UPGRADING LINEAR FLUORESCENT FIXTURES TO LED

ENERGY SAVING FACT SHEET

Linear fluorescent lamps (tubes) are widely used in offices, factories, retail space, hallways, stairwells, and restrooms. Fixtures types include troffers in suspended ceilings, "strip" with a bare lamp, and "wrap" if there is a plastic lens around the lamp. LED options are now available to upgrade virtually all linear fluorescent fixtures to LED.

Selecting a LED replacement from over 50,000 LED products is challenging. The efficiency of LED products can vary by 50% and equipment prices can vary from $10 to $200.

This guideline is intended as an aid in sorting out the options for upgrading fluorescent lighting to LEDs. **Some precautions are identified; however, the specifics of a project should be reviewed by a person with sufficient electrical expertise to judge the suitability/safety of proposed hardware and wiring arrangments.**

WHY UPGRADE TO LED

Light emitting diode (LED) technology has evolved to the most efficient light source for these applications. Benefits of upgrading from fluorescent to LED include:

- Energy use reductions of 50% are typical and 75% is possible.
- Payback time can be reduced by rebates, if available; however, rebate amounts are decreasing over time.
- Maintenance costs are reduced due to longer life, about two times longer than T-8 fluorescents.
- Future disposal costs of lamps containing mercury are eliminated.
- Compatible LEDs can be combined with dimmers and occupancy sensors to further reduce energy consumption.
- Possible reduction in air conditioning load due to reduced heat dissipation by lighting.

TYPES OF UPGRADES AND RECOMMENDED APPROACH

Fluorescent fixtures have a wide variety of geometries and wiring arrangement. LED innovations have responded with a broad array of products.

The preferred upgrade for linear fluorescents is with hardware specifically designed for LEDs (new fixture or an integrated LED retrofit module). An integrated LED retrofit module replaces the fluorescent lamps/ballast and eliminates fluorescent lamp holders. Products designed for LEDs can better direct the light where needed and energy use reductions of 75% are possible. For lamp replacement, a 50% reduction is more typical.

TYPES OF UPGRADES AND RECOMMENDED APPROACH - Continued

Gaining widespread adoption, due to the lower purchase price, is a retrofit by swapping the fluorescent tubes with an LED tube made for the application. These LED tubes are commonly referred to as tubular LED (TLED). A safe and successful upgrade can be achieved only if the tradeoffs with these products are carefully considered. There are several global issues:

- There is no national wiring standard for LED replacement lamps, so intermixing LED types/models/manufacturers may create a safety risk or not function.
- Fixtures for linear fluorescent lamps can be wired in distinctly different arrangements (series/parallel, shunted/non-shunted lamp holders, magnetic versus electronic ballast). LED replacement lamps can work with some wiring arrangements but not others.

The major advantages/disadvantages of the available LED products are compared in Table 1. LED retrofit kits for troffers are popular due to their high efficiency and rapid installation (5 to 10 minutes). Replacement lamps (TLEDs) are more suitable for strip and wrap fixtures because they are compatible with the variety of fixture shapes.

CAUTION: Ballast Bypass lamps are generally NOT recommended. The issue here is to consider future risk relative to the advantage of eliminating the fluorescent lamp ballast. For example, there is a shock risk with double ended ballast-bypass lamps if only one end is installed and contact is made with the other end with the circuit energized. In the future, there is a risk of installing incompatible lamps such as: different type of ballast-bypass LED tube, another category of LED tube, or even reinstalling a fluorescent tube because they all look similar. An organization should determine if they can mitigate these issues before selecting ballast bypass products. Possible mitigation steps include:

- Buying tubes with built-in safety features for shock or other risks.
- Applying labels on fixtures identifying type of LED and wiring arrangement.
- Moving responsibility for lamp replacement from janitorial staff to trained maintenance electrical staff.
- Purchasing spare lamps so correct replacement is be available on site.

Table 1. TYPES UPGRADES

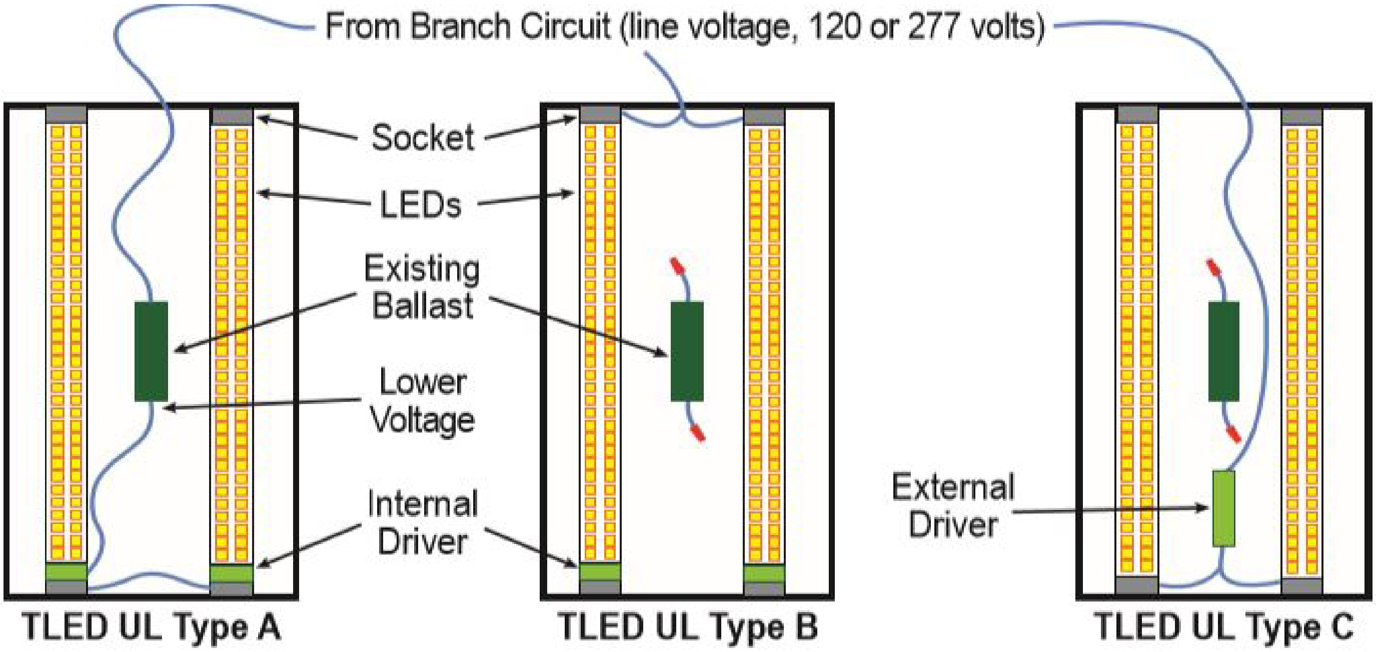
Type	Advantage	Disadvantage
LED Luminaire - Recommended Entire fluorescent fixture removed and replaced with LED fixture.	• Optimized for efficiency (75% wattage reduction possible) • Can accept sensors and controls • Larger rebates • Better light distribution	• Higher purchase cost • Labor cost to rewire fixture • Working in ceiling plenum can trigger problems with falling dirt, asbestos, etc.
LED retrofit kit - Recommended Remove fluorescent lamps/ballast/lamp holders and install LED module in existing fluorescent frame.	• Optimized for efficiency (75% wattage reduction possible) • Larger rebates • Better light distribution	• Higher purchase cost • Labor cost to rewire fixture • Sometimes hard to get exact size needed
All Replacement Lamps Recommendations vary with type. Sometimes called tubular LEDs (TLEDs).	• Low purchase cost	• Less efficient than new fixture (50% wattage reduction typical) • Smaller rebates • Glare if LED diodes are exposed • Beam spread may not match needs
Replacement lamp (Type A) "Plug and Play" Recommended if cost is a constraint.	• Simplest (provided fluorescent ballast and sockets are compatible and in good condition)	• Continued ballast maintenance • May have to replace ballast with manufacturer's approved ballast to validate LED warranty
Replacement Lamp (Type C) with external LED driver Recommended if cost is a constraint. (Should not allow a fluorescent lamp to be reinstalled)	• Eliminates ballast	• Higher purchase cost • Labor cost to rewire fixture

Table 1. TYPES UPGRADES - Continued

Type	Advantage	Disadvantage
Replacement Lamp (Type B) "Ballast Bypass" Generally NOT recommended (see caution text)	• Eliminates ballast maintenance	• Shock risk with double ended wiring if only one end installed * • Overheating risk wrong tube installed • Wiring arrangements differ so products from other manufacturers may not work • Lampholder compatibility. Example: Leviton's lamp holder instructions state: "Not intended for direct connection to the branch circuit." • Labor cost to rewire fixture
Replacement lamp (Hybrid A/B) Works with/ without ballast Generally NOT recommended (see caution text)	• Can use with ballast until ballast fails and then connect directly to line voltage • Some products work with both shunted and non-shunted lampholders (wiring may be different)	• When connected without a ballast it may have the shock and safety risks of "ballast bypass"

* Some products include shock protection circuitry.

The replacement lamps come in three distinct wiring arrangements illustrated in Figure 1 by Underwrites Laboratory type.



Source: Additional Resource 2.

Figure 1. Types of Replacement Lamps

ADDITIONAL CONSIDERATIONS

- Use Design Lights Consortium (DLC) qualified products. Some LED products carry an Energy Star® rating; however, Energy Star requirements are too low to be useful in selecting products. The Design Lights Consortium (DLC) establishes more stringent minimums for a wide range of performance parameters. As the technology improves, DLC increases the minimum efficiency, so listed products represent the latest advances.

  https://www.designlights.org/solid-state-lighting/qualification-requirements/

  DLC maintains a searchable qualified products list including over 50,000 LED products for linear fluorescent replacement, but it may be simpler to work with a supplier.
- Use LED manufacturer's wattage equivalent as guide to select LED output. The directional capability of LEDs allows them to produce the same amount of useful light with less total output (lumens). As an example, an LED fixture producing 4000 lumens and on a 10 x 10 foot spacing should meet a 30 foot candle minimum for office environment and use less than 40 watts. For an 8 x 8 foot spacing, a 3000 lumen output may be sufficient with wattage less than 30 watts. See Appendix for illumination levels in other locations.
- Some LEDs are still perceived as too bright, so evaluate a sample if possible. To avoid glare, the bare, light-producing diodes should not be visible to the occupant.
- If upgrading an area with a large number of fixtures (>20 fixtures), discuss with a lighting professional the lumens needed and whether redesigning the lighting layout is warranted. Also seek professional help if repurposing an area has changed lighting needs.
- Low operating hours of some fixtures can make it impractical to upgrade. More or less than 1800 hours per year is a way to distinguish low versus high use (and is the minimum for Duke Energy rebates).
- Any light that is hard to access (must be worked off of a large ladder/bucket truck/scaffolding/etc.) is a prime candidate for LED upgrade, due to their long life and corresponding reduced maintenance.
- Duke Energy rebates have been decreasing over time and categories have changed as the application form has been revised. Submitting a prequalification application is recommended to ensure payment. Several rebates are listed in Table 2 and a list of financial resources are included in the Appendix.

Table 2. REBATES OF FIXTURES OPERATING > 1800 hours/year

Upgrade	Duke Rebate (as of 7/20)
LED Panel 1x4	$25 per fixture
LED Panel 2x4	$40 per fixture
LED Panel 2x2	$20 per fixture
LED retrofit lamps	$3 for 4 ft. T8 or T12 lamp
	$6 for 8 ft. T8 or T12 lamp
	$6 for 4 ft. T5 lamp

The Appendix provides a seven-step approach to evaluate the important parameters.

SETTING GOALS TO SCREEN OPTIONS

Adopting goals for key parameters is a method to more rapidly converge on a LED selection (see Table 3).

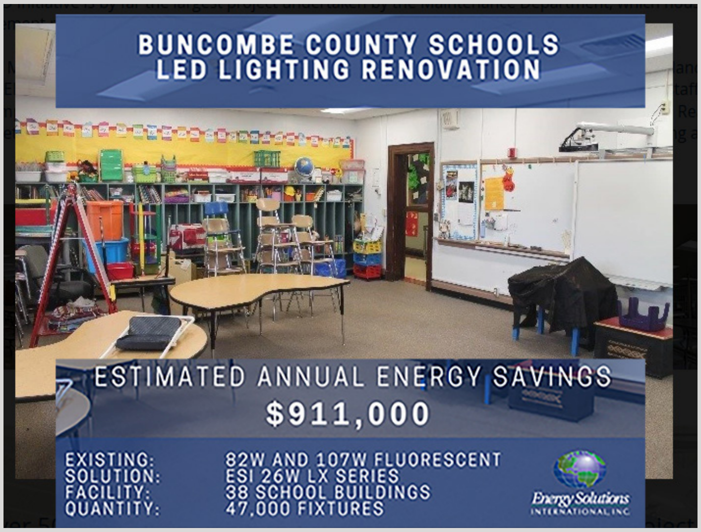
Table 3. SUGGESTED GOALS FOR UPGRADE

Goal	Comments
Efficiency of LED should be at least 110 lumens per Watt (LED light output in lumens divided by wattage of LED item).	Eliminates inefficient LED technology.
Reduce the electrical usage (wattage) to less than 50% of the total wattage of the fluorescent lamps in the fixture (number of lamps times wattage of individual lamps). Calculate the percentage by dividing the LED wattage by the total fluorescent lamp wattage[1].	Provides a significant reduction in operating costs.
Provide sufficient light (see Additional Considerations)	Eliminates LED products with inadequate light output.
Simple payback of LED upgrade is less than ten years. (See Financial Analysis Section)	Ensures upgrade project makes economic sense.

1. The wattage of a fluorescent fixture is different from sum of the lamp wattages, however, this approach makes it easier to define the goal.

BUNCOMBE COUNTY SCHOOLS CASE STUDY

Buncombe County Schools completed a three-year project retrofitting fluorescent lighting to LED lighting in July 2020. The scope of the Buncombe County Schools LED Initiative includes 44 school buildings ranging in age from 1920 to 2017. The existing 82W and 106W fluorescent fixtures were replaced by 26W LEDs in over 40,000 2x4, 1x4, 4x4 and 1x4 troffers. In addition, more than 41,000 LED tubes were installed replacing fluorescent tubes in non-troffer style fixtures. The net cost was approximately $3.3 million after rebates from Duke Energy Progress and avoided utility costs are projected to be $911,000 annually. The payback is estimated to be 3.6 years.



The project started in the spring of 2017. The work is being done in-house by several newly hired electricians, with extra support from the Maintenance Department.

At the beginning of the project a 24W (3115 lumen) kit was installed in hallways and a 32W (4030 lumen) kit in classrooms and offices. The first several schools were determined to be over lit by 15 to 20 foot candles. Subsequently a 26 W (3304 lumen) kit was found to be satisfactory for all spaces and achieving the 40 foot-candle target in classrooms.

One challenge was that the schools' pendant and surface mounted troffers could not use a standard size retrofit kit. The supplier came up with modified kits manufactured to custom dimensions. Another issue was that the original LED driver. interfered with the school's radios, however, the supplier was able to remedy the problem by changing the LED driver.

MANAGEMENT OF USED FLUORESCENT LAMPS AND BALLASTS

Under federal and state regulations, commercial and industrial entities cannot dispose of mercury-containing lamps in landfills unless testing proves they are not hazardous waste. Recycling information can be found at:
deq.nc.gov/conservation/recycling/fluorescent-lights.
A list of recyclers can be found at:
http://www.p2pays.org/dmrm/start.aspx.

COST ANALYSIS

For current lamps operating more than 40 hours per week, the energy usage cost saving alone may be sufficient to justify upgrading a fluorescent fixture to LED. In other situations, the initial cost of the LED upgrade may appear to be a barrier. For these cases a more detailed cost analysis is required.

Lighting is an essential component of the building architecture; therefore, financial analysis should look at a longer timeframe. A payback of less than ten years can still be a prudent choice of investment cost versus operating cost. Work with your accounting or financial staff to understand if the current lighting is categorized as an asset or an expenditure. This difference could affect depreciation and impact financial analysis.

The accompanying form uses a few basic parameters and formulas to determine how many years it would take to reach the simple payback point. Maintenance costs and timeframes differ widely between fluorescents and LEDs. To make a fair comparison, the maintenance costs for both fluorescent and LED are prorated on an annual basis. Note that LED troffers and retrofit kits may have a high maintenance cost when the LED unit eventually fails. This form can also be used to compare LED options.

COST COMPARISON AND PAYBACK FORM FOR LED UPGRADE

Completing the Form

- The wattage and life of the LED fixture can be obtained from product literature. The wattage of the fluorescent fixture includes the ballast; however, number of lamps times lamp wattage is sufficiently accurate for this comparison. Fluorescent lamp life can be found in their specifications. Estimate operating hours.
- Refer to an electric bill or utility web site for rate schedules. The incremental usage rate is the rate that would be applied to the last kWh consumed. For meters on a Time of Use rate, estimate the fraction of on-peak and off-peak for the lighting involved. Then combine the on-peak and off-peak rates weighted by these fractions. The demand rate would apply only if the lighting was turned on during the period when peak demand occurs.
- Make reasonable estimates for maintenance expenses. Be sure to include replacing fluorescent ballasts and fluorescent disposal fee.
- For investment cost use pricing from major manufacturers with known reputations for reliability. Estimate labor or get quotes. Identify rebates from Duke or other sources. Disposal cost of replaced fluorescent lamps are a necessary part of project costs.
- Finally use equations to calculate remaining values.

COST COMPARISON FOR LIGHTING UPGRADE

Enter values in white cells.
Values in gray cells calculated using formulas.

	EXAMPLE PER FIXTURE			PER FIXTURE			PROJECT
	A	B	Savings A - B	A	B	Savings A - B	Savings A - B
Fixture Parameters							
Fixture Type	T12 4 34W lamps	LED Troffer		T12 4 34W lamps	LED Troffer		# of Fixtures
Watts per fixture	136	43					
Life, hours	20,000	50,000					
Operating hours per year	2500	2500					
Incremental usage rate per kWh, Note 1	$0.065	$0.065					
Demand rate per kW, Note 1	$3.76	$3.76					
Annual Electric Usage and Costs							
Kilowatt hours, kWh [Watts] x [Operating hours] x [.001 kW/W] =	340	108	$233				
Electric usage cost [kWh] x [Incremental usage rate] =	$22	$7					
Electric demand cost [Watts] x [.001 kW/W] x [demand rate] x 12 =	$6	$2					
Annual Electric Cost [Usage] + [Demand] =	$28	$9	$19				
Maintenance							
Maintenance cycle material cost, Note 2	$23	$70					
Maintenance cycle disposal cost, Note 2	$4	$0					
Maintenance cycle labor cost, Note 3	$10	$15					
Prorated Annual Maintenance Cost							
Total cost per mainteneance cycle [material] + [Disposal] + [Labor] =	$37	$70					
Prorated number of Maint. Cycles per Year [Hours on per year] / [Life] =	0.13	0.05					
Prorated Maintenance cost per year [Cost per maint. cycle] x [No. of Maint. Cycles] =	$5	$4	$1				

INVESTMENT COST FOR LIGHTING UPGRADE

	Example	Per Fixture	Project
Material cost of fixture, kit or lamp(s)	$70		
Rebate	$31		
Disposal cost of replaced fixture/lamps	$4		
Labor cost for installation	$15		
Total Investment cost [Material] - [Rebate] + [Disposal] + [Labor] =	$58		

SIMPLE PAYBACK IN YEARS

	Example	Per Fixture
Simple Payback for B replacing A, years, [Investment cost] / [Saving (Elect. + Maint.)]	2.8	

Note 1. Example uses Duke Energy Small General Service Rate for over 3000 kWh and over 30 kW per month.
Note 2. Example assumes 4 fluorescent lamps at $2 each, ballast at $15 and $1 per fluorescent lamp for disposal. LED assumes complete unit is replaced.
Note 3. Rebate may not be available from your utility provider. Duke Energy rebates are only applicable to customer opting into energy efficiency programs.

Click to download worksheet

APPENDIX. SEVEN STEPS TO EVALUATE LED UPGRADE OPPORTUNITIES

1. Get the right quantity of light. The objective is to provide sufficient illumination (measured in foot candles) for people to do their activity comfortably and in a pleasing environment. LED products, however, re-characterized by the amount of light they produce (measured in lumens). The directional capability of LEDs allows them to produce the same amount of useful light with less total output (lumens). Use LED manufacturer's wattage equivalent as guide to select LED output. Illumination levels for different types of areas are listed in the sidebar.

Uniformity of illumination is as important as amount of light. The darkest areas should have at least 1/3 the illumination as brightest. If areas appear too bright or too dim have a professional check the light levels with a light meter and make recommendations for overlit or underlit conditions.

2. Get the right quality of light. Determine the color temperature (K) and Color Rendering Index (CRI) needed for the location. Color temperature is typically specified as 3000 K or less for hospitality, 3000 to 4000 K for indoor, and 4000 K or more for outdoor. We have grown accustomed to incandescent lighting which has been defined as a color rendering index of 100. Other light sources differ in their distribution of light through the spectrum and this affects the perceived color of objects. Specify a CRI of at least 80 for retail or other locations where color is a critical consideration. Evaluate color temperature and CRI of samples before committing to a large scale replacement.

How Much Light Is Enough?

Illuminating Engineering Society of North America sets officially recognized standards measured in foot candles (or lux). www.ies.org.

RECOMMENDED ILLUMINATION LEVELS

Space or Task	Foot Candles, fc
Corridor, Stairs	5 min.
Parking Garage	1 to 10
Lobbies, Reception, Hospitality, Guest Rooms	10 to 30
Offices, Meeting Rooms, Kitchen, Industrial	30 to 50

3. Consider only manufacturers with known quality and reliability. A major reason to install LEDs is for their 50,000 hour life. The lowest cost items may not last and warranties are only for five years. A product's listing by the Design Lights Consortium (DLC) is the first but not the only evaluation.

4. Special requirements checklist. Check the condition of existing fixtures. Worn wiring, damaged sockets, degraded reflective surfaces, or discolored lenses are justification for replacing the entire fixture. **Check for glare.** How the light is diffused varies significantly between products. If the light source is visible in the fixture, then evaluate sample parts or fixtures in proposed setting. Lens selection is critical to eliminating glare**. IInstallation issues.** New fixtures may not be appropriate if clearance or disturbing insulation are an issue. **Consider adding controls.** Occupancy sensors or harvesting daylight with sensors can be used to further reduce usage. Make sure proposed equipment is compatible.

5. Determine annual energy costs. Start with an estimate of the hours a fixture is operated per year and the electric rate. Annual operating cost] = [Wattage] x [Hours per year]] x [.001 kW per Watt] x [Cost per kWh]

As an example, consider a two lamp troffer operating 3000 hours per year and billed at a rate of $0.0866 per kWh. The annual electric costs per fixture are listed below.

OPERATING COST FOR 3000 HOURS PER YEAR		
T12 2 lamp	T8 2 lamp	LED
68 W	64 W	29 W
$17.66	$16.62	$7.53

What Electric Rate Should You Use?

For a rough estimate, use the average North Carolina commercial sector rate of $0.0866/kWh or use the average rate, total cost for usage and demand divided by total kilowatt hours from a recent bill.

CAUTION: The average rate may over estimate the savings because the actual saving depends on the incremental rate for the usage and demand reductions. The increment rate can vary from more than $.116 to less the $.050 per kilowatt hour depending on the rate schedule, amount of use, and/or time of use. See the cost-analysis section for a more detailed analysis.

APPENDIX. SEVEN STEPS TO EVALUATE LED UPGRADE OPPORTUNITIES (Continued)

6. Compare Costs and Determine payback. For lamps operating more than 40 hours per week, the energy cost saving alone may be sufficient to justify upgrading a fluorescent fixture to LED. In other situations, the cost of the LED up grade may appear to be a barrier. For these cases a more detailed cost analysis is required. See Cost Analysis section.

7. Identify financing options.

Duke Energy assistance: 866-380-9580.
https://www.duke-energy.com/business/products/smartsaver/lighting

Utility rebates are available for most upgrades but be aware that amounts have generally decreased over time. Duke offers rebates through four programs:

1. Duke provides instant rebates on bulbs at many local retailers. Look for Duke stickers at the stores. Duke also operates its own retail discount store at:
   https://www.duke-energy.com/home/products/discounts-local-retail
2. With Smart $aver Rebates, the customer does the upgrade and receives rebate from Duke. To qualify, LEDs must be listed by Energy Star or Design Lights Consortium (https://www.designlights.org). Additional requirements are listed on the application available at:
   https://www.duke-energy.com/business/products/smartsaver/lighting
   (downloadable application near bottom of web page)
3. Midstream Distributors provide instant incentives at point of purchase and do installation.
   See: https://www.duke-energy.com/business/products/midstream
4. The Small Business Energy Saver program uses Lime Energy to both quote a proposed upgrade package and then perform the work. Duke rebates are deducted from the costs up front. See:
   https://www.duke-energy.com/business/products/small-business-energy-saver

Other financing sources can be located at DSIRE, a comprehensive database of information on federal, state, local, and utility incentives and policies that support renewable energy and energy efficiency.
http://www.dsireusa.org

Additional Resources:

1. Case Study: https://www.energy.gov/sites/prod/files/2018/02/f49/forrestal_espc.pdf
2. Troffer Retrofit Guide:
   https://www.energy.gov/sites/prod/files/2017/03/f34/led_troffer_retrofit_guide.pdf

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