PIN-BASE LED LAMPS

A guide to replacing pin-base CFLs with LED lamps in downlights.

Summary

The LRC studied 4-pin G24q/GX24q LED lamps to replace 4-pin G24q/GX24q CFLs in downlights and found:

- Luminaire light output was sufficient to replace most 26 W CFLs and may be sufficient to replace 32 W CFLs. Light output was not sufficient to replace 42 W CFLs.
- The LED lamps met IESNA uniformity recommendations in a simulated hallway.
- CRI was suitable for most commercial environments.
- Specifiers need to determine if the existing ballast is compatible with the LED lamp product under consideration, based on the LED lamp manufacturer's specifications.
- The payback period for pin-base LEDs is about two years. The payback period will be shorter if financial incentives are available.

Consider an LED retrofit kit if:

- there are concerns about ballast compatibility;
- the existing ballast is near its end of life—typically 50,000 hours;
- magnetic ballasts are currently in use;
- existing CFLs are greater than 32 W.

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Lighting Research Center at Rensselaer

Introduction

CFL recessed downlights with 4-pin G24q/GX24q lamps are typically used in commercial spaces and operate using electronic ballasts in the luminaire (not integrated into the lamp). Several pin-base LED lamps (sometimes referred to as "CFLEDs") are available that can replace these pin-base CFL lamps by simply plugging the LED lamp into the original socket. No new wiring is needed. The original CFL ballast continues to operate the pin-base LED lamp.

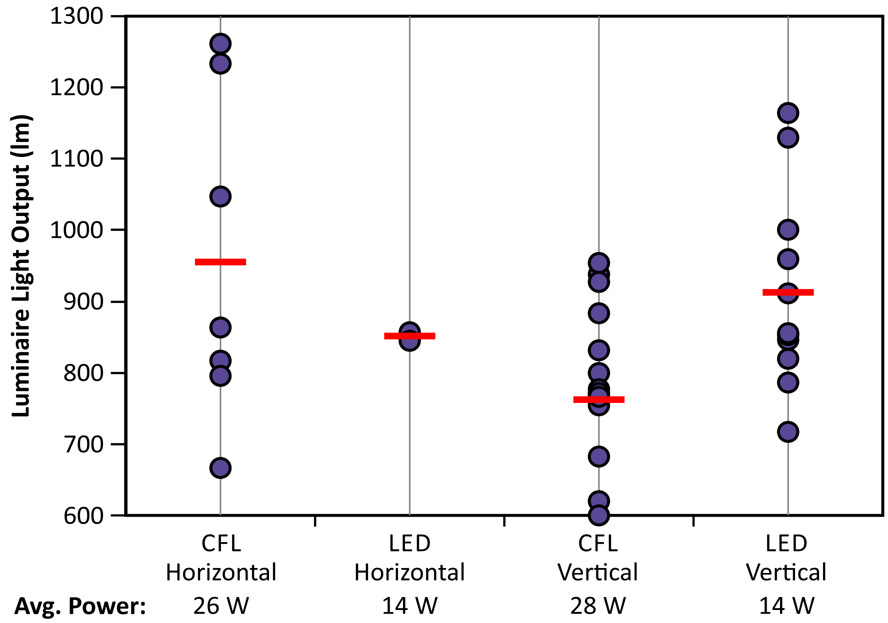
Under the direction and sponsorship of the Lighting Energy Alliance (LEA), the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute tested eight models of pin-base LED lamps from five manufacturers for photometric performance, temperature during operation, and electromagnetic compatibility. Products were purchased from March 2015 to March 2016. All of the tested LED lamps were specified by the manufacturer to replace 26W CFLs. (Some specified they could replace other CFL wattages, too, from 13W to 42W.) Testing was conducted with ballasts that were specified by the lamp manufacturers as being compatible with each lamp, except as noted below. The LRC also analyzed application illuminance and uniformity using lighting simulation software and investigated ballast compatibility in existing buildings.

Eight pin-base LED lamp models were tested for this study.

Performance

LEDs provided enough light output to replace 26W CFLs.

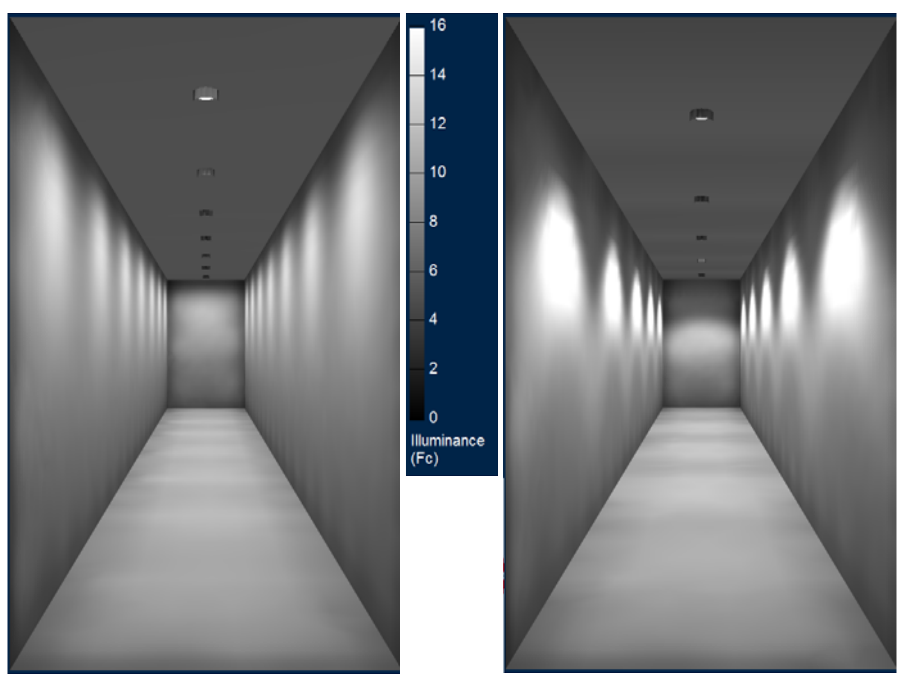
The tested LED lamps provided sufficient luminaire light output to replace most CFL downlights up to 26 W.



Downlight light output with various lamp/ballast/luminaire combinations. The CFL data include 26 W lamps tested for this study as well as data from previous testing from the LRC's National Lighting Product Information Program (NLPIP) and the Lighting Analysts' InstaBase. *The LED data are from this study. The red bars indicate the average for columns.*

Uniformity recommendations were met.

In photometric simulations of a hallway, the tested LED downlights met or exceeded IESNA illuminance and uniformity recommendations when replacing 26 W CFL downlights on a one-for-one basis. (The spacing of the downlights was optimized for CFLs.)



CFL Downlights
Average: 10.4 fc; Max/Min: 1.5

LED Downlights
Average: 15.0 fc; Max/Min: 1.5

The pin-base LED lamps tested by the LRC will likely provide suitable illuminance levels and uniformity when replacing 26 W CFLs in downlights. In both AGi32 simulations shown here, there are seven evenly spaced downlights with vertically-oriented lamps in a 50' x 10' x 6' hallway.

Power demand was cut by about half.

In downlights, the pin-base LED lamps decreased luminaire power demand by an average of 49% compared to downlights with 26 W CFLs.

CCT was close to the specification.

The correlated color temperature (CCT) of the lamps was close to the specification. All of the tested LED lamps were specified to have a CCT of 3500K. The average of the tested lamps was 3485K (ranging from 3364K to 3623K).

CRI was acceptable.

The color rendering index (CRI) of the lamps was acceptable for most commercial environments, ranging from 82 to 85, with an average of 84.

Power quality was not an issue.

All lamps met DesignLights Consortium's *Qualified Product List* requirements for power factor (PF) and total harmonic distortion (THD) when paired with compatible ballasts as specified by the lamp manufacturers.

Considerations

Use with a compatible ballast.

The manufacturers of the tested LED lamps provide a list of compatible ballasts. Specifiers need to inventory existing ballasts, either from as-built drawings or specifications or by accessing the ballasts, to determine lamp compatibility. When some of the tested lamps were used with a ballast that was not listed as compatible by the lamp manufacturers, the power factor (PF) and total harmonic distortion (THD) did not meet DesignLights Consortium's *Qualified Product List* requirements.

Don't count on energy savings until in-place ballasts are identified.

The total anticipated energy savings for a building can't be determined until the number of in-place ballasts that are compatible with LED lamps is determined. As a case study, ballast models in three Rensselaer Polytechnic Institute buildings were investigated to determine their compatibility for any of the eight tested LED lamp models. The percentage of compatible ballasts in these buildings are shown below.

Fraction of CFL downlight ballasts at three Rensselaer buildings that were compatible with any of the eight tested pin-base LED lamps in this study.

athletic building	50%
student union	100%
LRC	19%

LED lamps may provide enough light to replace a 32 W CFL, but not enough to replace a 42 W CFL.

Illuminance levels from the tested lamps may not be sufficient to replace 32 W CFLs in all cases. The illuminance level depends on the ballast, luminaire spacing, and the target illuminance level. Specifiers should check illuminance levels with a mockup (or photometric testing and modeling).

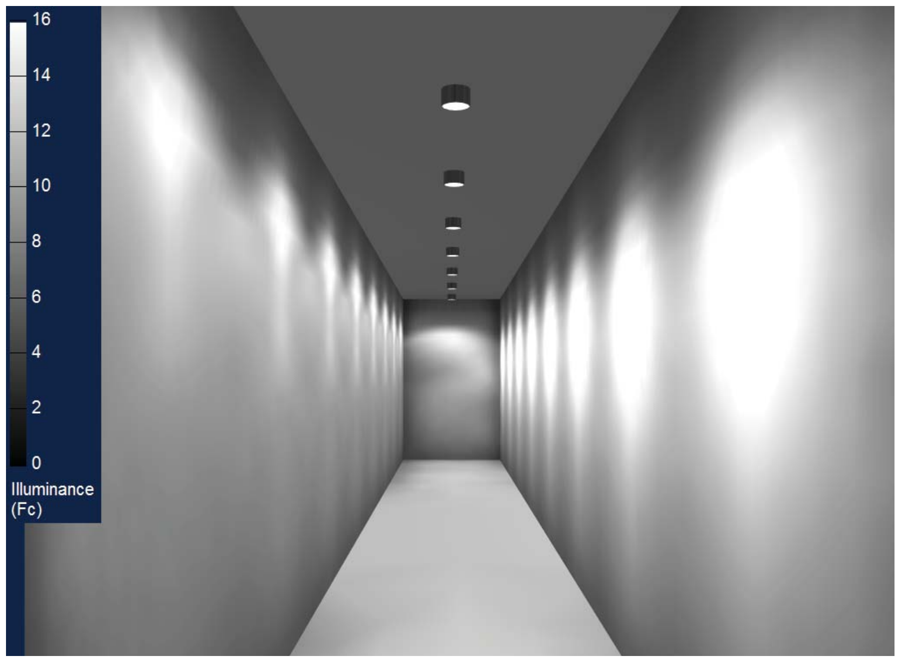
The tested LED lamps did not produce enough light to replace 42 W CFLs.

Use caution when installing in an insulated ceiling or lensed downlight.

The temperature at the LED circuit board may be higher than the maximum temperature recommended by the LED manufacturer in insulated ceilings (IC), even in open downlights. This may cause lamps to not operate or shorten operating life. LED lamps in lensed downlights, even in non-IC conditions, might have temperatures close to the maximum specified by the manufacturers. This may shorten the operating life of the lamp, depending on the electrical current at the LED.

Socket position in horizontal downlights may need to be adjusted.

Horizontal LED lamps might be shorter than the CFLs lamps they replace and may not be centered in the downlight. This could result in asymmetrical patterns of light on adjacent walls. The forward-and-back position of the socket may need to be adjusted so the lamp is centered within the reflector.



Depending on the orientation of the socket and the position of the lamp in the luminaire, horizontally positioned LED lamps may produce asymmetric patterns of light on adjacent walls.

Electromagnetic compatibility requirements may not be met.

Electromagnetic compatibility (EMC) standards set by the Federal Communications Commission (FCC) may not be met. Most of the pin-base LED systems tested (downlight, lamp and ballast as a whole) exceeded the radiated and conducted emissions criteria set by FCC for commercial and industrial digital devices. All of the tested systems exceed the FCC conducted emissions criteria for residential, commercial, and industrial digital devices. The LRC did not test CFLs for EMC, so it is possible that some CFL systems would also exceed allowed levels.

Inspect the socket before installing the lamp.

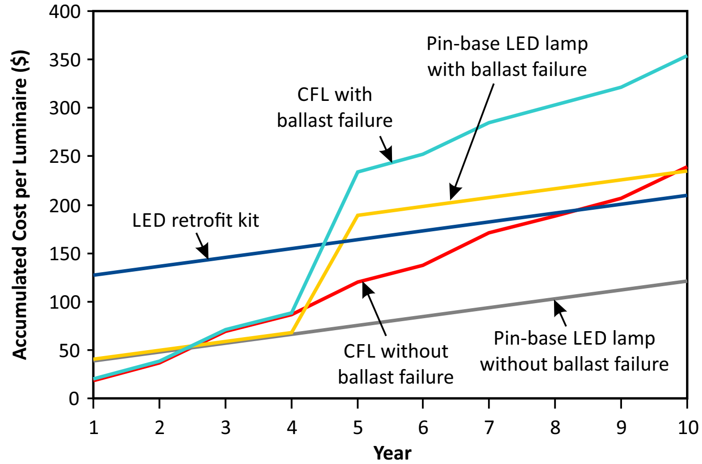
Socket condition should be inspected in conjunction with inspection of existing ballasts for compatibility.

Energy and Economic Savings from Pin-base LED Lamps and LED Retrofit Kits

Consider three economic factors when deciding to upgrade lighting: initial cost, simple payback period, and cost of ownership. These factors can help decide between upgrading with pin-base LED lamps or LED retrofit kits, which bypass the CFL ballast and connect directly to the electric line power.

Upgrading with a pin-base LED lamp incurs a lower initial cost than installing a retrofit kit, which has a higher material cost and requires an electrician rather than maintenance staff for installation.

However, payback period and cost of ownership are dependent on whether the CFL ballast fails within the period of analysis (10 years in the example below), which would require an additional ballast purchase and installation. With no ballast failure, the pin-base LED lamp offers the shortest payback period (2.0 years) and lowest cost of ownership. However, if the CFL ballast were to fail, the retrofit kit would have the lowest cost of ownership. The retrofit kit's payback period is 8 years or the length of time until the CFL ballast fails, whichever is shorter. Many electronic CFL ballasts have a rated life of 50,000 hours, and specifiers should consider how many hours a CFL ballast has been previously used before deciding between pin-base LED lamps and LED retrofit kits.



Accumulated cost of ownership of five scenarios: CFL with and without a ballast failure, pin-base LED lamp replacement with and without ballast failure, and an LED retrofit kit. The ballast failure is assumed to occur during the fourth year. The economic assumptions used in the table are also used here.

	Lamp	CFL base case		Pin-base LED lamp		LED downlight retrofit kit
	Ballast	Ballast does not fail	Ballast fails and is replaced	Ballast does not fail	Ballast fails and is replaced	N/A
Assumptions	Hours of use	4,380 hours per year				
	Cost of electricity	$0.15/kWh				
	Labor rates	Maintenance staff: $33/h (lamp replacement) Electrical contractor: $81/h (retrofit kit installation, ballast replacement)				
	Power demand	27.5W		13.9W		14W
	Material costs	$4/lamp, $30/ballast		$19/lamp, $30/ballast		$35/retrofit kit
	Lamp life	10,000 h		50,000 h		50,000 h
	Labor	0.3h per lamp replacement	0.3h per lamp replacement, 1.0h per ballast replacement	0.3h per lamp installation, 1.0h per ballast replacement		1.0h per retrofit kit installation
Results	Initial cost (material + labor)	N/A	N/A	$29		$104
	Simple payback period	N/A	N/A	1.9 yr		7.8 yr (or at time CFL ballast would have failed, if earlier)
	Average annual cost of ownership over 10 years	$24/yr	$35/yr	$12/yr	$23/yr	$21/yr

Economic analysis of five scenarios: CFL with and without a ballast failure, pin-base LED lamp replacement with and without ballast failure, and an LED retrofit kit. Any ballast failure is assumed to occur during the fourth year. Initial cost, simple payback period, and annual average cost of ownership is calculated. The LRC did not test the life of LED lamps or conduct any testing of LED retrofit kits. Pin-base lamp LED lamp power demand is the average measured. Retrofit kit power demand is the average rated power of six products. Material prices are an average of online retail prices for a quantity of one product in September 2016. Labor rates and time are from R.S. Means Facilities Maintenance & Repair Cost Data for the Albany, NY, area. Maintenance staff labor rate includes fringe. Electrical contractor labor rate includes fringe, overhead, and profit. No economic incentives are included.

In addition to economic reasons, other reasons to consider an LED retrofit kit include:

- if a compatible lamp isn't available for the existing ballast, or the ballast in unknown.
- if adding dimming capability is desired and the existing ballast is non-dimmable.
- if the existing ballasts are magnetic. The tested LED lamps are not compatible with magnetic ballasts, and these ballasts are less efficient than electronic ballasts.
- if the aesthetic appearance of the retrofit kit is preferred.