LED Performance Specification Series:

LED T8 Replacement Lamps

LED T8 replacement lamps are proliferating in the lighting marketplace. How do these products compare to fluorescent T8 systems in terms of light output, distribution, color quality, and energy efficiency? What level of LED product performance should buyers specify for replacement applications?

Photo credit: PNNL

LED T8 replacements may contain dozens of high power LEDs or hundreds of 5mm LEDs behind a clear or frosted lens, all in a medium bi-pin T8 lamp package.

Recessed "troffer" fixtures with four-foot fluorescent T8 lamps are commonly specified in commercial and institutional lighting applications, and represent a significant installed base of fluorescent fixtures. Are LED replacement lamps a "drop-in" equivalent to T8 fluorescent lamp-ballast systems, as claimed by many manufacturers? DOE's CALiPER program has tested 12 different LED T8 replacement lamps to date, and finds that their performance falls short of fluorescent benchmarks.[1] Major findings (bare lamp and in a fixture) are summarized and compared with fluorescent benchmarks in Table 1.

Average initial bare lamp light output of the LED T8 replacements tested was about one-third the average for fluorescent T8s. On initial two-lamp system efficacy, two-lamp fixture output, luminaire efficacy, and CRI, the LED T8 replacement performance was significantly below that of the fluorescent T8s. Average fixture efficiency was higher with LED T8s because LEDs are directional, so less light is lost inside the fixture. This was not enough to compensate for the much lower light output however.

Table 1. CALiPER Test Results for 4-foot LED T8 Replacements with Fluorescent Benchmarks

Performance Characteristics	LED T8 Replacements		Fluorescent Benchmarks	
	Range (12 lamps tested)	Average	Mfr. Data (75 lamps)	CALiPER (2 fixtures tested)
Initial Lamp Light Output (lm)	345 – 1,579	1,111	2,778	3,091
Initial 2-Lamp System Efficacy (lm/W)	19 – 76	50	87	---
Initial 2-Lamp Fixture Light Output (lm)	597 – 2,038	1,563	3,577	4,064
Initial CRI	63 – 76	71	75 – 80	82
Fixture Efficiency (%)	74 – 86	83	74	66
Initial Luminaire Efficacy (lm/W)	17 – 57	41	64	57

Defining Minimum Performance

What performance level is reasonable to demand of LED T8 replacements? DOE's recommended specifications are summarized in Table 3 (over). Initial light output is based on matching fluorescent T8 lumens, and accounting for fluorescent ballast factor, lumen depreciation, and the better fixture efficiency measured with LED T8s compared to fluorescent. Note that luminous efficacy for the LED T8 is not specified. This is because LED T8 wattage varies. Table 2 below shows the efficacy levels the most common LED T8 wattages would have to achieve to meet the specified initial light output. Median efficacy for LED T8s tested by CALiPER to date is 44 lumens per watt. The highest efficacy measured to date is approximately 70 lm/W. At that efficacy, an LED T8 producing equivalent light output to fluorescent would draw 38 watts, increasing total energy use. To provide equivalent light output to fluorescent T8s and also save energy, LED T8s will need to become two to three times more efficacious than they are today.

Table 2. Implied LED T8 Lamp Efficacy to Provide Light Output Equivalent to Fluorescent

LED T8 wattage	Implied efficacy for 2,700 initial lumens (lm/W)
20	135
19	142
18	150
17	159
16	169
15	180

1 See CALiPER Round 5 and Round 9 summary reports for additional details: www.ssl.energy.gov.

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Table 3. Suggested Specifications for Four-Foot LED Linear Replacement Lamps

Performance Attribute	Specification	Notes
Initial minimum lamp light output *LED useful life is based on 70% lumen maintenance. Fluorescent T8 lamps have much higher lumen maintenance, about 94%. The initial lumen specification for LED T8 aims to ensure equivalent output to fluorescent T8.* *Measured fixture efficiency with LED T8s averaged 17% higher than with fluorescent, due to LED directionality.*	**2,700 lumens**	Based on equivalency to fluorescent T8 (average of 75 T8 lamps) with the following: – Average initial fluorescent T8 lumens = 2,778 – Normal ballast factor = 0.87 – Depreciation of fluorescent lamp lumens at time of relamping (70% of rated life) = 0.94 – Fixture efficiency factor, fluorescent compared to LED = 0.17 – Fluorescent depreciated lumens = 1,886 – Divide by 0.7 to get LED initial lumens = 2,694, round to 2700
Minimum lamp life, L70 *Unlike for conventional light sources, there is no standard life rating method for LED T8 lamps. The products are too new to have long-term operating data available.*	**35,000 hours** Ask for 6000 hours of integral lamp operating data (not just LED data). Lumen maintenance at 6000 hours should be at least 94.1% of initial value.	Fluorescent T8 rated life averages 24,000 hours on 3-hour starts and 30,000 hours on 12-hour starts, both on instant start ballasts. Longer life of 40,000 hours or more is possible with programmed start ballasts.
Luminous intensity distribution	Varies, but users are strongly encouraged to evaluate intensity distributions in comparison to those from fluorescent systems. If possible ask for an intensity distribution plot for the LED T8 lamps in the intended fixture type (e.g., parabolic, lensed, etc).	
Correlated color temperature (CCT) (Kelvin)	Nominal CCTs and tolerances as defined in ANSI_NEMA_ANSLG C78.377-2008, "Specifications for the Chromaticity of Solid State Lighting Products."	Chromaticity tolerances defined in ANSI C78.377 correspond to approximately 7-step Macadam ellipses for fluorescent chromaticity. In addition to the six nominal CCTs defined for fluorescent sources, the standard defines 4500K and 5700K for SSL products.
	Nominal CCT: Tolerance 2700 K: 2725 ± 145 3000 K: 3045 ± 175 3500 K: 3465 ± 245 4000 K: 3985 ± 275 4500 K: 4503 ± 243 5000 K: 5028 ± 283 5700 K: 5665 ± 355 6500 K: 6530 ± 510	
Minimum CRI	**80**	Equivalent to 800 series fluorescent lamps.
Warranty	**3 years**	
Electrical Safety	ANSI/UL 8750	

What information should you request from the LED T8 replacement lamp manufacturer?

- LM-79 photometric test report from a CALiPER-qualified or NVLAP-accredited laboratory (see DOE SSL website www.ssl.energy.gov for more information).
- Lumen maintenance testing on the full lamp. At least 6,000 hours is recommended.

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