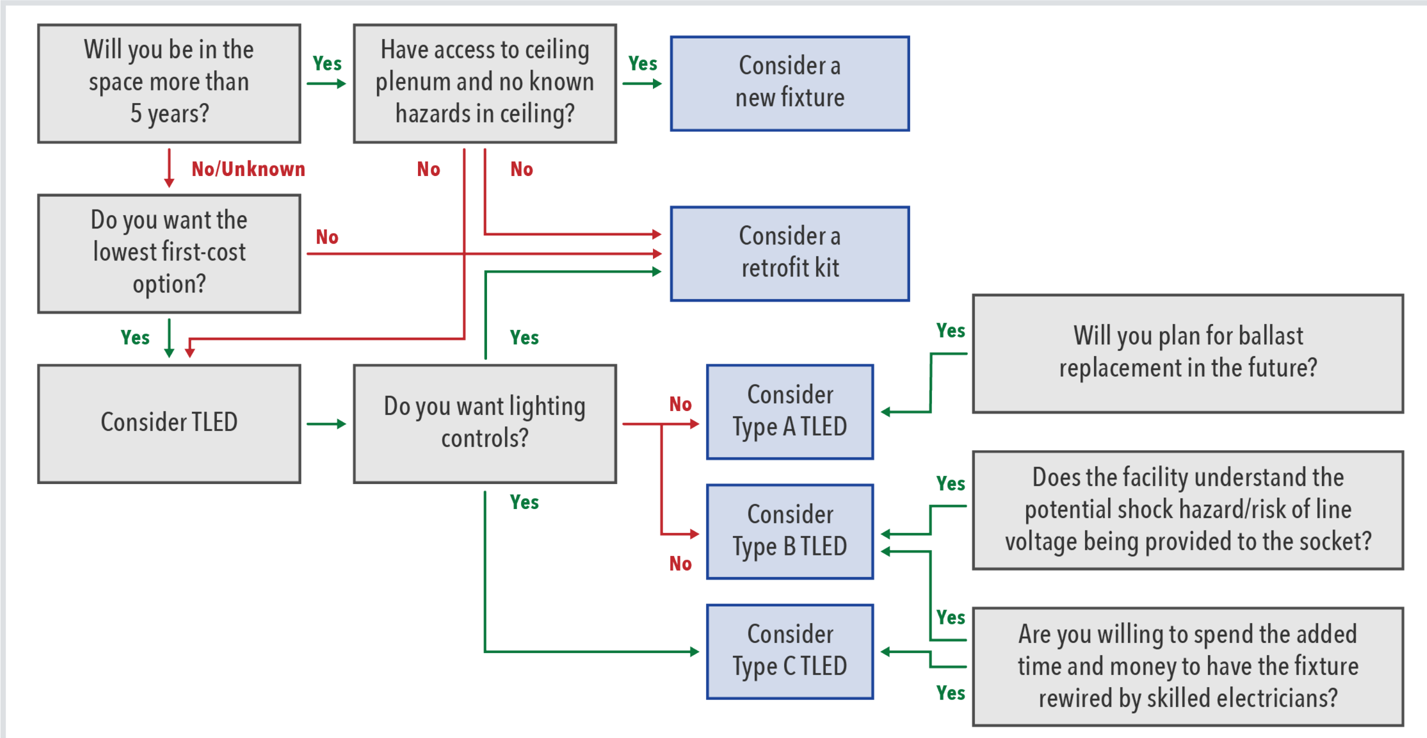


Figure 1. Determining the best LED troffer retrofit option for your facility.

2. UL Type B – The wiring from the existing ballast is terminated, the sockets are rewired from the branch circuit, and the TLED operates from line voltage supplied directly to the fixture; this TLED has an internal driver.

3. UL Type C – This TLED uses line voltage, but electrical connections to the ballast are terminated and the line voltage is connected to an external driver that powers the TLED.

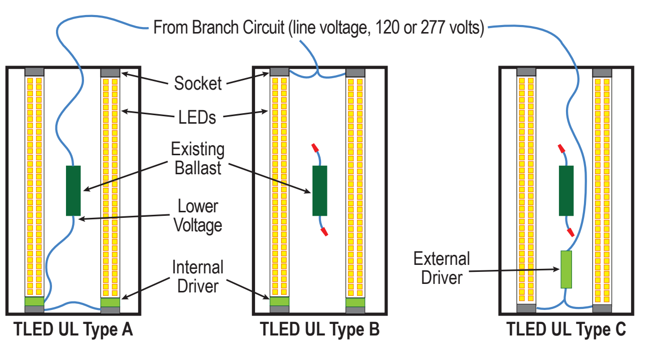


Figure 2. TLEDs can fit into existing sockets. UL Type A TLEDs use the existing driver. UL Type A and B TLEDs have internal drivers, while Type C TLEDs have external drivers.

When considering retrofit options, TLEDs tend to be the least expensive first-cost option. Another significant advantage of TLEDs is the time savings. In many cases, the reflectors and louvers or lens remain—the only part being replaced is the lamp (however, sometimes the sockets also need to be replaced). Installing a UL Type A TLED is as easy as replacing a fluorescent lamp. UL Type B and Type C lamp replacements take slightly longer because they require some rewiring, which can also increase the labor costs because an electrician is required. Figure 2 depicts these three TLED types, and Table 1 lists pros and cons of each.

With UL Type A TLEDs, the existing ballast stays connected to the sockets, whereas with Type B and C TLEDs, the ballast is disconnected. While fluorescent lamps use a ballast to regulate current and provide voltage to start the lamp, LEDs instead use a driver that controls the current and regulates the power. While UL Type A and Type B TLEDs have an internal driver, UL Type C TLEDs have an external driver, which provides better thermal management and may contribute to a longer-lasting lamp.

Although UL Type A TLEDs may seem like the simplest retrofit option because you can reuse the ballast, there are several things to keep in mind about fluorescent ballasts and TLEDs:

Option	Retrofit Option	Pros	Cons	Installation Time	Energy Savings	First Cost
1	TLEDs					
1 (Type A)	In-Line Ballast TLEDs	Use existing ballast and sockets. No rewiring, no electrician needed. Low shock risk. Fast. Lowest cost on parts and labor.	Aging ballast may fail soon; may be hard to find ballast replacement in the future. Possible ballast incompatibility. Possible flicker. High risk of product failure. May not dim. Least efficient of TLED options. To add dimming controls, must change the ballast.	< 5 min	20%	$
1 (Type B)	Line-Voltage TLEDs	Does not rely on existing ballast. Greater energy savings than in-line ballast. Low cost on parts. Quick installation.	Potentially fatal shock hazard at installation. Requires electrician. Requires label. Heavy TLEDs might cause issues with the lamp holders. To add controls to dim or reduce wattage, you must change the ballast.	< 15 min	30%–50%	$
1 (Type C)	External-Driver TLEDs	Safer than Type B. External driver provides better thermal management. Easier to add controls. Lower voltage from driver to sockets. Lower cost than retrofit kits. Most efficient of the TLED options.	Requires electrician. Requires a label. Not as efficient as retrofit kits. Heavy TLEDs might cause issues with the lamp holders.	< 15 min	30%–50%	$$
2	Retrofit Kits	Uses existing housing but replaces old lamps, ballasts, and sockets with new electronics and LED modules for longer life. Better heat management and lower failure potential than TLEDs. Higher efficiency than TLEDs. Can add lighting controls. Less labor than a new fixture.	Higher part and labor costs than TLEDs. Requires electrician.	< 15 min	60%	$$
3	New Luminaires	Maximum energy savings. Fixture is designed to optimize LED source performance. Maximum potential for adding lighting controls. Could add non-lighting controls (carbon dioxide, heat, etc.) Lowest failure potential; longest lasting.	Most expensive for parts and labor. Requires electrician. May require access above ceiling; potential safety and health risks. Most time to install. One-for-one replacement may over-light space and may require costly redesign for maximum efficiency.	> 30 min	60%	$$$

Table 1. Comparison of LED options for retrofitting troffers: pros and cons, costs and benefits.

- The fluorescent ballast will limit the energy efficiency of the luminaire. UL Type A TLEDs are the least efficient of the TLEDs.
- Ballasts vary, and it cannot be assumed that all ballasts will work with all TLEDs. Fixture manufacturers supply different ballasts in the same fixture line to reduce supply chain risks, so two otherwise identical fixtures could have different ballasts, which could lead to compatibility issues with some fixtures in a project.
- Aging ballasts are likely to fail before the TLED fails. As LEDs gain market share, some ballasts may become harder to find. If your ballasts are older than 5 years, consider UL Type B or C replacement lamps, retrofit kits, or new luminaires instead.
- As fluorescent ballasts age, they may cause flicker in some UL Type A TLEDs.
- Emergency lighting might be incompatible with some UL Type A TLEDs, so test the TLEDs if using them in an emergency lighting system.

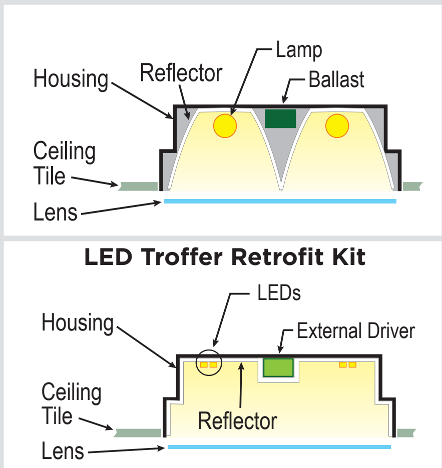


Figure 3. Troffer Retrofit – before and after installing the retrofit kit

UL Type B TLEDs, also sometimes referred to as line-voltage TLEDs, have the greatest safety risk because they involve rewiring 120-or 277-volt line voltage directly to the sockets. The installer is required to put a label on the fixture indicating that the fixture has been modified, that a potential shocking hazard exists, and that the lamp should not be replaced with a fluorescent lamp. Because of the high voltage, the shock could cause serious injury or death.

The DLC's requires that TLEDs have a minimum efficacy of 120-lm/W, which is a good rule of thumb to achieve at least 10% energy savings over the minimum requirement for fluorescent tubes.[2]

The DLC's requirement of 1,600 lumens (bare lamp) is a good minimum for TLED lamp retrofits.

Retrofit Kits

Retrofit kits cost more than TLEDs but are generally more efficient and, in some cases, can be installed almost as quickly as UL Type B or Type C TLEDs. Figure 3 shows the components in a fluorescent troffer and the same troffer housing with an LED retrofit kit.

The industry uses the term retrofit kit, while some federal agencies use the term conversion kit. The DLC defines an integrated troffer-type retrofit kit as a system that replaces the entire optical systems of the existing luminaire and fully integrates a replacement light source, optics, and reflective panel, These retrofit kits may not employ existing lamp holders or "pin" bases, and retrofit kits that have exposed LEDs, tube style lenses, or bar-style components are not eligible.

Installation Time Requirements

Although the electrical components (ballasts, sockets, and wiring) of the troffer are disconnected and usually removed with retrofit kits, retrofit kits allow for the fixture housing to remain in place. Not having to disconnect the housing from the ceiling to install a new housing is a significant time-saving feature of retrofit kits. The space above a fixture might have hazardous materials that could require remediation. Because labor costs can easily exceed the cost of materials, any reduction in labor time will add to the cost-effectiveness of the upgrade. Some troffer fixture designs are more difficult to retrofit because the fixture housing is contoured around the lamps (see Table 3). Also, the light distribution may differ after retrofit because the optics are designed for fluorescent lamps.

Efficacy

For LED troffer replacement kits, the DLC requires a minimum efficacy of 110 lm/W.[2]

Controls

Retrofit kits offer greater energy savings potential from lighting controls than is possible with TLEDs. The retrofit kit body itself provides a physical location to mount the sensors to. For small retrofit projects, retrofit kits can interface with stand-alone wireless controls systems. For large-scale whole-building retrofits, more complex controls systems can be deployed while new retrofit kit wiring is being installed.

New Luminaires

Replacing the entire fixture with new fixtures is typically the most expensive option, but also offers several advantages. It will likely provide both the highest efficiency and effectiveness in terms of the light source itself because the fixture components and housing shape are designed to maximize light output from an LED light source.

Depending on the model, whole-fixture replacement will likely work most seamlessly with controls and may come with the controls integrated in the fixture by the manufacturer. In addition, it will probably be a longer-lasting option. If the existing equipment is in poor condition, total fixture replacement may be the only option. The biggest disadvantage is the need to remove the housing from the ceiling, which may require access above the ceiling and potential health and safety risks, as well as increased product and labor costs.

Factors to Consider

Selecting the best option for an installation depends on several factors: the current condition of the ballast and luminaire components, desired photometric properties of the upgraded lighting system, accessibility of the ceiling plenum, purchase and installation budget, and ongoing economic goals for the upgrade. Product quality and performance vary widely within each upgrade option, and individual products should be evaluated on their own merits. Here is some guidance on the various factors to consider when deciding among the options for an upgrade to LED troffer lighting.

Existing Condition of Luminaires

Consider the condition of the luminaire when deciding whether to relamp, retrofit, or replace. Damaged housings, cracked or discolored lenses, scratches, yellowing of the reflector, peeling paint, and rusted or broken components can all contribute to the decision to replace or retrofit the luminaire rather than just replacing the lamps. If the ballast is older than 5 years, a UL Type A TLED lamp-only replacement is not recommended. Luminaire design can also make replacing the lamps challenging (see Table 3).

Equipment Purchase Costs

When considering purchase price, LED replacement lamps are usually the lowest-cost option, retrofit kits are higher, and new LED luminaires are the highest cost. Compare purchase and installation prices when considering retrofit kits versus new luminaires; retrofit kits are not always a bargain.

Installation Labor Costs

TLED replacement lamps that simply snap into the existing fluorescent lamp sockets can be installed in minutes per lamp, providing the lowest labor installation costs. However, some products marketed as replacement lamps require modifications to the luminaire and will have labor costs similar to products marketed as retrofit kits. (For example, UL Type A TLED lamps do not require wiring modifications, but Type B and C TLEDs do.)

Labor costs for installing retrofit kits are generally higher than those for installing replacement lamps but should be less than those for installing new LED luminaires. Some older systems have ballasts that contain PCBs—hazardous substances that require proper handling and disposal—which can add to the installation costs.

Ceiling Plenum Access

If you are considering replacement luminaires, determine if access above the ceiling will be required for installation, if the space is accessible, and if above-the-ceiling work might release contaminants into the occupied space. Some older buildings may contain asbestos in the ceiling tiles or above the ceiling tiles that could become harmful if disturbed. When working in health care environments, additional protocols may apply (for example, if the troffer replacement work could introduce dust into the space), and these protocols could add time and cost to the project.

Energy Savings

Generally, one would expect new LED luminaires to provide the greatest energy savings, followed by retrofit kits and then replacement TLEDs. In some cases, the retrofit products advertised as offering the greatest wattage reduction also deliver much less light than the existing system. Compare efficacy ratings to assure you are getting the amount of light you want—efficacy is the number of lumens produced per watt of power drawn.

Controls can greatly add to project savings. New luminaires may allow for more controls options and can be purchased with integrated controls; see the "Lighting Controls" section of this guide for more information.

Light Levels

For light output equal to what you currently have, measure your current lighting using a light meter, compare luminaire efficacy ratings, or use the estimates under "light output" in the "How LEDs Measure Up" box. If the current space is over-lighted, the greatest savings may result from installing lower-light-output luminaires or reconfiguring the layout to use fewer luminaires.

The light distribution also needs to be evaluated. LEDs have different distribution characteristics that can increase the chances of glare from the luminaire, cause uneven light levels in task areas, and reduce light on the walls. Detailed calculations or measurements of a mock-up installation can help you assess the light levels beneath and between the luminaires.

Color Quality

In addition to the light output of the troffer, the color characteristics of the light from the troffer play a critical role in the acceptability of the technology. Color quality can affect the work being done in lab and manufacturing facilities and is an important aspect of diagnoses in health care settings.

Correlated color temperature (CCT) is the color appearance of the light generated and is expressed in Kelvins (K). The CCT values of most commercially available light sources range from about 2700 K to 6500 K, with warmer, yellow-white light at the lower end (incandescent light is typically about 2700 K), and cooler blue-white light at the higher end. U.S. residents prefer lighting in the range of 2700 K to 4000 K.

Some LED fixtures allow for "color tuning," which means the CCT can modulate from about 2700 K to 6500 K.

How LEDs Measure Up

There are several measurements for describing lighting.

Efficacy is one key metric for comparing the energy efficiency of lighting equipment. Lighting efficacy is the conversion of power (Watts) into light (lumens) and is expressed as lumens per Watt (lm/W). Federal agencies and industry use several terms for efficacy that are all basically synonymous as long as the unit is lm/W: luminaire efficacy, luminaire efficiency, luminaire efficacy rating (LER), luminous efficacy, or efficacy. There are three key points to remember about lighting efficacy: (1) The higher the quantity of lumens (in lm/W), the greater the energy efficiency. (2) Efficacy does not measure effectiveness. You should test the light distribution with an actual installation in the space, if possible, before doing a building-wide retrofit. (3) Pay attention to whether the efficacy rating is for the bare lamp (or retrofit kit alone) or for the whole fixture. When a TLED or kit goes into a fixture, the efficacy of the fixture will be lower than the bare lamp/kit efficacy because the fixture traps some of the light.

If you know the efficacy of the TLED, you can determine the efficacy of the whole luminaire fairly easily using this rule of thumb. Troffer fixtures absorb roughly 25%–35% of the light generated by the fluorescent lamps, i.e., one-quarter of the light produced by the lamps never leaves the fixture. This 25% value can be used as a proxy to determine the LER for LEDs.

Illuminance is the amount of light falling on a surface and is measured in foot-candles, which is lumens/square foot.

When determining illuminance levels for a space, consider the age of the occupants and what type of work will be done in the space. Older eyes and highly detailed work may both require higher illuminance levels from the troffer lighting, or perhaps the addition of task lighting.

Brightness is a perception and is related to the amount of light emitted by the fixture. Two troffers can emit the same amount of lumens, and one can appear brighter than the other. The reasons for differences in perceptions of brightness include distribution, optical design, and spectrum of the source. Evaluate luminaires before installation to prevent complaints that the lighting may be too bright. Fixes to reduce brightness can also reduce illuminance, which could result in complaints that the lighting level is too low.

Light output is the amount of light emitted by a device and is measured in lumens. If you wish to maintain the current lighting levels when upgrading lighting from fluorescent to LED using retrofit kits or luminaire replacements, you can use the light outputs listed in Table 2 as an estimation of what your current light levels are, based on your current fluorescent troffer configuration. When considering replacing an existing fluorescent lamp with a TLED, assume that each fluorescent lamp has an output of 2,500 lumens.

Troffer Configuration	1 Lamp	2 Lamps	3 Lamps	4 Lamps
1′ × 4′	1,000–1,500	3,000–4,000	4,500–6,000	NA
2′ × 2′	NA	2,500–3,500	NA	NA
2′ × 4′	NA	2,500–4,000	4,000–5,000	6,000–7,500
NA = No applicable lamp models exist. Light output listed in lumens.				

Table 2. Typical fluorescent light output.

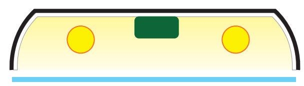
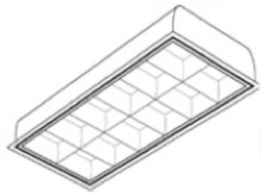
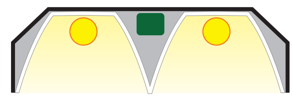
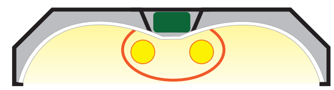
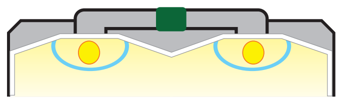
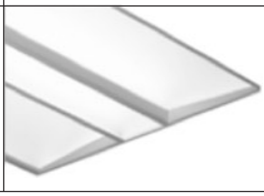
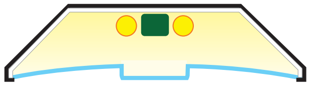
Description	Troffer Image	Troffer Cross-Section View	Retrofit	
			TLED	Kit
Prismatic Lensed – This was the original troffer design. It utilizes a flat lens and is required in clean rooms, food processing areas, and some health care applications.			●	●
Parabolic Louvers – The vast majority of troffers in offices are parabolic louvers. The louvers act to reduce glare from fluorescent lamps. When TLEDs are installed, there might be more glare because of differences between the light distribution of the TLEDs and fluorescent lamps.			▲	●
Recessed Indirect – These are "softer" in appearance. The perforated metal reduces light output and addresses glare. However, these fixtures are very inefficient. More than 50% of the light generated by the fluorescent lamp can be absorbed by the perforated metal.			▲	▲
Volumetric – These are lensed troffers where the lenses contour around the fluorescent lamps. The term volumetric was coined because these troffers light high on the wall, making the space feel brighter while managing potential glare.			●	●
High Performance – These are next-generation volumetric troffers. The optical system has been maximized for light output while the distribution has been optimized to properly light the space.			●	●
		Color key to components: yellow circle = lamp; white bar = reflector grey square = housing; orange bar = louvers dark green square = ballast; blue bar = lens	● = few limitations ▲ = proceed with caution	

Table 3. Types of troffers and retrofit options.

The color rendering index (CRI) indicates how well the light source renders the colors of an object compared to a reference light source on a scale from 0 to 100, where the higher numbers correspond with a closer match to an incandescent reference lamp. However, research has indicated that this metric does not provide the best comparison of light sources, and the lighting industry is moving beyond this metric to include more elements of color. The DLC requires a minimum CRI of 80, and the specification also allows for reporting of Rf and Rg (IES-TM-30).

Flicker

Flicker is a cyclic variation in output of a light source. Virtually all humans perceive flicker when the frequency is 50 hertz (Hz) or lower; some can perceive it between 50 and 100 Hz. Factors that could introduce flicker in an LED include the electrical supply, the LED driver, a dimming system, and, when using TLEDs, possibly the existing fluorescent ballast. The characterization of flicker, especially in the field, is important to assure comfortable living and working conditions. Many flicker meters are available, including more handheld meters that range from simple smartphone applications to scientific-grade meters. A DOE study found that handheld flicker meters today are capable of providing performance near that of a benchtop meter in a controlled environment.[3]

Lighting Controls

Lighting controls like occupancy sensors, vacancy sensors, and daylight sensors can significantly add to the energy savings in a retrofit project. Sensors can be hard wired to the fixture or be wireless and battery powered. Many troffer manufacturers now incorporate one or more controls in their LED troffer products. However, sensors don't work with all retrofit products.

Occupancy sensors are auto-on/auto-off and reduce the light output when a space is not occupied. They are most effective for spaces that are used intermittently. To maximize savings, limit the time until the setting goes to its lowest to be the shortest acceptable. Occupancy sensors can add 28% to savings on average.

Vacancy sensors are manual-on/auto-off and should be considered in small private spaces that are used most of the day.

Daylighting sensors reduce or turn off electric lighting when sufficient daylight is available. These sensors can be integrated with occupancy sensors as well. When daylighting sensors are added to a retrofit project, savings can be expected to increase 32% on average.

Multiple sensor strategies should be considered. Although multiple strategies may yield greater savings than any one strategy alone, energy savings are not additive.

Dimming controls reduce the light output and energy consumption as controlled by the occupant, by timers, or by daylight sensors. Not all LED products are dimmable. Evaluate product samples throughout the dimming range for possible flicker.

Task tuning is the reduction of light output via dimming to suit occupant needs. Tuning at the institution level can typically save 8% energy, and tuning at the individual level can save about 7% on average. However, the energy savings are less consistent than for other strategies because they depend on finishes in the space, the lighting system installed, and the occupant's preference. Depending on how the lighting system is designed initially, tuning may be not needed or not achievable.

Control	Available for:		
	TLED	Kit	Luminaire
Controls integrated into device	■ (None/few)	▲ (Some)	● (Many/most)
Sensors integrated into device	■ (None/few)	▲ (Some)	● (Many/most)
Dimming ready	■ (None/few)	● (Many/most)	● (Many/most)
Dims linearly	▲ (Some)	▲ (Some)	▲ (Some)
Works with wireless control systems	■ (None/few)	▲ (Some)	● (Many/most)
Communication protocol	■ (None/few)	● (Many/most)	● (Many/most)
Non-lighting sensors (e.g., Bluetooth low energy)	■ (None/few)	■ (None/few)	▲ (Some)

■ None/few ▲ Some ● Many/most

Table 4. Controls for each LED troffer retrofit option.

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References

1. *U.S. Energy Information Administration. 2017. Trends in Lighting in Commercial Buildings. Accessed 19 November, 2021 at https://www.eia.gov/consumption/commercial/reports/2012/lighting/.*
2. *DesignLights Consortium. 2020. Solid-State Lighting (SSL) Technical Requirements Version 5.1. Technical Requirements Document, DesignLights Consortium.*
3. *U.S. Department of Energy: Office of Energy Efficiency & Renewable Energy. 2018. Characterizing Photometric Flicker: Handheld Meters. Prepared by Pacific Northwest National Laboratory for the U.S. Department of Energy, Richland, Washington.*