Economic and Performance Analysis of T8 Linear LED Replacement Lamps

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Disclaimer: The products were tested using the methodologies described in this report. CCHRC cautions that different results might be obtained using different test methodologies. CCHRC suggests caution in drawing inferences regarding the products beyond the circumstances described in this report.

Abstract

Upgrading from linear fluorescent lighting technology to linear LED lighting technology can present facility owners and operators with difficult decisions due to the sheer number of LED replacement options on the market. Research staff at the Cold Climate Housing Research Center (CCHRC) conducted a brief literature review and market analysis to assemble a list of LED lamps meeting predetermined criteria. Representative LED lamps from the list were selected for performance testing. The lamps were measured for power usage and illumination in a test room and monitored for incidences of 60Hz related flicker. Three lamps exhibited illumination that was comparable to fluorescent lighting along with significant power savings. Additionally, an economic analysis was completed on LED replacement scenarios for UL Type B and UL Type A lamps in a typical public facility in Fairbanks, Alaska. A UL Type A LED lamp retrofit is the most cost-effective selection when the ballasts are relatively new and compatible. A UL Type B LED lamp retrofit is the most cost-effective selection when the ballasts need to be replaced for any reason. Simple economic payback occurs within the warranty period and rated life of LED lamps regardless of the LED replacement type selected.

Keywords: LED, fluorescent, illumination, UL Type A, UL Type B, ballast compatible, line voltage

Background information

In Alaska, over 5,000 publicly owned and leased facilities spend an estimated $641,245,000 annually on energy (Armstrong et al., 2012). Lighting accounts for approximately 9% of a public building's total energy use yet accounts for an average of 18% of the overall energy cost or approximately $115,424,100 (Wiltse, Madden, Valentine, 2014). Linear fluorescent lamps have a consistent track record, known issues and labor components, and established manufacturers, which has led to their ubiquity in public facilities and private commercial buildings, especially T8 four-foot lamps.

Light emitting diode (LED) lamps are more efficient than fluorescent lamps, thereby decreasing lighting costs in buildings where retrofits are implemented. LED technology has progressed rapidly and gained market share as the number of products and manufacturers has increased. However, building owners and operators are faced with a potentially difficult decision when it comes to retrofitting fluorescent lighting with direct replacements due to the vast number of options available on the market.

There are different types of LED tube replacements that offer a one-to-one replacement: UL Types A, B, and C. These lamp types are known as ballast compatible (A), ballast bypass or line voltage (B), and external driver (C), respectively. UL Type A replacement lamps contain an internal circuit that allows the lamp to be operated from a ballast. Ballast compatibility is critical to the successful operation of these types of lamps and is dependent on the manufacturer; however, many newer ballasts tend to be compatible with LEDs. Lamp-only replacements can be done instead of ballast and lamp replacement if relatively new and compatible ballasts are already present in the facility. UL Type B replacement lamps contain an internal driver, function without the use of ballasts, and operate directly off of the facility's line voltage. The UL Type B internalized electrical components in the tube can increase the likelihood of a lamp failure compared to a UL Type A. Modifications of existing fixtures to house UL Type B lamps require visible documentation in the form of a sticker in the fixture. UL Type C replacement lamps have an external driver that powers the tube via low voltage and have more control options than types A and B. Modifying existing fixtures requires licensed electricians and adherence to manufacturer's instructions to maintain the UL listing of the fixture.

The focus of this project was on the lowest cost solutions, and therefore, the emphasis of this report is on Type A and B lamps. This report is intended to be a resource for facility owners, operators, and maintenance personnel to help make informed decisions about lighting-related energy savings.

This study is a follow-up to an initial study completed by the University of Alaska Fairbanks Bristol Bay Campus Sustainable Energy Program (Marsik, 2016). That report focused on UL Type A and B replacement lamps for direct replacement. De-lamping and using higher-powered LEDs to achieve desired lumen outputs was not considered in this report as de-lamping is not always an option. For recommended illumination levels, consult the Illuminating Engineering Society's (IES) Lighting Library (Illuminating Engineering Society, 2019).

For this report, a brief market study was performed to determine which lamps are appropriate choices for replacing fluorescent lamps. From that list, Cold Climate Housing Research Center (CCHRC) research staff selected 7 representative lamps identified in the market study for purchasing and testing in a dark room at the CCHRC Research and Testing Facility (RTF).

Lamp Selection Methodology

CCHRC performed a brief market review to determine appropriate choices for replacing fluorescent lamps. This review entailed searching the LM-79 database, the DesignLights Consortium (DLC) database, and information directly from manufacturers. The LM-79 database, which is no longer available, has manufacturer independent performance data on over 7000 linear LED products. The DLC designates high performance products within the lighting industry. DLC certification is a typical requirement for energy efficient rebate programs related to lighting. Several parameters were utilized to determine a final list for this study from the myriad products:

- System power (not just bare lamp power) less than 17 watts (W) per lamp
- Minimum 1500 manufacturer reported lumens
- UL listed for field installation
- Restriction of Hazardous Substances (RoHS) compliance
- Lamp or product family has been third-party tested using the LM-79 procedure
- Manufacturer with a substantial track record and at least a 5-year warranty
- DesignLights Consortium (DLC) certification
- Availability and prevalence in Alaska

The LM-79 test is performed on lighting products that are referred to as parent products. The testing information is then used to represent a greater set of products (e.g. different color temperatures). Parent lamps that met the above criteria were selected and compiled in a list that is available in the Appendix. A smaller list of representative lamps was selected for testing in order to expedite testing and manage costs (Table 1).

Table 1.Tested lamps. All of the tested lamps had a color temperature of 4000K.

Manufacturer	Model	Type	Reported lumens	Reported wattage (bare lamp)
Philips	10T8/48-4000 IF 10/1 TAA/NAFTA	A	1600	10
Philips	13T8/48-4000	A	2100	13
Topaz	L4T8E/840/12/F-79	A	1900	16
GE	LED10ET8/G/4/840 GE LAMP 34280 LED	A	1600	10
Philips	12T8/PRO/48-840/BB18/G 10/1 FB	B	1800	12

Philips	16.5T8PRO/48-840/BB21/G	B	2100	17
Sylvania	LED12T8/L48/FG/841/BF	B	1800	12
Satco	F32T8/841/ENV	Fluorescent	2800	32
GE	F32T8/SP30/ECO	Fluorescent	2800	32

The LED manufacturer reported luminous flux (the amount of light that can be perceived by human eyes) with a normal ballast factor is much lower than the typical luminous flux for fluorescent lamps. Fluorescent lamps distribute light over 360°, which includes casting light into the fixture. Even though fluorescent lamps have a greater luminous flux, the directionality of the LED light allows a lower lumen output to equivalently illuminate a space.

Testing Methodology

CCHRC research staff utilized a room in the RTF that had one luminaire and no windows to the exterior. The interior windows were covered to ensure that no other lighting would interfere with the testing luminaire (Figure 1).

Figure 1. LED testing room at the RTF. The plywood is covering the interior window; it was taped in place to block all light infiltration.

The products selected from the market review summary were evaluated in-situ for the following:

- Measured system power in Watts (W)
- Measured illumination in foot-candles
- 60 Hertz (Hz) related flicker

Each test utilized four lamps. Two 2-lamp ballasts were used for the UL Type A and fluorescent tests. System power was analyzed through a Fluke 43B Power Quality Analyzer and a Kill A Watt P4400.01. Illumination was measured with a Sylvania DS-3050 Lightmeter. The 60Hz related flicker, which is the flicker from the lamp due to the 60Hz frequency of the electric grid, was evaluated with a cell phone camera, which has a scan rate that interferes with the 60Hz related flicker and results in stripes (Figure 2). The 60Hz flicker can produce adverse health effects, some of which can be extreme, such as epileptic seizures for photosensitive individuals. It is recommended, at a minimum, that lamps have flicker modulation less than 5% for limited effects (Lehman, 2015). This study did not measure flicker modulation.

Figure 2. A cell-phone photograph may show horizontal stripes across the image from the 60Hz related flicker, as in this case, exhibited by a UL Type B lamp. Flicker modulation was not measured in this study.

Testing was performed with new Philips Advance Centium ICN-2P32-N ballasts for all of the ballast-compatible products (Figure 3). Initially, existing fluorescents (GE) with unknown age and usage history from the RTF were evaluated. New fluorescent lamps (Satco) were burned in for 100 hours and then tested after the existing fluorescents. After the fluorescent lamp illumination baseline was established, testing proceeded for the LED replacements.

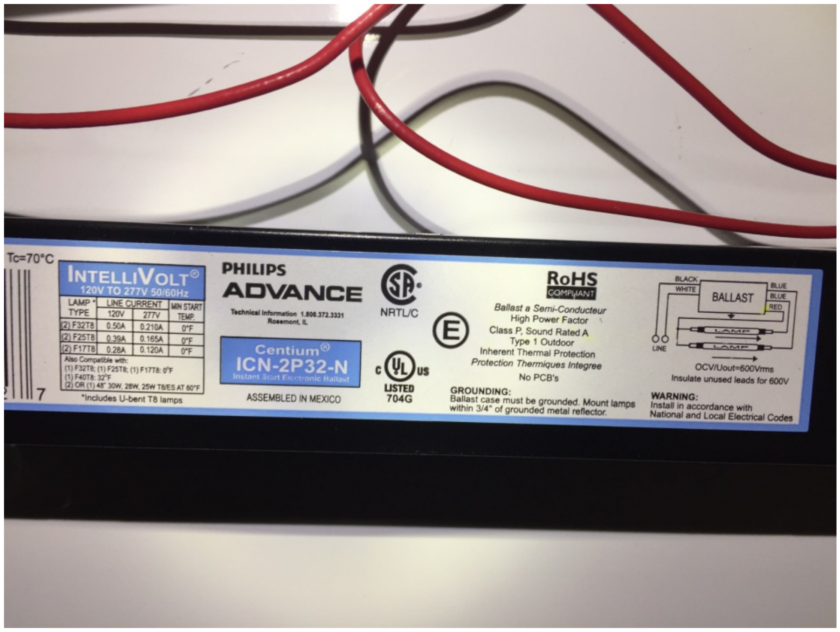

Figure 3. Ballast used for testing UL Type A LED and fluorescent lamps. This ballast was indicated by the manufacturer to be compatible with a wide range of LED lamps.

The testing luminaire is a 4-lamp recessed troffer. Each lamp test allowed at least 10 minutes for stabilization before measurements were taken. Illumination was measured with the light meter in 5 locations per lamp test:

- 24” off the ground and directly below the luminaire
- 69” and 93” off the ground on the luminaire’s long axis wall
- 69” and 93” off the ground on the luminaire’s short axis wall

Results and Discussion

As shown in Figures 4 and 5, none of the tested LED lamps had higher illumination directly below the luminaire than a new fluorescent lamp. However, the Topaz, Philips 13T8, and Philips 16.5T8 lamps demonstrated greater illumination below the luminaire than an older fluorescent lamp. The Philips 13T8 and Philips 16.5T8 are designated high-output UL Type A and B models from that manufacturer’s line of lamps, respectively. The Topaz lamp was the only lamp that was not marketed as a high-output lamp that provided illumination greater than the older fluorescent. Lamps significantly lower in illumination than the old fluorescents (like the Philips 10T8) will not be adequate one-to-one replacements for the fluorescents unless there is a change in a room’s use or design foot-candle requirement.

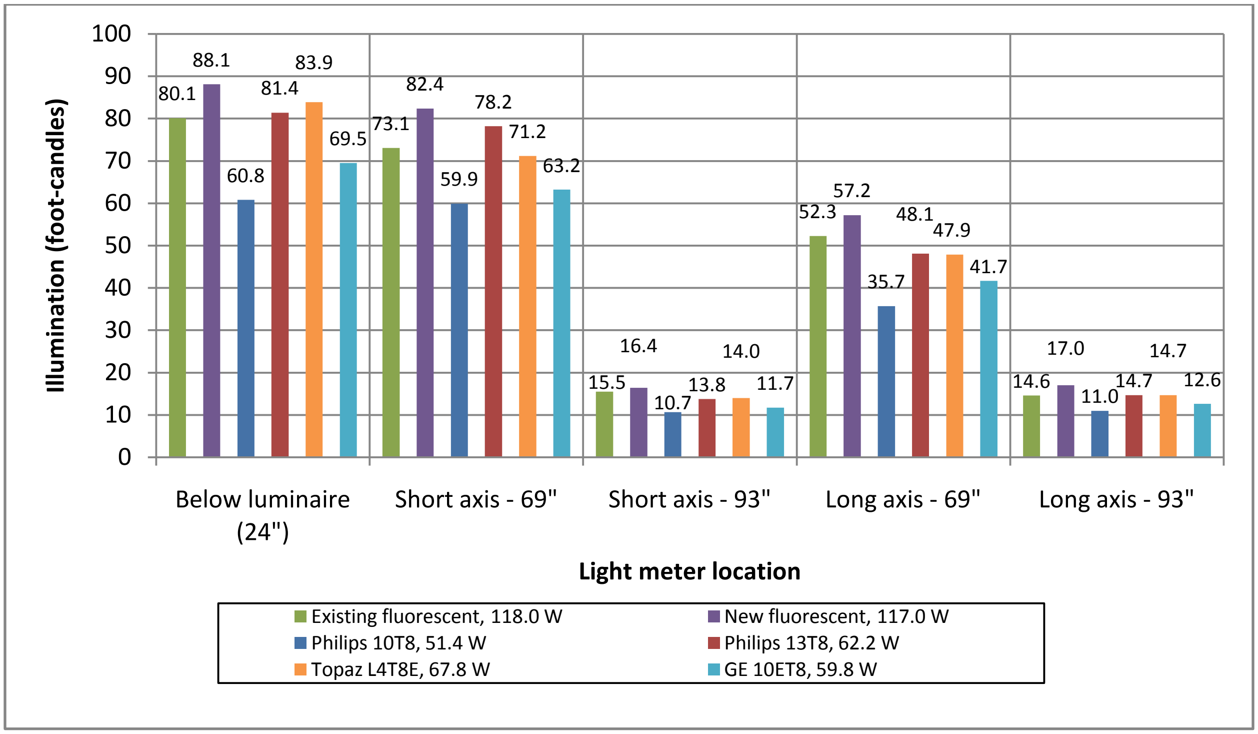

Figure 4. Type A and fluorescent illumination comparison. The results of power and illumination measurements for the fluorescents and ballast compatible LEDs are in a 4-lamp, 2-ballast luminaire configuration.

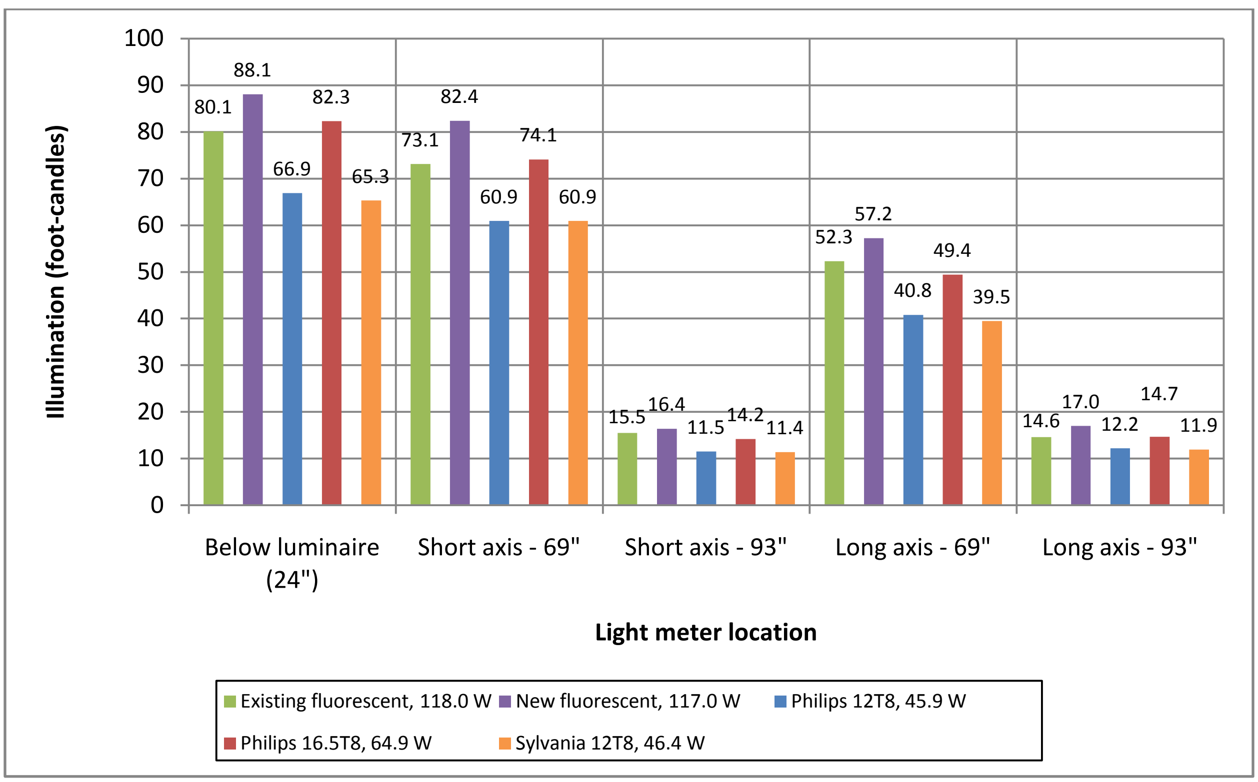

Figure 5. Type B and fluorescent illumination comparison. The results of power and illumination measurements for the fluorescents and ballast bypass LEDs are in a 4-lamp, 2-ballast (fluorescent only) luminaire configuration.

Table 2 shows the measured system power from the tested lamps. The UL type A lamps were measured in conjunction with the Philips ICN-2P32-N ballast, which has a normal ballast factor of 0.88. The UL Type B lamps are measured for lamp power only since they preclude the use of ballasts. All tested LED lamps demonstrated considerable power reduction over the fluorescent lamps. The three lamps that had the highest illumination, the Topaz, Philips 13T8, and Philips 16.5T8, had an average reduction of 45% compared to the fluorescent baseline.

Table 2. LED Power Measurements and Comparison

Manufacturer	Model	Type	System Power (W)	System Power (W)/Lamp	% Reduction
Philips	10T8	A	51.4	12.9	56.1
Philips	13T8	A	62.20	15.6	46.8
Topaz	L4T8E	A	67.80	17.0	42.1
GE	LED10ET8	A	59.80	15.0	48.9
Philips	12T8	B	45.9	11.5	60.8
Philips	16.5T8	B	64.90	16.2	44.5
Sylvania	LED12T8	B	46.40	11.6	60.3
Satco	F32T8	Fluorescent	117.0	29.3	-
GE	F32T8	Fluorescent	118.0	29.5	-0.9

The Philips 16.5T8 emitted an audible buzzing noise that was apparent to research staff. All of the UL Type B lamps exhibited some 60Hz flicker. None of the UL Type A lamps demonstrated 60Hz flicker.

Economics

LED conversions from fluorescent lamps present ample opportunities to reduce the energy use of buildings. The economic payback calculation for an LED conversion includes maintenance schedules, lamp use, and labor in addition to the initial capital cost of the new materials. The following example, exhibited in Table 3, demonstrates the potential cost inputs and payback outcomes associated for a public facility with 1000 lamps in Fairbanks, Alaska. These are the basic parameters:

- Electric rates utilize Golden Valley Electric Association’s (GVEA) GS (S/P) effective rate of $0.14 per kWh and $21.62/KW demand charges.
- The reduction in power utilized by an LED compared to the fluorescent baseline uses the average reduction in power, 45%, from the three candidate lamps that provided the closest one-to-one illumination replacement.
- The LED lamps are priced at $10.00/lamp for either ballast compatible (Type A) or line voltage (Type B) lamps and $15.00/ballast for 2-lamp ballasts. The fluorescent lamps are $4.00/lamp. Prices for the lamps and ballasts can change depending on the volume purchased and discounts available to the purchaser from different manufacturers.

- The lamp usage rate used is 8 hours/day, which is the average lamp usage rate for 4’ T8 linear lamps in commercial facilities (Buccitelli et al., 2017).
- The labor rate is the prevailing rate for a licensed electrician in Fairbanks, AK of $100.00/hour. A licensed electrician is presumed to perform the work in these scenarios.
- Scenario 1 presents a situation where the ballasts are still appropriate to continue using after a change-out from fluorescent lamps to LED lamps has occurred.
- Scenario 2 has the ballasts replaced for fluorescent relamping or a ballast compatible LED lamp upgrade.
- The line voltage LEDs inputs for materials and labor remain the same irrespective of the ballast condition.

As shown in Table 3, any scenario with an LED retrofit provides a simple payback within the 5-year warranty period. An LED lamp’s rated life is typically about 50,000 hours, and at the average lamp usage rate for 4’ T8 linear lamps in commercial facilities would last for 17.3 years (Buccitelli et al., 2017). This means the payback is much shorter than the life of the lamps. If the lamps are upgraded during a normal fluorescent re-lamping cycle then the cost of the normal re-lamping is deducted from the costs of the LED upgrade, thereby shortening the payback period. Conversely, if an LED retrofit is executed outside of a normal maintenance cycle then the payback is extended but still favorable. The line voltage LED (UL Type B) upgrade shows a negative payback in Scenario 2’s simple payback during a maintenance cycle because the labor and capital costs of ballasts and fluorescent lamps exceeds the labor and capital cost of line voltage replacement lamps. This analysis does not account for lamps or ballasts that do not meet their rated life.

Table 3. LED Retrofit economic scenarios

T8 Fluorescent Replacement	**Scenario 1**	**Scenario 2**
Material Costs per Lamp	$ 4.00	$ 11.50
Labor (Replacement Costs) per Lamp	$ 6.67	$ 8.33
Power per Lamp	29.4 (W)	29.4 (W)
Line Voltage (UL Type B) Retrofit		
Material Costs per Lamp	$ 10.00	$ 10.00
Labor (Replacement Costs) per Lamp	$ 8.33	$ 8.33
Power per Lamp	16.2 (W)	16.2 (W)
Ballast Compatible (UL Type A) Retrofit		
Material Costs per Lamp	$ 10.00	$ 17.50
Labor (Replacement Costs) per Lamp	$ 6.67	$ 8.33

Power per Lamp		16.2 (W)	16.2 (W)
CAPITAL COST OF			
T8 Fluorescent Replacement	Per Lamp	$ 10.67	$ 19.83
	Whole Building	$ 10,666.67	$ 19,833.33
Line Voltage (UL Type B) Retrofit	Per Lamp	$ 18.33	$ 18.33
	Whole Building	$ 18,333.33	$ 18,333.33
Ballast-Compatible (UL Type A)Retrofit	Per Lamp	$ 16.67	$ 25.83
	Whole Building	$ 16,666.67	$ 25,833.33
ELECTRICAL MONTHLY COST REDUCTION OF			
T8 Replacement	Per Lamp	$ -	$ -
	Whole Building	$ -	$ -
Line Voltage (UL Type B) Retrofit	Per Lamp	$ 0.45	$ 0.45
	Whole Building	$ 445.18	$ 445.18
Ballast-Compatible (UL Type A)Retrofit	Per Lamp	$ 0.45	$ 0.45
	Whole Building	$ 445.18	$ 445.18
MONTHLY DEMAND COST REDUCTION OF			
T8 Fluorescent Replacement	Whole Building	$ -	$ -
Line Voltage (UL Type B) Retrofit	Whole Building	$ 285.38	$ 285.38
Ballast-Compatible (UL Type A) Retrofit	Whole Building	$ 285.38	$ 285.38
SIMPLE PAYBACK - If During Maintenance Cycle			
T8 Fluorescent Replacement	Years	-	-
Line Voltage (UL Type B) Retrofit	Years	0.88	(0.17)
Ballast-Compatible (UL Type A) Retrofit	Years	0.68	0.68
SIMPLE PAYBACK - If Out of Maintenance Cycle			
T8 Fluorescent Replacement	Years	-	-
Line Voltage (UL Type B) Retrofit	Years	2.09	2.09

Ballast-Compatible (UL Type A) Retrofit	Years	1.90	2.95

Conclusions

Upgrading fluorescent lamps to LED lamps presents potentially significant energy and financial savings for facilities, whether UL type A or B lamps are chosen. However, the wide range of available products creates a difficult scenario for building owners or managers to decide on an appropriate replacement for fluorescent lamps. Additionally, lamp selection incorporates many factors and can be unique to each facility depending on the life and use of the existing lamps. There are some advantages to each lighting type, such as Type A lamps not exhibiting 60Hz related flicker or Type B lamps not ever needing ballast replacements.

When a low-cost solution is the determining element for lamp selection, the following guidelines may apply:

- If the ballasts are relatively new and compatible with LEDs, then a UL Type A LED lamp replacement is the most cost effective.
- If the ballasts need to be replaced for any reason, then a UL Type B LED lamp replacement is the most cost effective.

As the LED market matures, the risk of high rates of premature lamp failures diminishes. Additionally, the risk of upgrading is reduced due to the payback occurring well within a lamp's warrantied life. However, past failures are known so care should be taken to purchase lamps from established manufacturers that can support significant warranty claims, if need be.

Appendix

Table A.1. The list of lamps that met the criteria outlined in the Lamp Selection Methodology section.

Manufacturer	Model No.
GE Lighting Solutions	LED10ET8/G/4/835
GE Lighting Solutions	LED12ET8/G/4/830
GE Lighting Solutions	LED12ET8/4/830
GE Lighting Solutions	LED15BT8/G4/830
GE Lighting Solutions	LED13ET8G4/830US
GE Lighting Solutions	LED15ET8/G4/840W
GE Lighting Solutions	LED12ET8/G/4/850
GE Lighting Solutions	LED12ET8/4/850
LEDVANCE, LLC (formerly OSRAM SYLVANIA, INC)	LED13T8/L48/DIM/830/SUB/G8
LEDVANCE, LLC (formerly OSRAM SYLVANIA, INC)	LED17T8/L48/FG/830/BF
LEDVANCE, LLC (formerly OSRAM SYLVANIA, INC)	LED14T8/L48/FG/830/BF
LEDVANCE, LLC (formerly OSRAM SYLVANIA, INC)	LED12T8/L48/FG/830/BF
Philips Lighting North America Corporation	14T8/48-3000 IF 10/1 ROT
Philips Lighting North America Corporation	14T8 PRO LED/48-3000 IF G 10/1
Philips Lighting North America Corporation	14T8 PRO LED/48-3500 IF G 10/1
Philips Lighting North America Corporation	16.5T8PRO/48-830/BB20/G
Philips Lighting North America Corporation	10T8 LED/48-3500 IF 1PK 10/1
Philips Lighting North America Corporation	13T8 LED/48-3000 IF DIM 1PK
Philips Lighting North America Corporation	12T8/PRO/48-830/BB17/G 10/1 FB
Philips Lighting North America Corporation	10T8/48-3000 IF 10/1 TAA/NAFTA
Philips Lighting North America Corporation	14T8/48-3000 IF 10/1 DIM TAA/NAFTA
Philips Lighting North America Corporation	13T8 LED/48-4000 IF DIM 1PK
Topaz Lighting Corp.	L4T8B/830/12F/DE-39C
Topaz Lighting Corp.	L4T8B/830/15F/DE-70
Topaz Lighting Corp.	L4T8E/830/12/F-88
Topaz Lighting Corp.	L4T8B/830/14F/DE-39
Topaz Lighting Corp.	L4T8E/830/13/F-70
Topaz Lighting Corp.	L4T8E/830/12/F-39
Topaz Lighting Corp.	L4T8E/830/12/F-79

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