Are LEDs Ready for Recessed Downlight Applications?

BY JAMES BRODRICK

It seems that every new building has recessed downlights these days. The U.S. Department of Energy (DOE) estimates there are more than 400 million installed downlights in residential buildings alone, with some 20 million added each year. In both commercial and residential settings, downlights are often found in high-use areas, making them a logical target for measures to increase lighting energy efficiency and longevity.

This popularity has provoked interest in the question of whether recessed downlights are a good application for light-emitting diodes (LEDs). The potential advantages of using LEDs in downlights are considerable: directionality, dimmability, long life and lower wattage than incandescent downlights. Near-term technology improvements are expected to make LED downlights a compelling option within the next one-to-two years.

Several LED downlights are currently available on the market, with more coming in 2007. How do they compare to downlights with traditional lamping? As new LED downlights enter the market, how can you evaluate their performance claims and determine if the product is right for your lighting application?

Several considerations are important when evaluating downlights in general. First, color quality and consistency are important. Often multiple downlights are installed in a space, and color variations are noticeable and undesirable. Second, glare can be a significant issue, particularly with downlights used for general ambient illumination. The fixture must be designed to balance the need for some light at relatively high viewing angles to avoid the "cave effect," while still minimizing discomfort glare. A third aspect, particular to residential settings, relates to downlights installed in insulated ceilings. Most states require them to be rated for insulation contact and air-tight (ICAT), which results in a high-temperature operating environment for the light source.

COMPARING DOWNLIGHTS

A comparison of current downlight lamping options is detailed in **Table 1**. Note that the listed disadvantages for LED downlights reflect the status of 2006 LED technology. Recent industry announcements about technology improvements and new product launches make it clear that LED technology is evolving rapidly. Concurrently, significant progress is being made on development of industry standard test procedures specific to LED luminaires.

One key advantage in LED downlights is that LEDs are inherently directional. In that regard, LEDs are like reflector-style lamps, which are specially shaped and coated to emit light in a defined cone. Downlight fixtures that use standard "A"-style incandescent and non-reflector CFLs are typically only 50 percent efficient, meaning

Table 1 . Comparison of Recessed Downlight Lamping Options

	Advantages	Disadvantages
Incandescent Reflector	• Dimmable • High color quality • Low initial lamp cost	• High wattage • Low luminous efficacy • Short life (2000 hrs) • Heat increases cooling load
CFL Reflector	• High efficacy • Long life (6000-8000 hrs)	• Few dimmable products • Higher initial lamp cost than incandescent
CFL Pin-based	• High efficacy • Long life (10,000 hrs)	• Few dimmable products • Higher initial lamp cost than incandescent • Replacement lamps can be difficult to find
LED Downlight	• Dimmable • Potentially long life (30,000-50,000 hrs) • Lower wattage than incandescent • Directional light source	• Relatively low light output • Expensive to purchase • Very sensitive to high-temperature environment • Replacement lamps not available

** Replacement lamps not available*

Table 2. Examples of Recessed Downlight Performance Using Different Light Sources

		Commercial		Residential		
		26W pin-based vertical CFL	LED downlight	65W R-30 incandescent	15W R-30 CFL Edison base	LED downlight
Lamp	Rated lamp lumens	1800 lm		755 lm	750 lm	
	LED "typical luminous flux"		*100 lm/LED**			*45 lm per LED**
	Nominal lamp wattage	26W	10x3W LEDs	65W	15W	9x1W LEDs
	Lamp efficacy	70 lm/W	*33 lm/W*	12 lm/W	50 lm/W	*45 lm/W*
	CCT	3500 K	6500 K	2700 K	2700 K	2700 K
	CRI	80	70	100	82	67
Luminaire	Fixture efficiency	50%	n/a**	90%	90%	n/a**
	Delivered light output (lumens), initial	900	475	680	675	300
	Luminaire wattage	27W	28W	65W	15W	15W
	Luminaire efficacy	**33 lm/W**	**17 lm/W**	**10 lm/W**	**45 lm/W**	**20 lm/W**

**Italics indicate values not based on industry standard test procedures.*

***Fixture efficiency cannot be determined for the LED luminaires because there is no lumen rating test procedure available for LED devices or arrays.*

Source: U.S. Department of Energy, http://www.netl.doe.gov/ssl/general_illumination_recessed.htm

that about half of the light produced by the lamp is wasted inside the fixture. If designed effectively, LED downlights could sharply reduce this light loss. Another advantage is that, unlike CFLs, many LED systems work well with standard wall-mounted dimmers.

COMPARING PERFORMANCE

To provide the light output typically expected for downlights, multiple LEDs must be grouped together. This clustering generates heat, which requires good thermal management in the fixture. If the fixture temperature rises too high, the LEDs' light output will fall and their life will be shortened. This thermal management is especially critical in insulated ceiling applications, where fixture temperatures can be much higher than in other applications.

Table 2 compares the typical light output and efficacy of downlights using fluorescent, incandescent and LED sources. The downlights with LEDs were more efficacious than those with incandescent lamps, but far less efficacious than those with CFLs. As LED technology and product designs mature, this performance is expected to improve. LED downlight products announced for market introduction this year are expected to exceed CFL performance (more on this in future columns).

To provide reliable, unbiased product performance information, DOE recently began independent testing on commercially available solid-state lighting products. The department allows its test results to be distributed in the public interest for noncommercial, educational purposes only. To date, 13 products have been tested, including four downlights; approximately 40 more products will be tested in 2007, including more downlights as they come on the market. For more information on the testing program, or to request test reports, see: *http://www.netl.doe.gov/ssl/comm_testing.htm*.

WHAT TO ASK

As new LED downlights are introduced on the market, they should be evaluated carefully, keeping the following considerations in mind:

- The light output of current commercially-available LED down-

lights is lower than standard incandescent and CFL downlights. Ask the manufacturer for photometric test data and request a sample fixture to evaluate.

- If intended for residential use, ask the manufacturer about the product's measured performance in insulated ceilings. Does the design provide a thermal path by which heat from the LEDs can be dissipated? If adequate information is not available, it may be best to avoid use of the product in insulated ceilings.
- Ask for information on the correlated color temperature and color rendering of the LEDs used, but don't depend exclusively on this data. Limitations of traditional color metrics with respect to LEDs, especially CRI[1], dictate the need to evaluate the luminaire in person.

For more information on using LEDs in recessed downlight applications, visit the LED Applications section of the DOE Solid-State Lighting website at: *www.netl.doe.gov/ssl/general_illumination_recessed.htm.*

James Brodrick is the lighting program manager at the U.S. Department of Energy, Building Technologies Program. The DOE's national strategy to guide high efficiency, high-performance solid-state lighting products from laboratory to market draws on key partnerships with the lighting industry, research community, standards organizations, energy efficiency programs, utilities and many other voices for efficiency.

1 Protzman J, Houser K. 2006. LEDs for General Illumination: The State of the Science. Leukos Vol 3 No 2.

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