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LEDs vs. Linear Fluorescent Lamps, Who Wins Battle for Supremacy?

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The rise of LEDs is stirring-up an interesting battle for supremacy in the world of lighting. All that may be missing is the entertaining "who's gonna win" style of analysis you get from the game-day, broadcasting booth on television. In an attempt to raise the analytical bar, a ***LED Shootout*** was conducted recently with early results indicating that LEDs are the winning choice to replace *incandescent* lamps, but are not when LEDs compete directly with the *fluorescent* lamp.

Assessments show that replacing incandescent lamps such as 60-watt A-type lamp, MR-16, or PAR-38 with LED replacement lamps is a smart, economical move even with a tenfold first cost premium. LEDs offer energy savings, longer life, suitable color rendering (CRI), and better color temperature (K°) when compared with incandescent lamps. Replacing a single 79-watt PAR 38 halogen lamp with a 7-watt PAR 38 LED lamp yields an 86% return on investment, and a net savings of $255 present value over its ten-year life.

For now the four-foot, 25-watt T-8, high CRI, low mercury, long life, dimmable linear fluorescent lamp is the gold standard.

During a ***LED vs. Linear Fluorescent Lamp Shootout***, we determined the trend of sticking LEDs into luminaires (*see below for this and other definitions*) designed for linear fluorescent does not offer the sought-for savings. On the other hand, using luminaires specifically designed to maximize the benefits of LEDs will offer an opportunity to save energy. This opportunity will grow as LED technology continues to improve.

There has been significant improvement in LED technology since 2009, as major lighting manufacturers with big R&D budgets moved into this market segment. Today, you can order a luminaire with either linear fluorescent lamps or LEDs as the light source. The major impediment for replacing linear fluorescent lamps with LEDs is the high initial cost premium, but **Total Cost of Ownership** still favors the T-8 fluorescent bulb. (See Table 4 below.)

In addition to the drive for energy savings, government regulations have factored in as the T-12 has been kicked out of the game. The U.S. Department of Energy ordered a halt to producing magnetic ballasts used for T-12 fluorescent lamps in July 2010. This order also banned production and importation of most T-12 fluorescent lamps in the U.S. effective July 14, 2012. Approximately 30% of all fluorescent lamps sold in the U.S. are still T12 technology. Suppliers could only sell what remained in their remaining T-12 inventory. It's estimated that approximately 2 billion T-12 lamps are still installed in the non-residential sector. Retrofitting of lighting in existing buildings will continue to be a very active market.

Ground Rules for The Shootout

In comparing LEDs and newer generation of fluorescents, the shootout concentrated on assessment of performance and the economics issues. The assessment was divided into three sections; 1) light source, 2) luminaire or light fixture, and 3) application design. This enabled us to pinpoint the relative merits of linear fluorescent lamps and LEDs.

We also took note of U.S. Department of Energy's CALiPER Program (Commercially Available LED Product Evaluation and Reporting) where a study was released in 2009 on standard 4-ft fluorescent lamps (i.e., T12 and T8) and commonly used 2-ft by 4-ft recessed luminaires. Also examined in the study were LED replacements for T12 and T8 fluorescent lamps and their application in these luminaires. The study concluded that LED technology was not yet ready to oust linear fluorescent lamps as replacement light sources for general interior lighting.

We selected a luminaire that is broadly used in the marketplace, and was available with T8, T5, TT5, T5HO, or LED light source. The luminaire chosen was the Lightolier HP-90. Every major lighting manufacturer produces a comparable luminaire, and is reflective of the current state of the market.

Electrical System Efficiency

Table One reveals the electrical system efficiency of each light source – the ratio of light emitted by the light source to the energy consumed. It's important to note the lumen output of a fluorescent lamp is affected by the ballast used, this is called ballast factor. To avoid cherry picking, that is selecting a ballast to maximize the light output at the expense of lamp life; we used the ballast the manufacturer uses with the luminaire for the lamp type selected.

The efficiency of the light source is expressed in lumens per watt (lm/W). Accounting for ballast factor and the input power of the combined lamp-ballast system, light source efficiency can be calculated as follows:

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Table One
Number of lamps per luminaire × rated lamp light output (lm) × ballast factor
Luminaire input power (W)

Lamp Type	**T-8 F17T8**	**T8 F17T8**	**T5 F14T5**	**TT5 F40BX /SPX30IS**	**T5HO F24T5HO**	**LED –**
Lamps/Luminaire	1	2	3	1	2	n/a
Lumens/Lamp	1,400	1,400	1,200	3,150	1,760	2,363
Total Lumens	1,400	2,800	2,400	3,150	3,520	2,363
Ballast Factor	.88	.88	1.06	1.0	1.0	
Lumen Output	1,232	2,464	2,544	3,150	3,520	2,363
Input Power(Watts)	16.7	30.6	31.1	37.6	49.4	31.7
Lumens/Watt	**73.7**	**80.5**	**81.8**	**83.8**	**65.8**	**74.5**

In this case, the LED light source was ranked fourth out of six at 74.5 lumens per watt.

Testing done in the previously mentioned CALiPER assessment found that some manufacturers are providing inaccurate or misleading information regarding their efficiency. Many LED manufacturers test their LED chips on lab benches at room temperature with short pulses that produce high lumens per watt rating. While these results are not incorrect, they do not reflect the typical expected output of LED sources used in luminaires. Rather than use the test results of their LED source suppliers, reputable LED fixture manufacturers use independent, third-party testing labs to measure and validate the output of their lighting fixtures. To ensure accurate performance data, make sure the test complies with LM-79 standard, published in 2008 by the Illuminating Engineering Society of North America (IES).

Luminaire Efficacy

Because linear fluorescent lamps are omnidirectional light sources, a portion of their light output is trapped within the luminaire. On the other hand, LEDs are a point light source so the manufacturer assumes all light emitted by the LEDs reach the work surface. So, an important performance measure is luminaire efficiency (also referred to as fixture efficiency) — that is, the ratio of light emitted by the fixture to the lumen output of the lamp-ballast system alone. Table Two shows luminaire efficacy, how effective the fixture was at delivering the lumen output to the work surface.

Fixture efficiency is calculated as follows:

Table Two
Lumen output (lm) × luminaire efficiency
Luminaire input power (W)

	T-8	**T8**	**T5**	**TT5**	**T5HO**	**LED**
Lumen Output	1,232	2,464	2,544	3,150	3,520	2,363
Luminaire Efficiency	82.5%	80.3%	83.2%	72.9%	80.3%	–
Delivered Lumens	1,016	1,979	2,117	2,296	2,827	2,363
Input Power – Watts	16.7	30.6	31.1	37.6	49.4	31.7
Delivered Lumens/Watt	**60.9**	**64.7**	**68.1**	**61.1**	**56.9**	**74.5**

After adjusting for luminaire efficiency the LED fixture moved from fourth to the top spot with 74.5 lumens per watt.

Application Design

Table Three reveals the impact of application design on performance. In an open office setting 2x2 light fixtures are laid out typically in an 8 foot x 8 foot grid. This translates to one luminaire per 64 sq.ft. of office space.

Average Foot Candles is calculated as follows:

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Table Three
Total Delivered Lumens (lm)
Area in Square Feet

	T-8	T8	T5	TT5	T5HO	LED
Delivered Lumens	1,016	1,979	2,117	2,296	2,827	2,363
Avg. Fc/Sq Ft (8x8)	16	31	33	33	33	37
Watts/Sq Ft	.26	.48	.49	.59	.77	.50

The average foot candles/sq.ft. for each configuration ranged from 16 to 37 for the LED luminaire. Half of the luminaires provide an average of 33 foot candles/sq.ft. The watts per square foot for each configuration ranged from 0.26 to 0.77. Overall, the performance of the LED is very similar to the luminaire with two 17 watt T-8 fluorescents lamps, and the luminaire with two 14 watt T-5 fluorescents lamps. This is not surprising since these fixtures were designed to be used in this 8 foot by 8 foot configuration; and so the overall light output for each luminaire will be very similar.

Total Cost of Ownership

Bottom line, it's all about the money. The total cost of ownership is calculated using the initial cost of a luminaire and lamps, plus the present value of the energy and replacement lamps over 10-years. LEDs have long been touted for their long lamp life – high quality fluorescent lamps now have a rated life of 50,000 hours on par with LEDs. The purchase cost of the luminaire and lamps was based on buying 500 units. Energy costs are $0.10 kWh and a 5% discount rate was used. Table Four shows the total cost of ownership per luminaire.

Table Four

	T-8	T8	T5	TT5	T5HO	LED
Initial Luminaire Costs w/Lamps	$71	$80	$87	$91	$95	$134
Energy/Replacement Lamps – (PV 10-yrs)	$135.50	$249.18	$246.30	$300.06	$393.34	$284.75
TCO	**$206.50**	**$329.18**	**$333.30**	**$391.06**	**$488.34**	**$418.75**

The luminaire using the 17 watt T-8 lamps had the lowest total cost of ownership, while the LED luminaire was fifth out of six configurations. For the LED luminaire to be competitive it needs to overcome a $90 present value cost premium. It's unlikely that manufacturers can reduce the first cost of the luminaire to offset this cost premium. As a result, manufacturers will need LEDs with an average maintained light output over 100 lumens per watt to be price competitive with linear fluorescent luminaires.

Important Definitions

Light Source: The fluorescent lamp and ballast constitute the light source in a fluorescent lighting application. The LED light engine (LLE) and the electronic Control Gear (ECG), commonly called the driver, are the light source in an LED lighting system. The LLE and ECG can be separate components or integrated into one unit.

Luminaire: The fixture that contains the light source. Typically, this is a 2 x 2, 2 x 4, or 1 x 4 metal box that is recessed into the ceiling or surfaced mounted.

Application Design: The selection of a suitable luminaire, light source, lighting controls, and layout of the luminaires.

A Better Approach for LEDs is Needed

We should ask if stuffing LEDs into 2x2, 2x4, 1x4 fluorescent fixtures is the best design strategy. Using LEDs to mimic fluorescent lamps is a pothole in the road to better lighting. Manufactures need to design luminaires that fully use the unique advantages of LEDs; and designers need to take advantage of all the benefits that LEDs offer as a light source. For now the four-foot, 25-watt T-8, high CRI, low mercury, long life, dimmable linear fluorescent lamp is the gold standard. ■

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