

Next Generation Luminaire (NGL) Downlight Demonstration Project:

Hilton Columbus Downtown

June 2014
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Prepared by:

Pacific Northwest National
Laboratory

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Final Report prepared in support of the Commercial Building Initiative
NGL Downlight Demonstration Project

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Prepared for:
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Preface

The U.S. Department of Energy (DOE) estimates that there were about 700 million downlight luminaires installed in residential and commercial buildings in the U.S. as of 2012, with light-emitting diode (LED) luminaires representing less than 1% of this installed base. Downlight luminaires using conventional incandescent, halogen, and compact fluorescent lamps have lower efficacies and shorter expected lifetimes than comparable LED systems, but the lower initial cost of the conventional technology and the uncertainties associated with the newer LED technology have restricted widespread adoption of LED downlight luminaires. About 278 tBtu of energy could be saved annually if LED luminaires were to saturate the downlight market, equating to an annual energy cost savings of \$2.6 billion.¹

To increase the adoption rate of high-quality, energy-efficient LED systems and to stimulate ongoing product development, DOE conducts demonstration projects that document the real-world performance of LED luminaires relative to conventional technologies. These demonstration projects evaluate all aspects of the lighting system design, purchase, installation, and operation, assessing the impacts of implementing LED technology for the building owners and users. DOE collaborates with commercial building owners in these demonstrations and evaluates projects based on general criteria of saving energy, matching or improving lighting system performance and lighting quality, and offering cost-effective solutions relative to standard competing light sources.

This report is the first in a series of demonstrations that will focus on documenting the implementation of LED downlight luminaires. For these projects, DOE sought projects where the host organization implemented products available from manufacturers who had participated in the DOE Next Generation Luminaires (NGL) competitions. Preference for host organizations was given to members of the DOE's Better Buildings Alliance (BBA), which promotes energy efficiency in U.S. commercial buildings through collaboration with building owners, operators, and managers.

For this report, the DOE evaluated the use of LED downlight luminaires in the Hilton Columbus Downtown hotel.

¹ DOE, *Adoption of Light-Emitting Diodes in Common Lighting Applications*, May 2013, (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led-adoption-report_2013.pdf).

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- Phil Hornstra, Director of Property Operations for the Hilton Columbus Downtown
- Ardra Zinkon, President and Director of Lighting Design, Tec Studio, Inc.
- Cheryl Fabian, Marketing Manager for Eaton's Cooper Lighting Business.

Each of these individuals generously shared information for the project, and each was very responsive to numerous inquiries from the authors. Mr. Hornstra and Ms. Zinkon made themselves available for several phone interviews and for several hours of in-person discussions during the site visit in March 2014.

Acronyms and Abbreviations

AFF	above finished floor
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BBA	Better Buildings Alliance
Btu	British thermal unit
CCT	correlated color temperature
CFL	compact fluorescent lamp
CRI	color rendering index
DOE	U.S. Department of Energy
fc	footcandle
FL	fluorescent
HVAC	heating, ventilation and air conditioning
IES	Illuminating Engineering Society
IESNA	Illuminating Engineering Society of North America
K	kelvin
kBtu	thousand British thermal units
kWh	kilowatt hour
LED	light emitting diode
LEED	Leadership in Energy and Environmental Design
LFL	linear fluorescent
lm	lumen
lm/W	lumens per Watt
lx	lux
NGL	Next Generation Luminaires
nm	nanometer
PNNL	Pacific Northwest National Laboratory
REC	renewable energy credit
SSL	solid-state lighting
tBtu	trillion British thermal units
W	Watt

Executive Summary

Guest room lighting represents a major use of energy for hospitality facilities in the U.S. Past efforts to reduce lighting energy use in guest rooms have mostly consisted of implementing CFL lamps and luminaires. CFLs offer the hospitality segment reduced energy consumption, higher efficacy, and much longer lifetimes than incandescent and halogen lamps, but they also have drawbacks. CFLs usually have a warm-up period before they reach full light output, vary in color consistency, have lower color rendering indices (CRI) compared to incandescent lamps, and are difficult or impossible to dim. LEDs improve upon many of these drawbacks and offer an attractive combination of additional energy savings, longer lifetimes, and turning instantly “on” at full light output, often with improved dimming and other control capabilities.

The Hilton Columbus Downtown hotel is a Leadership in Energy and Environmental Design (LEED) Gold certified contemporary facility designed by architects HOK and Moody-Nolan. Each of the 484 guest rooms uses seven 15 W LED downlights: four downlights in the entry and bedroom and three downlights in the bathroom. The 48 suites use the seven 15 W LED downlights and additional downlights depending on the space requirements. In total, the 450,000 ft² facility has more than 3,700 LED downlights. The LED downlights for this facility were selected not only to meet Hilton’s sustainability goals and LEED rating energy criteria, but also based on the designer’s desire to provide hotel guests with familiar lighting quality and operation. Lighting designer Ardra Zinkon, President and Director of Lighting Design for Tec Studio Inc. in Columbus, wanted the hotel guests to feel at least as comfortable in their guest room as they feel in their own homes.

“Hotel guests do not expect a delay when they turn on a light switch before the light comes on, and they do not expect to have to wait for the light to warm up before it is at full brightness,” Zinkon told the PNNL project team during an interview. “LED technology allowed us to provide guests lighting that was instant-on at full brightness, plus we could provide cost-effective dimming capability with LED.”

Initially, the lighting designer hoped to include wireless vacancy sensing within the bedroom to control the lighting. This desire led to the consideration of a Lutron scene control system, but this possibility was rejected based on the increased costs to purchase and implement such a system. The Lutron Maestro dimming solution was subsequently evaluated based on its compatibility with wireless controls. However, several operational difficulties were encountered with this solution during a full-scale mock-up evaluation, and the dimming control at the switch location was seen as not being intuitive for the guest, who was assumed to only be familiar with common residential-style incandescent dimmers. Consequently, the possible use of wireless sensors in the bedroom was eliminated and the designers selected the Lutron Diva dimming system. This system uses simple phase-control dimming of the LED luminaire. The interface for the guest is an on-off rocker switch with a slide dimmer control alongside the switch, which was viewed as a more familiar type of dimming control.

PNNL research staff documented the performance of the LED luminaires during a site visit in March 2014 and found that the system provided adequate light levels and lighting quality for the guest room tasks while utilizing controls that enable great flexibility for the guest. Wall switches for different luminaires are clearly labeled, and slide dimmers next to the switches for the LED downlights in the bedroom and the bathroom make dimming control obvious and easy. A master switch at the entry door enables the guest to turn off all the room lighting when leaving the room, avoiding the need to access individual fixtures, and a well-designed placard instructs the guest on using the master switch. A ceiling-mounted wireless vacancy sensor automatically turns off the bathroom lighting when the bathroom is vacant.

The LED downlights provided sufficient lighting to satisfy IES task requirements, in most cases exceeding the IES recommended values for guests of any age. In the entry area, the LED downlights provided measured horizontal illuminances on the floor that ranged from 120 lx to 203 lx. On the desk, the illuminances measured ranged from 177 lx to 275 lx across the desktop with just the LED downlights on; these values increased to a range of 220 lx to 332 lx when the other room ambient lighting (millwork and bed fixtures) were also turned on. At the front edge of the bathroom vanity, the horizontal illuminance from just the LED downlights was 562 lx.

All of the light sources in the room had measured CRI values in the range of 80 to 85 but the LED downlights, in particular, rendered reds (evaluated based on R_9^2 values) better than the other sources, especially the CFLs. Color consistency between different samples of the same lamp type has also been a major concern with energy-efficient sources. Although there were seven LED downlights in the guest room, the total range of measured CCT values for those products was less than 40 K. The difference between two samples of each of the fluorescent types was greater than the total difference between seven samples of the LED sources.

From an energy standpoint, the electrical power for the guest room lighting in the Hilton Columbus Downtown was more than 20% less than the power allowed by ANSI/ASHRAE/IESNA Standard 90.1-2007, which was the prevailing energy code at the time of installation. This resulted in 145,236 kWh in annual energy savings relative to code, for the same operating hours (assumed as 3,500 hours per year). Further savings are expected from a reduction in operating hours and light levels due to dimming, clearly labeled and convenient controls, and an occupancy sensor. Based on simulations using similar downlights, the LED downlights provided 50% energy savings compared with horizontal CFLs and even greater savings compared with other incumbent technology (e.g., incandescent). Additionally, the light distribution and quality prove comparable, if not better, than other incumbent technologies proving that, with proper application, LEDs can fulfill lighting needs while enabling both greater control for the user and additional energy savings.

² R_9 is a metric for evaluating the rendering of red colors.

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1.0 Introduction

1.1 Overview

This report summarizes an evaluation of LED recessed downlight luminaires in the guest rooms at the Hilton Columbus Downtown hotel in Columbus, OH. The facility opened in October of 2012, and the U.S. Department of Energy (DOE) conducted a post-occupancy assessment of the facility in January–March of 2014. Each of the 484 guest rooms uses seven 15 W LED downlights: four downlights in the entry and bedroom and three downlights in the bathroom. The 48 suites use the seven 15 W LED downlights and additional fixtures depending on the space requirements, so that in total the facility has more than 3,700 LED downlights. The downlights are controlled through wall-mounted switches and dimmers. A ceiling-mounted wireless vacancy sensor ensures that the bathroom luminaires are turned off when the room is not occupied.

After an overview of the entire hotel facility, details about the lighting design goals, products (e.g., lamps, luminaires, and controls) used in the guest rooms, the selection process, and the installation of the system will be discussed. Following, the findings from the PNNL Project Team’s on-site data collection, where the photometric, colorimetric, and ease of use characteristics were assessed, will be addressed. Finally, a discussion of the energy and economic performance of the LED downlight and control system concludes the report.

1.2 Lighting in hospitality facilities

As of October 2012, there were approximately 8,500 hotels occupying 1.7 billion ft² in the U.S.³ Using data collected from 2006 to 2012, ENERGY STAR® reported that the median hotel is 75,000 ft² and has about 1.8 rooms per thousand ft². According to the most recent data from the DOE, average electricity consumption in hotels was 61.3 kBtu/ft² and total average energy consumption was 110 tBtu/ ft².⁴ Hotels rank fifth in energy use within the commercial buildings sector.⁵ Hotel guest room energy usage typically represents between 40% and 80% of the total facility energy use, depending on the hotel size, location, type, heating, ventilation and air conditioning (HVAC) equipment, occupancy, and other characteristics.⁶

The hospitality sector is dominated by very large global organizations that manage thousands of facilities each.⁷ With energy use representing one of the fastest growing operating costs in this sector, energy efficiency has been and continues to be a high priority for these organizations. For example, in 2006, through the installation of 450,000 compact fluorescent lamps (CFLs), conversion of outdoor signage to LED and fiber optic lighting, and other energy-efficient changes, Marriott saved \$6 million and reduced greenhouse gas emissions by 70,000 tons.⁸ Hilton, as part of their plan to reduce energy consumption by 20% from 2009 to 2014, chose Renewable

³ EPA, *Energy Use in Hotels*, October 2012

(http://www.energystar.gov/buildings/sites/default/uploads/tools/DataTrends_Hotel.pdf?f0ea-5d04).

⁴ DOE, *Buildings Energy Data Book: 3.10 Hotels/Motels*, March 2012

(http://buildingsdatabook.eren.doe.gov/docs/xls_pdf/3.10.1.pdf).

⁵ EIA, *Commercial Buildings Energy Sector Energy Intensities: 1992-2003*, August 2009

(http://www.eia.gov/emeu/efficiency/cbecstrends/cbecs_tables_list.htm).

⁶ DOE, *Guest Room HVAC Occupancy-Based Control Technology Demonstration*, September 2012

(http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/creea_guest_room_occupancy-based_controls_report.pdf).

⁷ Marriott manages 3,800 facilities (<http://www.marriott.com/marriott/aboutmarriott.mi>; February 5, 2014); Hilton manages more than 4,000 (<http://hiltonworldwide.com/portfolio/>; February 5, 2014).

⁸ Energy Star, *Hotels: An Overview of Energy Use and Energy Efficiency Opportunities*

(<http://www.energystar.gov/buildings/sites/default/uploads/tools/SPP%20Sales%20Flyer%20for%20Hospitality%20and%20Hotels.pdf>).

Choice Energy as their energy provider and purchased Renewable Energy Credits (RECs) totaling 315 million kWh from small hydropower and wind energy projects—equivalent to 94% of electricity used at Hilton-hotels.⁹

In terms of lighting in hotels, many of the major hotel chains have transitioned away from incandescent and halogen lamps to CFLs. Recent informal surveys of the guest rooms in a number of hotels found that these facilities have implemented CFL technology on a wide scale (see Section 4.3). CFLs offer the hospitality segment reduced energy use, higher efficacy, and much longer lifetimes than incandescent and halogen lamps, but they also have drawbacks. CFLs usually have a warm-up period before they reach their full light output, vary in color consistency, have lower color rendering indices compared to incandescent lamps, and are difficult or impossible to dim. In fact, lighting designer Domingo Gonzalez, President of Domingo Gonzalez Associates Architectural Lighting Design in New York City, recently noted that most major hospitality chains no longer provide dimmers for their lighting - in order to achieve the energy savings offered by CFLs, providing guests with the ability to dim is sacrificed.¹⁰

LEDs improve upon many of the drawbacks to CFLs, and offer an attractive combination of additional energy savings, longer lifetimes, and turning instantly “on” at full light output, often with improved dimming and other control capabilities. LEDs lamps and luminaires can have efficacy ratings that approach (or in some cases exceed) twice the efficacy of CFL lamps and luminaires, providing the potential for reducing lighting power density by as much as 50%. Many LED products offer warranty periods that far exceed the expected lifetime of CFL products, enabling operating savings in replacement and labor costs. Compared to CFLs, LED products can make it much easier for hotels to implement solutions that use both dimming and occupancy control systems. The implementation of LED downlights in the Hilton Columbus Downtown hotel demonstrates many of these advantages.

⁹ EPA, *LightStay and Sustainability at Hilton Worldwide*, August 2012 (http://www.epa.gov/greenpower/documents/events/21aug12_gaines_presentation.pdf).

¹⁰ B. Millard, *Meet the replacements*, March-April 2013 (http://www.archlighting.com/technology/meet-the-replacements_2.aspx).

2.0 Guest room lighting

2.1 Building context

The Hilton Columbus Downtown hotel is a Leadership in Energy and Environmental Design (LEED) Gold certified contemporary facility designed by architects HOK¹¹ (design architect) and Moody-Nolan¹² (architect of record for interiors). Located in the heart of the Columbus downtown area, the facility features local artwork (Figure 1) distributed through the hotel, as well as an iconic skybridge¹³ that connects the hotel to the Greater Columbus Convention Center. A 15,000 ft² skylight completes the atrium (Figure 2), providing an indoor-outdoor experience to accompany the amenities offered: 484 king and queen guest rooms, 48 suites, 32,000 ft² of event space, a 160-seat full-service restaurant, coffee bar and lobby lounge, fitness center, and indoor pool and whirlpool. With a 450,000 ft² footprint, the hotel is an economic generator for the Columbus area, while utilizing energy-efficient technologies. The hotel also provides easy access to The Ohio State University. Named the Best Urban Development of 2012 by Columbus Underground,¹⁴ the design of the Hilton started in 2009, with construction occurring from fall of 2010 through the opening in October 2012. The hotel cost upwards of \$140 million.



Figure 1: Local artwork (PNNL photo)

¹¹ HOK, April 2014 (<http://www.hok.com/design/type/hospitality/hilton-columbus-convention-center-hotel/>).

¹² Moody-Nolan, April 2014 (http://www.moodynolan.com/#portfolio/project_88b0a696-8cc7-4ff8-a16e-253cc749105b).

¹³ Skybridge Illumination: video of the color-changing LED lighting implemented on the skybridge, November 2012 (<https://www.youtube.com/watch?v=0akXxbCTBVw>).

¹⁴ Columbus Underground, April 2014 (<http://www.columbusunderground.com/>).



Figure 2: Atrium lighting (PNNL photo)

2.2 Lighting goals and techniques

Meeting the Hilton's sustainability and LEED rating goals required the use of energy-efficient light sources in the guest rooms. In addition, lighting designer Ardra Zinkon, President and Director of Lighting Design for Tec Studio Inc. in Columbus, wanted the hotel guests to feel at least as comfortable in their guest room as they feel in their own homes, and to have the lighting in their guest rooms provide the type of aesthetic appearance and operational behavior that was familiar. "Hotel guests do not expect a delay when they turn on a light switch before the light comes on, and they do not expect to have to wait for the light to warm up before it is at full brightness," Zinkon told the PNNL project team during an interview. "LED technology allowed us to provide guests lighting that was instant-on at full brightness, plus we could provide cost-effective dimming capability with LED." Design goals for the lighting included:

- Energy-efficient equipment (light sources, luminaires and controls) that would exceed energy codes and help the facility meet the LEED goals;
- Products that offered low operational costs with long lifetimes and low maintenance needs;
- A light source that was at full output immediately and did not require any warm-up time;
- A light source for which the expected operating lifetime was not affected by possible frequent switching;
- A light source that could be dimmed, offering the type of functionality that many guests expect in their homes;
- A downlight luminaire aesthetic in which the light appeared to come from a single light source, similar to a halogen or incandescent residential-style luminaire;
- A downlight luminaire that could physically fit within the architectural constraint of a 6" depth for recessed luminaires in the soffits beneath the concrete slabs; and
- A light source in the downlight luminaires with excellent color consistency, since the luminaires near the windows in many of the guest rooms would be visible from the atrium and any color differences would be easily seen.

2.3 Luminaires and light sources

2.3.1 LED downlights

Selection

Based on the design goals listed above, the design team decided to recommend the use of LED downlights for the general lighting in the guest room entryways, bedrooms, and bathrooms. The possible use of CFLs was eliminated from consideration early in the design process based on the inability of CFLs to meet goals related to dimming, color quality, full light output without warm-up time, and long life regardless of switching frequency. Dozens of LED downlight options were reviewed by the designers, using technical data sheets and photometric test reports. Product samples of each option were obtained and evaluated during table-top review sessions. Many options were quickly eliminated based on one or more of the following reasons:

- Visibility of multiple LED sources, defeating the goal of creating the appearance of a single light source similar to incandescent or halogen;
- Lack of availability of correlated color temperatures (CCTs) in the 2700 K to 3000 K range, desired by the designers and consistent with Hilton’s specifications for guest room lighting;
- Lack of color consistency assurance (through LED binning specifications), creating the possibility of noticeable color variations; and
- Lack of a lens, which is required for use in the shower area of the bathroom.

After carefully vetting many products, the designers selected the Portfolio¹⁵ LED downlight from Eaton’s Cooper Lighting Business as the basis for design, with the Philips Lightolier Calculite^{16,17} LED downlight listed as an acceptable alternate. Both of these selections provide lenses for obscuring a direct view of the individual LEDs. In the Lightolier product, the lens is part of a remote-phosphor system for the LED sources, whereas in the Portfolio product, the lens serves to diffuse the light and obscure the view of the LEDs. Figure 3 shows one of the Portfolio downlights (not in operation) mounted in the soffit in a guest room, with the recessed lens shielding any direct view of the LED components. A full-scale mock-up of two guest rooms using the specified LED downlights demonstrated that the luminaires satisfied the designer’s goal of evoking an impression of “familiar” lighting, when the participants of the mock-up did not realize that the luminaires used LED sources. The mock-up also helped to verify the performance of the specified dimming system, an important step to assure compatibility between dimming devices and LED products.

The detailed specification and performance information for the Portfolio LED downlight is summarized in Appendix A.

Installation

The lighting in the guest rooms consists of several layers. Figure 4 shows the luminaire and control scheme for the entry area, bedroom, and bathroom. Upon entering the room, two downlights (type GAI) provide the ambient lighting needed for entry. These downlights also illuminate the guest as he or she stands before the wall-mounted mirror. The entry area lighting is shown in Figure 5. Moving through the entry and into the bedroom, there are two downlights in the soffit near the window (Figure 6). The bathroom has three

¹⁵ DOE, Next Generation Luminaires, April 2014 (http://www.nglc.org/10/winners/indoor_downlighting_Portfolio.stm).

¹⁶ DOE, Next Generation Luminaires, April 2014 (http://www.nglc.org/09/winners/indoor_downlighting_Calculite.stm).

¹⁷ Philips Lightolier, April 2014 (http://www.lightolier.com/products/index.jsp?CATREL_ID=35294&BLK=N&CAT_ID=33700).

downlights: two providing general lighting for the sink and toilet area and one lighting the shower (Figures 8 and 9).



Figure 3: Portfolio LED downlight from Eaton’s Cooper Lighting Business (PNNL photo)

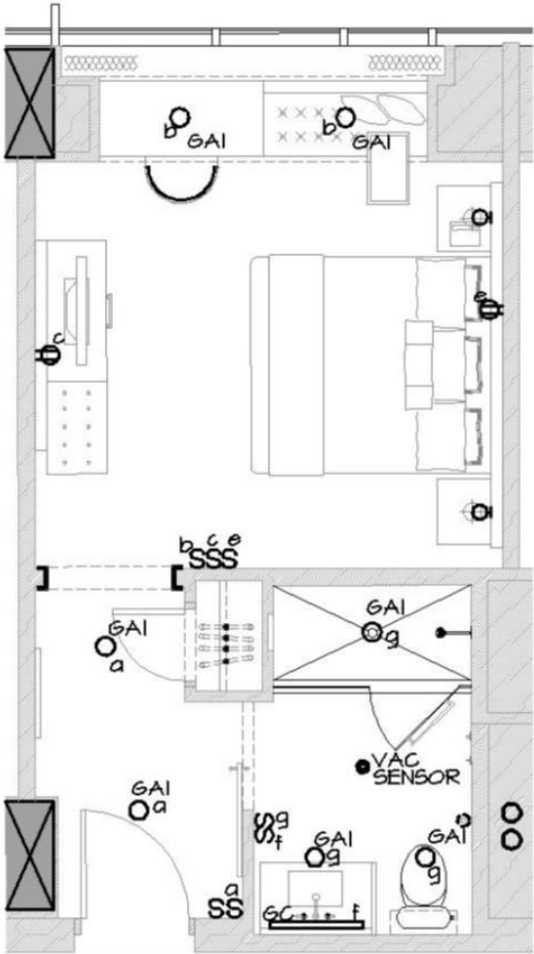


Figure 4: Lighting plan of guestroom (courtesy Ardra Zinkon)



Figure 5: Guest room entry area, showing the positions of the two LED downlights. (PNNL photo – flash photography was used; the photo does not accurately portray the lighting effect.)

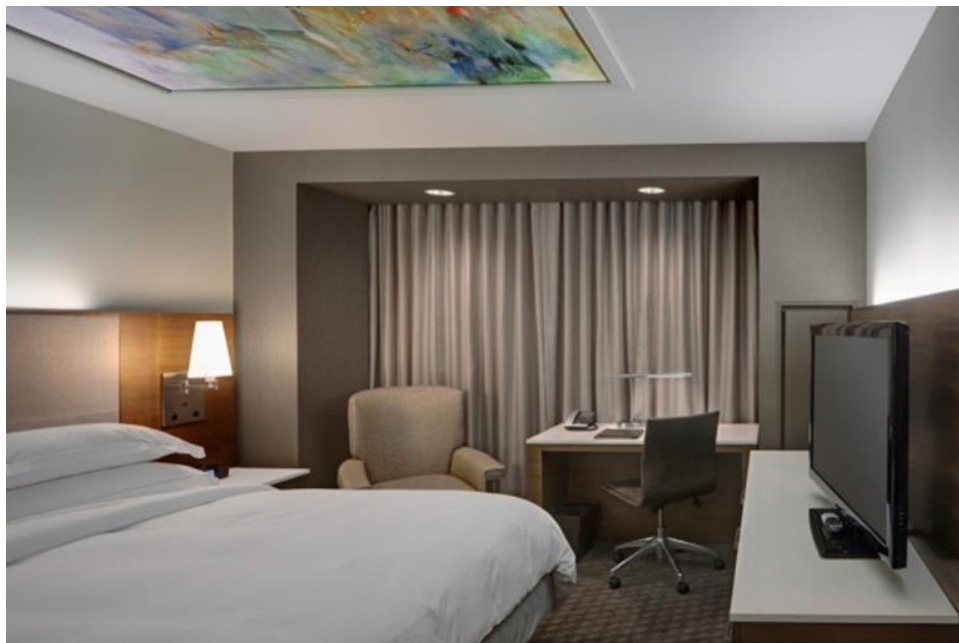


Figure 6: Guest room lighting (© Scott Pease Photography)



Figure 7: Bed headboard fixtures (PNNL photo)



Figure 8: Bathroom downlighting (PNNL photo)



Figure 9: Bathroom mirror lighting (PNNL photo)

2.3.2 Other sources and luminaires

Other than the LED downlights, two wall-mounted luminaires near the bed provide task lighting for reading, linear fluorescent luminaires integrated into the millwork behind the television and the bed provide ambient uplighting, and the bathroom mirror includes an integral linear fluorescent luminaire for additional lighting. While the LED downlights in the guest rooms were specified by the lighting designer, the wall-mounted luminaires that provide the reading task lighting near the bed were selected by the interior designer for the project (see Figure 7). The lighting design team specified the GE 13 W A19 LED screw-based lamp for these luminaires, which were designed for medium screw-based lamps. This lamp was selected for its lumen output, which matches or exceeds that expected from a 60 W incandescent lamp, as well as for its 3000 K CCT and 80 CRI, which nominally match the characteristics of the other LED sources in the room. However, the luminaire manufacturer provided these luminaires with their standard lamping using 18 W screw-based CFLs, and the luminaires were installed as provided. At the time of this report, the hotel was assessing the economics for upgrading to the originally specified LED lamp. The mirror-integrated luminaire is shown in Figure 9, and the millwork-integrated fixture with two fluorescent strips is shown in Figure 10.



Figure 10: Millwork fixture behind television, with lens removed (PNNL photo)

2.4 Lighting controls

2.4.1 Switching and dimming

As discussed in Section 2.2, the ability to dim at least some of the guest room lighting was an important design criterion. While the capability to dim is often either not possible or is very expensive for fluorescent and CFL technologies, most LED luminaires have dimming capability as a standard offering, with little to no increase in cost for the luminaire and its components. For this project, the two LED downlights in the window soffit area and the three LED downlights in the bathroom were installed with dimming capability.

Initially, the lighting designer hoped to include wireless vacancy sensing within the bedroom to control the lighting, since the necessary locations for the sensors made a hard-wired solution difficult to implement. This desire led to the consideration of a Lutron scene control system, but this possibility was rejected based on the increased costs to purchase and implement such a system. The Lutron Maestro dimming solution was subsequently evaluated based on its compatibility with wireless controls. However, several operational difficulties were encountered with this solution during a full-scale mock-up evaluation, and the dimming control at the switch location was seen as not being intuitive for the guest, who was assumed to only be familiar with common residential-style incandescent dimmers. (The operational difficulties encountered have subsequently been resolved through the availability of LED-rated forward-phase dimmers, which had not penetrated the market at the time of the Hilton project design. A recent GATEWAY report reviews phase-control LED dimming,¹⁸

¹⁸ DOE, *Dimming LEDs with Phase-Cut Dimmers: The Specifier's Process for Maximizing Success*, October 2013 (http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2013_gateway_dimming.pdf).

and the 2013 NEMA SSL-7A document establishes parameters for compatibility of LED phase-control dimming components.¹⁹⁾

Consequently, the possible use of wireless sensors in the bedroom was eliminated and the designers selected the Lutron Diva dimming system. This system uses simple phase-control dimming of the LED luminaire. The interface for the guest is on-off rocker switch with a slide dimmer control alongside the switch, which was considered a more familiar type of dimming control.

Due to the number of different switches used in the guest rooms, clear labeling was necessary to make the controls intuitive for the hotel guest. The two switches just inside the entry door include the switch for the two LED downlights in the entry area (marked ENTRY LIGHTS) and a master switch that allowed the guest to turn off all the room lighting upon leaving (marked ROOM MASTER and discussed further in Section 2.4.2). These switches and labels are shown in Figure 11; both are on-off rocker switches.



Figure 11: Entry area (left) and bedroom (right) switches with slide dimmer (outlined) for window lights (PNNL photo)

Upon entering the room, two downlights (type GAI) provide the ambient lighting needed for entry, and are controlled by a wall-mounted switch at the entry door; the switch is labeled “a” in Figure 4, which also appears next to the downlight it controls (GA1 in this case). Three switches control the lighting for the bedroom; one (labeled “b”) for the LED downlights in the window soffit (marked WINDOW LIGHTS) and two (labeled “c” and “e”) for the millwork-integrated uplights behind the television (marked TV UPLIGHT) and bed (marked HEADBOARD), respectively. The three uplight and entry switches are on-off rocker switches; the control for the window soffit downlights combines an on-off rocker switch with a slide dimmer beside the switch. Figure 11 shows these switches. The reading light fixtures mounted to the headboard have individual switches built into the fixtures for user convenience. Figure 7 shows these fixtures as well as the uplighting from the fluorescent fixture in the headboard millwork. The TV stand has a small task light integrated into the furniture which had a built-in switch. The desk also has an LED task light with a built-in switch; the task light can be seen in Figure 6.

¹⁹ NEMA, *Phase Cut Dimming for Solid State Lighting: Basic Compatibility (SSL 7A-2013)*, April 2013 (<http://www.nema.org/Standards/Pages/Phase-Cut-Dimming-for-Solid-State-Lighting-Basic-Compatibility.aspx>).

The bathroom within the guest room has three downlights: two providing general lighting for the sink and toilet area and one lighting the shower. These three luminaires are controlled by dimming switch “g”. The mirror has two built-in fluorescent luminaires vertically oriented along each side of the mirror; these are controlled by on-off switch “f”. All of the luminaires in the bathroom are controlled by a wireless vacancy sensor that is centrally mounted on the ceiling, to ensure that the bathroom lighting is switched off whenever the room is unoccupied. Figure 8 shows two downlights and the ceiling-mounted wireless vacancy sensor, while Figure 9 shows the downlight over the sink and the luminaires integrated into the mirror.

2.4.2 Occupancy control

Automatic controls based on motion detection, which are commonly used in other commercial and institutional applications, are problematic in hotel guest rooms because the guest may want one or more lights to remain on during times of little motion while relaxing or sleeping. But, manual controls for individual fixtures create an inconvenience for the hotel guest, who must turn off each fixture before vacating the room.

For the Hilton Columbus Downtown, the design team explored several options for automatic wireless vacancy control of the lighting in the bedroom but did not find a solution that was practical to implement and/or economically viable. The prevailing energy code for the project was based on ASHRAE/IES Standard 90.1-2007²⁰ and required a manual master control switch at the main room entry that controls all permanently installed luminaires and switched receptacles. As shown earlier in Figure 11, a master control switch was implemented for this project. In this project, the master switch controls the LED downlights in the entry area and the bedroom, the wall-mounted luminaires mounted at the bed headboard, and the millwork-integrate fluorescent luminaires. To further encourage guests to use the master switch, a special placard was designed and mounted just above the switch; Figure 12 shows this placard.



Figure 12: Entry area sign (PNNL photo)

The prevailing energy code did not require automatic control in the bathroom, but to enhance energy savings a passive infrared ceiling-mounted wireless vacancy sensor was implemented.²¹ Occupancy sensors alone are

²⁰ ASHRAE, *Energy Standard for Buildings Except Low-Rise Residential Buildings* (ANSI/ASHRAE/IESNA Standard 90.1-2007), 2007 (<https://www.ashrae.org/resources--publications/bookstore/standard-90-1-document-history#2007>).

²¹ Although automatic vacancy sensing was not required by the governing code at the time of the project, ASHRAE/IES Standard 90-2010 does require this feature.

estimated to provide 16% savings in lighting energy in guest rooms.²² PNNL verified that the vacancy sensor was operating properly during the site visit, as it consistently extinguished the bathroom lights after 15 minutes of vacancy during three different trials.

²² California Utilities Statewide Codes and Standards Team, *2013 California Building Energy Efficiency Standards: Guest Room Occupancy Controls*, October 2011
(http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/Nonresidential/Lighting_Controls_Building_Power/2013_CASE_NR_Guest_Room_Occupancy_Controls_Oct_2011.pdf).

3.0 Performance measurements

PNNL staff visited the Hilton Columbus Downtown Hotel on March 11–12, 2014 to document the lighting conditions in a typical guest room. Results are summarized here and Appendix B provides further detail.

3.1 Photometric performance

Illuminance levels were measured in the entry area, on the desk, and in the bathroom sink area. The LED downlights provide the primary illumination in each of these areas. In the entry area, the range of measured horizontal illuminances on the floor was from 120 lx to 203 lx, with a mean of 168 lx.^{23,24} On the desk, the illuminances measured ranged from 177 lx to 275 lx across the desktop with just the LED downlights on; these values increased to a range of 220 lx to 332 lx when the other room ambient lighting (millwork and bed fixtures) were also turned on.²⁵ The portable task light fixture on the desk provides supplementary light for the downlights and other room lighting if needed.

At the front edge of the bathroom vanity, the horizontal illuminance from just the LED downlights was 562 lx, which increased to 691 lx when the mirror lights (linear fluorescent) were also turned on. Vertical illuminances at a height of 5' above the finished floor (AFF) and aligned with the front edge of the vanity (at the location of a person's face as he or she looks in the mirror) were 250 lx with just the downlights on and 425 lx with the downlights and the mirror lighting.²⁶

In summary, the LED downlights provide sufficient lighting to satisfy IES task requirements, in most cases exceeding the IES recommended values for guests of any age. The dimming functionality of the downlights enabled further energy savings for guests who chose to reduce the light levels for comfort or purpose (e.g., room ambiance rather than task lighting needs).

3.2 Colorimetric performance

The guest room provided a good setting for comparing the color properties of several different light sources, as well as the variations in color between different samples of the same light source type. Color quality and color consistency are common concerns with energy-efficient light sources for designers and users, whether linear fluorescent, CFL, or LED. DOE measured the CCT, CRI, and R_9 values for each fixture in the guest room.

All of the light sources in the room had CRI values in the range of 80 to 85. Table 1 shows the average values for each of the color metrics, for the four different light source types in the room. The LED downlights had R_9 values which were greater than the other sources, particularly relative to the CFLs. Color consistency between different samples of the same lamp type has also been a major concern with energy-efficient sources. Although there were seven LED downlights in the guest room, the total range of measured CCT values for those products was less than 40 K, less than the range for any of the fluorescent sources, for which there were only two samples of each (Table 10). In other words, the difference between two samples of each of the fluorescent types was greater than the total difference between seven samples of the LED sources.

²³ This satisfies the IES illuminance recommendation of 20 lx for a guest room entry area as well as providing the higher illuminances required for visual task needs at the mirror and the closet.

²⁴ Illuminating Engineering Society, *The Lighting Handbook* (Table 28.2), ed. D. DiLaura, K. Houser, R. Mistrick, G. Steffy, 2011.

²⁵ IES recommends an illuminance of 200 lx for reading at a bedroom desk for guests ages 25-65 and 400 lx for guests over age 65.

²⁶ IES recommends 200 lx for ages 25-65 and 400 lx for ages over 65 for both the horizontal illuminance at the vanity and the vertical illuminance at face height.

Table 1: Summary of color performance – average for each source

Fixture	CCT	CRI	R _g
LED downlights (quantity 7)	3069	83	40
CFLs (2)	2798	81	-3
Millwork fixtures (Fluorescent - 2)	3802	85	29
Mirror fixtures (Fluorescent - 2)	3001	85	8

3.3 User response

A formal survey of hotel guests was not conducted as part of this project. However, the project team evaluated customer reviews and comments (March 12, 2014) about the Hilton Columbus Downtown on common travel websites (e.g., Trip Advisor, Yelp, Expedia, and Hotels.com), specifically looking for any comments related to the guest room lighting. Most comments touched on the windows overlooking the atrium, the bathroom lights, and the controls. For the most part, the vacancy sensor in the bathroom and the other controls (e.g., switches) were easy to use and appreciated. Selected comments are shown in Appendix C.

4.0 Discussion of energy savings

The decision by the design team to use LED downlights was driven primarily by the lighting needs of the hotel's guests and by the desired functional and aesthetic qualities, rather than by an economic analysis. The high efficacy of the LED downlights enabled the designers to provide the lighting needed for various guest activities at very low power density, freeing more of the lighting power budget for other task and ambient needs. Based on the design goals and some of the architectural constraints within the rooms, alternatives to LED technology were not seriously considered, and a traditional energy economic comparison was not required. Instead, the energy savings will be assessed in this report based on comparison to energy code requirements, to other downlight technologies, and to the lighting power installed in typical guest rooms in other facilities.

The selection of LED luminaires was based on the design goals for this project rather than economics alone, and the specific economic details for the project are confidential. Based on general cost information provided by Eaton's Cooper Lighting Business for products available as of this report, PNNL estimates that the dimmable LED downlight used ranges in price from roughly 10% less to 20% more than dimmable versions of the CFL downlights used in the comparisons in Section 4.2, depending on the type of dimming and dimming ballast used. (Some LED dimming options are more costly but the Hilton used the standard dimming provided with the fixture.) Consequently, the cost difference for this project between dimmable CFL downlights and dimmable LED downlights was not significant, especially considering any volume discounting which may have applied. As shown in Table 3 (section 4.2), the LED downlight saves 46% to 50% energy compared to the CFL downlights, and it provides the aesthetic appearance and dimming functionality desired for the Hilton guest rooms, unlike the CFL options.

4.1 Relative to energy code requirements

For the lighting of hotel guest rooms, the prevailing energy code in use when the Hilton Columbus Downtown was designed and constructed was based on ASHRAE Standard 90.1-2007, which established a lighting power density allowance for a hotel guest room of 1.1 W per ft² using the space-by-space method.²⁷ With an area of 300 ft², the code-allowed lighting power for each guest room was 330 W. The installed system in the guest rooms at the Columbus Hilton used 252 W, more than 20% less than the allowance. Based on the Hilton's assumptions of 3,500 annual operating hours for guest room lighting and the Hilton's energy rate of \$0.07 per kWh, the lighting in the 532 guest rooms and suites saves 145,236 kWh and \$10,167 in energy costs per year relative to the code power allowance.

Additional savings are expected from the level of control provided to hotel guests, but these savings are very difficult to accurately estimate. Providing the guest with the ability to separately control individual elements of the lighting, including the ability to dim the LED downlights, can reduce both the power and the operating hours for the lighting. Because LEDs operate more efficiently when operated at lower temperatures, input power when dimming may be reduced to a greater extent than the light output. For example, when a guest adjusts the light output by dimming it to 50% output, the input power may be reduced by more than 50%, since the LED efficacy increases. The specific reductions depend on the combination of dimmer and LED package and driver used. The wireless vacancy sensor in the bathroom and the master control switch at the guest room door can further reduce operating hours, yielding greater annual savings.

²⁷ For the space-by-space method, the lighting power allowance (W) is determined by multiplying the floor area of each space by the listed lighting power density (W/ft²) for the space type (determined by the proposed use of the space). The sum of the lighting power allowance for all space types gives the total.

As described earlier, the installed system combines LED downlights with several different fluorescent lighting sources. Additional savings are possible through further use of LED sources. For example, the specification for the reading lights by the bed called for 13 W LED A-lamps in these fixtures, but the fixtures were supplied with 18 W CFLs instead, amounting to an additional 10 W in each room. The lighting fixtures in the millwork were designed and supplied with linear fluorescent lamps based on lower cost; lower wattage LED options are available for this application and the relative cost difference has been decreasing during the months since the Hilton opened. In future projects, additional use of LED sources along with the additional control capability made easier with LED technology would likely enable even more energy savings in guest room applications.

4.2 Relative to other downlight options

In addition to comparing the installed LED solution to the energy code requirements, the PNNL project team also evaluated the energy implications of implementing the desired lighting design using alternate technologies. For these comparisons, three alternate 6" downlight luminaires were selected based on roughly matching their light output with the output from the 6" LED downlight used. The alternates were selected from the Portfolio downlight family, which includes the NGL-recognized LED model as well as downlights with vertical CFL lamps, horizontal CFL lamps, and/or halogen PAR lamps. Table 2 shows the luminaires used in the comparisons. The CFL downlight with a vertical lamp and the PAR lamp downlight require too great of a plenum depth to have been feasible for the Hilton project due to the ceiling plenum restraints, but they are included here for comparison purposes for other projects.

Table 2: Downlights used in comparisons

	Portfolio 6" Downlight			
	LED	CFL: vertical	CFL: horizontal	HALOGEN
Luminaire ID	LD6A10DLT ERM6A10830 6LW1H	CD6042E- 6CLV142M1H3	CD6142E- 6CLH1421H1	HD6-6500C
Lamp ID	high lumen LED	F32TBX/827/A/4P	F32TBX/827/A/4P	75PAR30L/FL
Lamp output (lm)	N/A	2,400	2,400	1,000
Luminaire output (lm)	928	1,173	981	816
Input power (W)	15	29	31	75
Luminaire efficacy (lm/W)	62	40	32	11

All performance values were taken from the corresponding IES files from Eaton's Cooper Lighting Business's website.

Based on the differences in input power for each of the alternate luminaires, Table 3 compares the estimated annual energy use for the guest room downlights in the Hilton Columbus Downtown, using 3,500 annual hours as assumed by Hilton. As shown, the LED downlights save 46% to 60% in predicted energy use relative to the two CFL alternates and 79% relative to the halogen PAR lamp alternate. Additional savings from the dimming and occupancy control strategies implemented would further reduce the annual energy use for the LED downlights.

Table 3: Comparisons of estimated energy use for downlighting

		Portfolio 6" Downlight			
		LED	CFL: vertical	CFL: horizontal	HALOGEN
Input power per fixture	(W)	15	29	31	75
Total power for downlights in guest rooms and suites	(kW)	58	108	116	279
Annual electricity use for downlights	(kWh)	203,330	377,986	406,661	977,550
Electricity savings for LED	(%)	N/A	46	50	79

To compare the photometric performance of the luminaires, the AGI32® program was used to simulate the lighting in the entry area of a guest room (Appendix D includes a full description of these simulations). Several different simulations were conducted to assess the illuminances at different horizontal and vertical points in the space. To check the accuracy of the architectural model used in the simulations, and to verify that the data file for the LED downlight matched the performance of the installed luminaires, illuminances were calculated at the same points as the measurement locations during the site visit. The calculated values varied from the measured values by 11% on average, seen in Table 13 (Appendix D), which is reasonable given the uncertainties in simulating the architectural details and finishes, as well as the normal tolerances in performance between installed luminaires and representative test data. Based on these findings, the simulation model was verified for use in the relative comparisons between different downlight technologies. Table 12 (Appendix D) provides a detailed description and full results of the simulations.

Table 4 provides a summary of the simulation results. The LED downlights produced an average calculated maintained illuminance on the floor of the entry area that was equal to or greater than the average calculated illuminance for the CFL downlights, and resulted in an average vertical illuminance at the entry-way mirror that was greater than that of the CFL downlights with a horizontal lamp but less than that from the vertical-lamp CFL downlight. The PAR lamp downlight produced a much more focused beam spread than the other options evaluated, delivering higher illuminance at the floor, but it resulted in much darker walls; the average vertical illuminance at the mirror from the LED downlight was 50% more than that from the halogen PAR fixture. Dark walls in this case would make certain visual tasks such as seeing into the closet more difficult, and would also produce a much lower level of perceived brightness. Figure 13 shows renderings of the LED and PAR lamp downlights, illustrating the difference in wall lighting (Figures 16 and 17 in Appendix D show additional renderings for comparison).

Table 4: Simulation results summary

	Portfolio 6" Downlight			
	LED	CFL: vertical	CFL: horizontal	HALOGEN
Horizontal illuminance on floor beneath downlight (lx (fc))	192 (17.8)	184 (18.0)	185 (17.3)	264 (24.5)
Average horizontal illuminance on floor (lx (fc))	190 (17.6)	191 (17.8)	175 (16.3)	258 (24.0)
Average vertical illuminance on mirror (lx (fc))	45 (4.2)	57 (5.3)	45 (4.2)	30 (2.5)

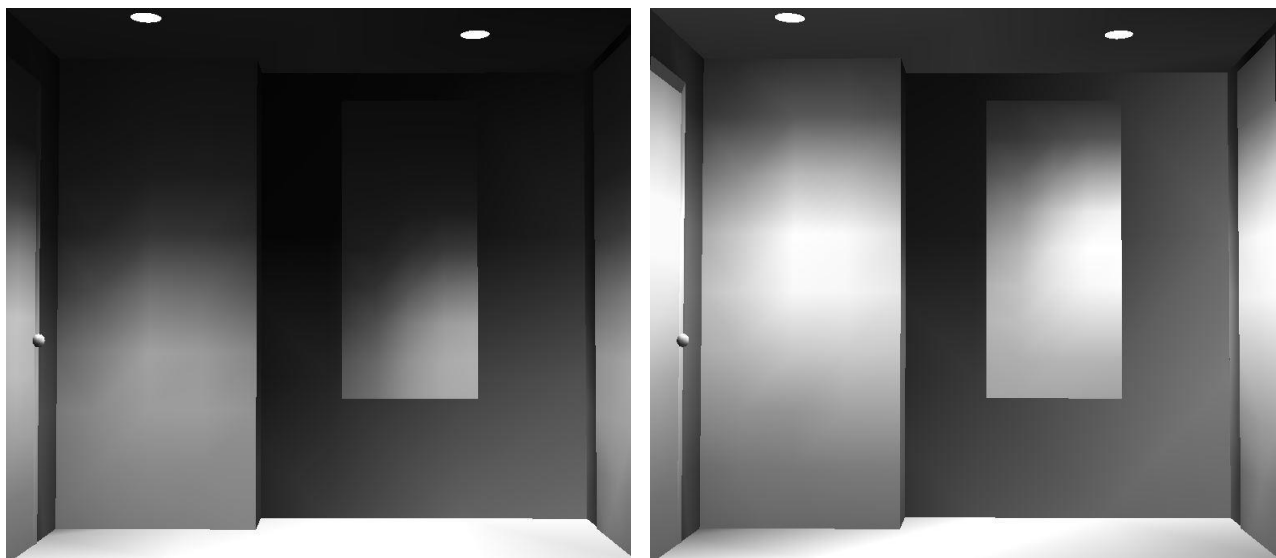


Figure 13: Entry area renderings comparing PAR (left) to LED (right) downlights

4.3 Relative to other guest rooms

While working on this project, various team members documented the lighting products and rated wattages used in other hotel rooms to provide a baseline for comparison with the Hilton Columbus Downtown guest room lighting. The results confirmed that CFLs are the primary light source currently used in hotel guest rooms, and also demonstrated that while the Columbus Downtown hotel used more fixtures than is typical, the total power used for lighting is less than typical.

Table 5 summarizes the findings. Excluding the Hilton Columbus Downtown, the five other hotel rooms surveyed used 62 lamps in total: 53 CFLs, four linear fluorescent lamps, three incandescent/halogen lamps, and two LEDs. The Hilton Columbus Downtown was the only hotel surveyed that extensively used LEDs.

The five other guest rooms surveyed had an average of 201 W of power for the lighting fixtures installed for the bedroom and entry area lighting (range of 159 W to 287 W), while the Hilton Columbus Downtown used only 149 W. Including the bathroom lighting, the average total lighting power for the other rooms was 279 W (range of 219 W to 362 W), while the total lighting power for the Hilton was 244 W. Although the bathroom lighting at the Hilton was higher than others at 95 W, the dimming controls on the LED downlights combined with the vacancy sensor reduce the lighting energy use.

Table 5: Survey of guest rooms

Hotel Location	Area of guest room	No. of fixtures*	Total no. of fixtures/lamps	Power by area (W)	Total power (W)
Hilton Downtown (Columbus, OH)	Guestroom	2 LED, 2 CFL, 1 (2) LFL	11/13	119	244
	Entryway	2 LED		30	
	Bathroom	3 LED, 1 LFL		95	
Portland, OR	Guestroom	2 (2) CFL	6/10	120	219
	Entryway	1 (3) CFL		39	
	Bathroom	3 CFL		60	
Albany, NY	Guestroom	5 CFL, 1 (2) CFL	9/13	149	258
	Entryway	1 (2) CFL		25	
	Bathroom	1 (2) CFL, 1 (2) LFL		84	
Tempe, AZ	Guestroom	2 LED, 2 (2) CFL, 1 CFL	10/12	174	271
	Entryway	1 CFL		16	
	Bathroom	4 CFL		81	
Las Vegas, NV	Guestroom	3 CFL, 1 (2) CFL, 2 IN	9/12	237	362
	Entryway	1 IN		50	
	Bathroom	1 (2) LFL, 1 (2) CFL		75	
Yuma, AZ	Guestroom	6 (2) CFL	9/15	168	285
	Entryway	1 CFL		28	
	Bathroom	2 CFL		89	

*All fixtures have one lamp each unless a value is indicated in parentheses (e.g. "2 (2) CFL" means 2 CFL fixtures with 2 lamps per fixture)

5.0 Conclusions

Guest room lighting represents a major use of energy for hospitality facilities in the U.S. Past efforts to reduce lighting energy use in guest rooms have mostly consisted of implementing CFL lamps and luminaires. CFLs offer the hospitality segment reduced energy consumption, higher efficacy, and much longer lifetimes than incandescent and halogen lamps, but they also have drawbacks. CFLs usually have a warm-up period before they reach full light output, they vary in color consistency and also have lower color rendering indices compared to incandescent lamps, and they are difficult or impossible to dim. LEDs improve upon many of these drawbacks, and offer an attractive combination of additional energy savings, longer lifetime, instant “on” at full light output, and improved control capabilities, including dimming.

The implementation of LED downlights in the Hilton Columbus Downtown hotel demonstrates many of these advantages. The Hilton uses more than 3,700 LED downlights in its 532 guest rooms and suites. Each guest room has seven 15 W LED downlights, five of which are controlled by slide dimmers. PNNL research staff documented the performance of the LED luminaires during a site visit in March 2014, finding that the system provided adequate light levels and lighting quality for the guest room tasks, and that the controls enabled great flexibility for the guest. Additionally, color variation for the LED luminaires was less than the variation found for linear fluorescent lamps and for CFLs in the guest room.

From an energy standpoint, the electrical power for the guest room lighting in the Hilton Columbus Downtown was more than 20% less than the prevailing energy code allowed at the time of installation, resulting in 145,236 kWh in annual energy savings relative to code, for the same operating hours. Further savings are expected from a reduction in operating hours and levels due to the dimming, clearly labeled and convenient controls, and a vacancy sensor. Based on simulations using similar downlights, the LED downlights provided 50% energy savings compared with horizontal CFLs and even greater savings compared with other incumbent technology (e.g., incandescent).

The LED downlights at the Hilton Columbus Downtown were selected not only to meet Hilton’s sustainability goals and LEED rating energy criteria, but also based on the designer’s desire to provide hotel guests with familiar lighting quality and operation. The implementation of LEDs provided substantial energy savings while also overcoming many of the aesthetic and operational drawbacks associated with CFL systems which has been both noticed and appreciated by the guests of the hotel.

Appendix A. Downlight information

DESCRIPTION

6 inch LED recessed wide beam downlight specially designed for LED technology. Two-stage reflector system produces smooth distribution with excellent light control and low aperture brightness. Lumen packages include 1000 and 1500 delivered lumens with color temperatures of 2700K, 3000K, 3500K, 4000K. Suitable for commercial construction and exceeds high efficacy requirements (with designated trims) for T24. Energy Star qualified.

SPECIFICATION FEATURES

Lower Shielding Reflector

Self-flanged, spun .050" thick aluminum lower reflector in combination with a lensed upper optical chamber provides superior lumen output with minimal source brightness. Available in all Portfolio Alzak® finishes.

Trim Retention

Lower reflector is retained with two torsion springs holding the flange tightly to the finished ceiling surface.

Plaster Frame / Collar

New Construction Housing: Die cast aluminum 1-1/2" deep collar accommodates ceiling materials up to 2".

Universal Mounting Bracket

Accepts 1/2" EMT, C channel and bar hangers and adjusts 5" vertically from above and below the ceiling.

Junction Box

(4) 1/2" and (2) 3/4" trade size pry outs positioned to allow straight conduit runs. Listed for (8) #12 AWG (four in, four out) 90°C conductors and feed thru branch wiring.

Thermal

Extruded aluminum heat sink conducts heat away from the LED module for improved performance and longer life.

LED

LED system contains a plurality of high brightness white LED's combined with a high reflectance upper reflector and convex transitional lens producing even distribution with no pixilation. Rated for 50,000 hours at 70% lumen maintenance. Auto resetting, thermally protected, LED's are turned off when safe operating temperatures are exceeded. Color variation within 3-step MacAdam ellipses. Flexible disconnect allows for tool-less replacement of LED engine from below ceiling. Available in 80 or 90 CRI.

Driver

Combination 120-277V 0-10V or 120V trailing edge phase cut driver provides flicker free dimming from 100% to 10%. Optional 1% 0-10V, Fifth Light, DMX or Lutron® Ecosystem. Driver can be serviced from above or through the aperture.

Environmental

Fixture should not be operated in ambient temperatures above 40° C.

Code Compliance

Thermally protected and cULus listed for protected wet locations. IP66 rated when used with IP66 gasket kit accessory. Optional City of Chicago environmental air (CCEA) marking for plenum applications. EMI/RFI emissions per FCC 47CFR Part 18 Class B consumer limits. Non-IC rated - Insulation must be kept 3" from top and sides of housing. RoHS Compliant. Title 24 Compliant with designated trims. ARRA Compliant. Photometric testing completed in accordance with IES LM 79 standards. LED life testing completed in accordance with LM 80 standards.

Warranty

5 year warranty.

PORTFOLIO™

Catalog #		Type	
Project		Date	
Comments			
Prepared by			



LD6A10
LD6A15

6LW

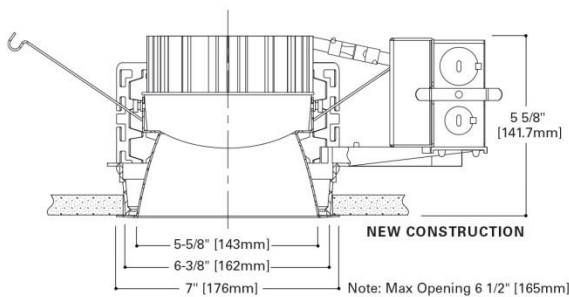
1000 Lumen LED
1500 Lumen LED

6-Inch

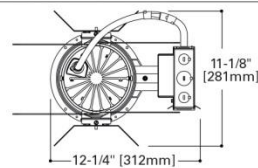
Wide Beam Downlight
New Construction



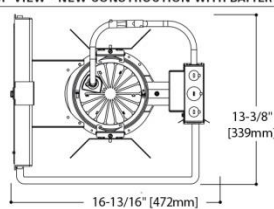
Qualified and Compliant. Refer to the ENERGY STAR® Qualified Product List and CEC (T24) Appliance Database for listings.



TOP VIEW - NEW CONSTRUCTION



TOP VIEW - NEW CONSTRUCTION WITH BATTERY



ENERGY DATA	
Sound Rating: Class A standards	
Operating Temperature: 40°C (104°F)	
1500 Lumen D010TE	
(Values at non-dimming line voltage)	
Minimum Starting Temperature: -30°C (-22°F)	
EMI/RFI: FCC Title 47 CFR, Part 15, Class B (Consumer)	
Input Voltage: UNV (120V - 277V)	
Power Factor: >0.90 (at nominal input 120/277 VAC & 100% of Rated Output Power)	
Input Power: 22.4W	THD: <20%
120V Input Current: .12A	277V Input Current: .08A
Maximum Non-IC Ambient Continuous	
Input Frequency: 50-60Hz	
1000 Lumen D010TE	
(Values at non-dimming line voltage)	
Minimum Starting Temperature: -30°C (-22°F)	
EMI/RFI: FCC Title 47 CFR, Part 15, Class B (Consumer)	
Input Voltage: UNV (120V - 277V)	
Power Factor: >0.90 (at nominal input 120/277 VAC & 100% of Rated Output Power)	
Input Power: 14.1W	THD: <20%
120V Input Current: .12A	277V Input Current: .08A
Maximum Non-IC Ambient Continuous	
Input Frequency: 50-60Hz	



Specifications and dimensions subject to change without notice.
Consult your representative for additional options and finishes.

ADP100519
2013-12-09 15:38:35

ORDERING INFORMATION

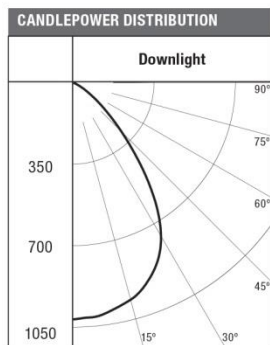
EXAMPLE: LD6A15D010TE ERW6A15835 6LW1LI=6" LED Wide Reflector Lens, 1500 Lumen 3,500 K Color with Universal 120 - 277V, 0 - 10 Driver

Housing	Lumens ¹	Driver	Options	Power Module	CRI	Color
LD6A=6" Aperture LD6ACP=6" Aperture, Chicago Plenum	10=1000 Lumens 15=1500 Lumens	D010TE=120-277V 0-10V 10% Dimming or Trailing Edge 120V Dimming D010TR=120-277V 0-10V 10% Dimming or Leading Edge 120V Dimming D5LT=Fifth Light* (DALI) Dimming 1-100% DE010=1 to 100% Dimming, 120-277V 50/60Hz, 0-10V DL3=1 to 100% Dimming, 120-277V Lutron* Hi-Lume, Ecosystem or 3 Wire DLT=1 to 100% Dimming, 120V Lutron* Hi-Lume Forward Phase Dimming DMX=DMX Dimming 1-100%	EMBOD=Bodine* Emergency Module with Remote Test Switch ^{3,4} WF=White Painted Flange	ERW6A10=6", 900 Lumen Module for Wide Beam Reflector ERW6A15=6", 1500 Lumen Module for Wide Beam Reflector	8=80 CRI 9=90 CRI	27=2700° K 30=3000° K 35=3500° K 40=4000° K 27CP=2700° K, Chicago Plenum 30CP=3000° K, Chicago Plenum 35CP=3500° K, Chicago Plenum 40CP=4000° K, Chicago Plenum

Reflector	Finish	Options	Accessories
6LW0=6" Wide Beam Reflector, Polymer Trim Ring 6LW1=6" Wide Beam Reflector, Self-flanged	LI=Specular Clear H=Semi-Specular Clear WMH=Warm Haze G=Specular Gold WH=Wheat WHH=Wheat Haze GP=Graphite GPH=Graphite Haze	B=Specular Black W=Gloss White 6LW0 Only BB=Black Baffle WB=White Baffle	Self-flanged Only WF=White Painted Flange HB26=C-channel Bar Hanger, 26" Long, Pair HB50=C-channel Bar Hanger, 50" Long, Pair RMB22=Wood Joist Bar Hanger, 22" Long, Pair H277=277 to 120V Step Down Transformer, 300VA H347=347 to 120V Step Down Transformer, 75VA H347200=347 to 120V Step Down Transformer, 200VA Housings, Specify Slope HSA6=Slope Adapter for 6" Aperture Housings, Specify Slope TRM6=Metal Trim Ring, Specify Color ² TRR6=Rimless Trim Ring ² DT6=Deco Trim ² LGSKT6IP66=IP66 Gasket Kit

- Notes:** 1 Nominal delivered Lumens will vary depending on selected color, driver and reflector finish.
 2 Order trim with polymer trim ring (Consult specification sheet for color ordering information and options).
 3 Not available with Chicago Plenum.
 4 Not CSA approved.

PHOTOMETRICS



Test Number	P98323
ERW6A835	6LW1H
Lumens	1463
Efficacy	67.1 Lm/W
Watts	21.8
CCT	3500K
SC	1.13

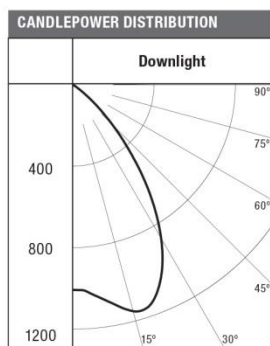
CANDELA TABLE	
Degrees Vertical	Candela
0	1008
5	1002
15	956
25	845
35	602
45	281
55	98
65	19
75	5
85	0
90	0

ZONAL LUMEN SUMMARY		
Zone	Lumens	%Fixture
0-30	750	51.3
0-40	1122	76.7
0-60	1434	98
0-90	1463	100
90-180	0	0
0-180	1463	100

CONE OF LIGHT		
Distance Fixture to Lighted Plane	Initial Footcandles at Nadir	Beam Diameter
5'5"	33	6.0
7'	20	7.8
8'	16	9.0
9'	12	10.0
10'	10	11.2
12'	7	13.4

LUMINANCE	
Average Candella Degrees	Average 0° Luminance
45	25954
55	11090
65	2964
75	1210
85	0

EMBOD MULTIPLIER	
1000 Lumen=	.64
1500 Lumen=	.45



Test Number	P97443
ERW6A835	6LW1LI
Lumens	1552
Efficacy	71.2 Lm/W
Watts	21.8
CCT	3500K
SC	1.22

CANDELA TABLE	
Degrees Vertical	Candela
0	1000
5	1021
15	1142
25	1022
35	663
45	267
55	39
65	2
75	0
85	0
90	0

ZONAL LUMEN SUMMARY		
Zone	Lumens	%Fixture
0-30	885	57
0-40	1294	83.4
0-60	1548	99.7
0-90	1552	100
90-180	0	0
0-180	1552	100

CONE OF LIGHT		
Distance Fixture to Lighted Plane	Initial Footcandles at Nadir	Beam Diameter
5'5"	34.0	6.5
7'	21.0	8.5
8'	16.0	9.5
9'	13.0	11.0
10'	10.5	12.0
12'	7.0	14.5

LUMINANCE	
Average Candella Degrees	Average 0° Luminance
45	24598
55	4425
65	340
75	277
85	0

EMBOD MULTIPLIER	
1000 Lumen=	.64
1500 Lumen=	.45

PHOTOMETRICS

CCT Multiplication Factors		CCT [K]	Multiplier from 3500K	80 -> 90 CRI
80 CRI	1000 Lumen	2700	0.93	
		3000	0.99	
		3500	1.00	
		4000	1.01	
	1500 Lumen	2700	0.93	
		3000	0.99	
		3500	1.00	
		4000	1.01	
90 CRI	1000 Lumen	2700	0.88	0.79
		3000	0.95	0.80
		3500	1.00	0.84
		4000	1.03	0.86
	1500 Lumen	2700	0.88	0.79
		3000	0.94	0.79
		3500	1.00	0.84
		4000	1.03	0.86

Figure 14: Portfolio LED 6" downlight spec sheet

Appendix B. Performance measurements

Guest room 715, which was assigned using the hotel's normal online reservation system, was evaluated on March 11–12, 2014. Its entry door was from the balcony along the open atrium and its windows faced west. The floor plan and lighting layout matched the plan provided by Ardra Zinkon exactly for the LED downlights: two LED downlights in the entry area, two LED downlights in the soffit near the window, and three LED downlights in the bathroom. Other lighting was also as shown on the plans, except that the luminaires mounted on the bed headboard had CFLs rather than the specified LEDs. Illuminances are reported here in both lux and in footcandles.

Photometric performance

Equipment

Illuminances were measured using a Konica Minolta T-10A meter (serial number: 207839, labeled "Battelle ESD Metering Lab EM10605") with an attached standard receptor head (serial number: 30011584). This meter has rated linearity of $\pm 2\%$, ± 1 digit, rated cosine response within 3%, and rated spectral response within 6% of the CIE spectral luminous efficiency function, $V(\lambda)$. The meter is marked as calibrated through June 25, 2014.

Illuminance levels were measured in the entry area, on the desk, and in the bathroom sink area. The LED downlights provide the primary illumination in each of these areas.

Entry area

The entry area had two LED downlights controlled by a single switch (non-dimming) at the entry door. All other room and bathroom lighting was turned off during the measurements, and the entry door and the bathroom door were both closed. Wall finishes were beige wallpaper (estimated reflectance of 60%); dark tile floor (10%), dark wooden doors for entry and closet (20%). The bathroom door had dark wooden border around a frosted glass door (30%).

All measurement point locations are shown in Figure 15. Horizontal illuminances were measured on the floor at 1' intervals along two lines, one along the length of the area (from the entry door to the room doorway) and one across the width of the area. The measurement points along the length were 1.5' from the outside room wall near the door. Point L0 was at the bottom of the door and other points were at 1' spacing through point L9, which was near the entry doorway into the room. The measurement points across the width were 4'7" from the entry door. Point X0 was at the bottom of the outside room wall and other points were at 1' spacing through point X5.

Table 6 summarizes the horizontal illuminances measured in the entry area. Illuminance values ranged from 120 lx to 203 lx, with a mean of 168 lx.

Table 6: Horizontal illuminances on floor in entry area

Measurement Point	Illuminance (lux)
L0	143
L1	154
L2	167
L3	176
L4	180
L5	203
L6	203
L7	158
L8	140
L9	120
X0	137
X1	159
X2	204
X3	197
X4	183
X5	169
Mean	168
Max	203
Min	120
Max: Min	1.7

Vertical illuminances (also shows in Figure 15) were measured on the north entry wall just inside the door (wall between the entry area and the bathroom). The measurement line was 1'4" from the entry door wall. Point V0 was at the bottom of the wall, other points were at 1' spacing through point V6. Table 7 shows the results.

Table 7: Vertical illuminances in entry area

Measurement Point	Illuminance (lux)
V0	57
V1	71
V2	88
V3	107
V4	128
V5	116
V6	61

Bedroom

The LED downlights in the guest room serve task lighting needs on the desk area and the sofa, as well as aesthetic needs for ambient brightness in the window and seating area (unlike the room shown in Figure 6, Room 715 had a small sofa beside the desk, rather than a chair). Horizontal illuminances were measured along the desktop, with just the LED downlights turned on and with all the room fixtures turned off, excluding the portable task light on the desk (the LED downlights plus the fluorescent uplights integrated into the millwork behind the bed and the TV, and the reading fixtures mounted to the headboard). The desk was 2'3" deep by 4'6" long and the desktop surface was 2'8" AFF. Illuminances were measured along a line 8" from the front edge of the desk. Point D0 was located at the edge of the desk near the south wall, other points were at 1' spacing through point D4. Table 8 shows the measured illuminance values on the desktop.

Table 8: Desk area illuminances

Lights on	Measurement Point	Illuminance (lux)
Downlights only	D0	177
	D1	217
	D2	259
	D3	274
	D4	275
All room lighting	D0	220
	D1	269
	D2	314
	D3	331
	D4	332

Bathroom

The LED downlights in the bathroom serve for general lighting as well as task area lighting at the sink and in the shower. Illuminances were measured at the sink, with just the LED downlights and with the downlights plus the integrated mirror fluorescent lighting. Horizontal illuminances were measured along the front edge of the sink, which was at a height of 2'10" AFF (Table 9). Point DE was at the edge of the sink immediately adjacent to the door wall, point CTR was at the center of the front edge of the sink, and point IE was at the edge of the sink on the interior side of the room. Point CS was measured on the same plane as the other points but above the center of the sink itself, just in front of the faucet.

Vertical illuminances were measured at a single point, with the meter held 5' AFF above the edge of the sink, similar to where the guest's face would be located during grooming. The illuminance detector was held facing the mirror to estimate the illuminance on the vertical plane of the face.

Table 9: Bathroom illuminance measurements

Lights on	Measurement Point	Illuminance (lux)
Horizontal Illuminance		
Downlights	DE: Edge of vanity near door	415
	CTR: Center of vanity	562
	IE: Inner edge of vanity	579
	CS: Center of sink	584
Downlights + Mirror lights	DE: Edge of vanity near door	500
	CTR: Center of vanity	691
	IE: Inner edge of vanity	654
	CS: Center of sink	682
Vertical Illuminance		
Downlights	5' AFF	250
Downlights + Mirror	5' AFF	425

Colorimetric performance

Equipment

Color measurements were made using a Konica Minolta Illuminance Spectrophotometer CL-500A (serial number: 10002008). This meter has rated wavelength precision of ± 0.3 nm and rated chromaticity accuracy in xy coordinates of ± 0.0015 .

Measurements

Color measurements for the LED downlights were taken with the detector held directly below the center of the downlight, at the ceiling plane. Measurement locations are shown in Figure 16. For other fixtures, the detector was held no more than 2" from the light source being measured. Lamp shades were removed from the bed fixtures as they were yellow tone shades that significantly altered the color properties, reducing the CCT by more than 200 K. The lens on the millwork fixtures was a simple diffusing acrylic lens that was difficult to remove so was left in place for the measurements; a spot check showed that it had less than a 15 K impact on the CCT. The mirror lamps were integrated into the mirror assembly behind diffusing glass; the color measurements were taken just in front of the glass. The CCT, CRI and R_9 values for each fixture are shown in Table 10. This data illustrates the range of CCT values found for the different samples of each fixture type, and shows that the LED downlight luminaires had less variation in CCT than any of the other types and that the two CFLs had greater CCT variation than any other type.

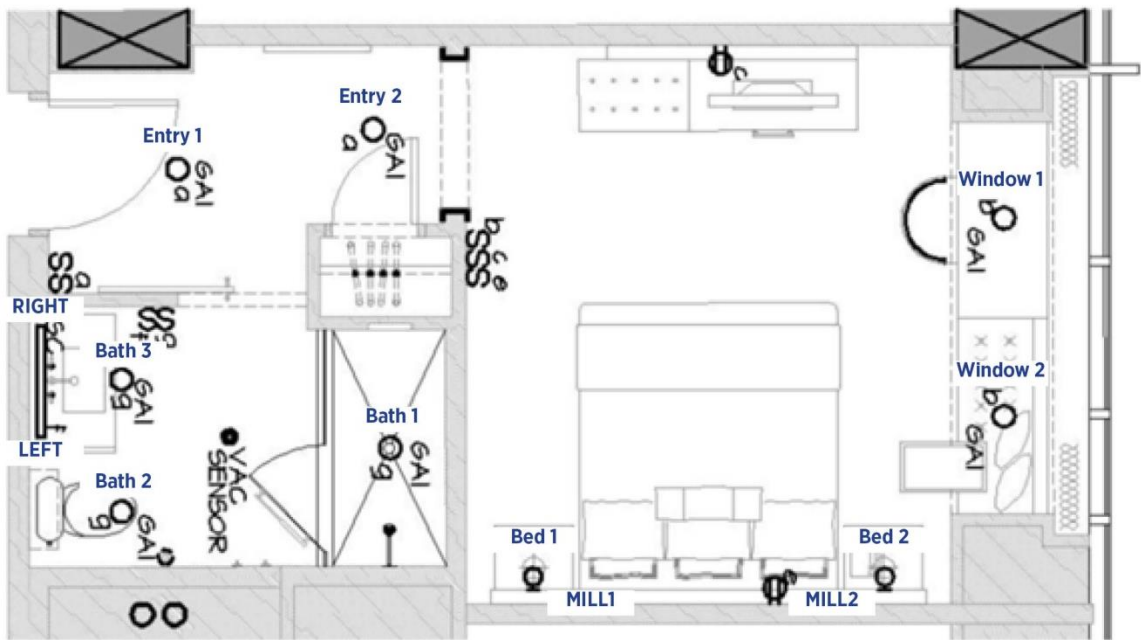


Figure 16: Diagram of fixtures labels for color measurements

Table 10: Color performance

Fixture		CCT	CRI	R _g
LED Downlights	ENTRY1	3060	85	43
	ENTRY2	3091	84	43
	WINDOW1	3062	84	43
	WINDOW2	3075	82	37
	BATH1	3075	81	37
	BATH2	3071	82	37
	BATH3	3052	84	42
	Mean	3069	83	40
	Range	39		
CFL Bed Light Fixtures	BED1	2753	82	-2
	BED2	2843	80	-3
	Mean	2798	81	-3
	Range	90		
LFL Bed Millwork Fixtures	MILL1	3762	85	29
	MILL2	3841	85	29
	Mean	3802	85	29
	Range	79		
LFL Mirror Fixtures	LEFT	3022	85	8
	RIGHT	2979	85	8
	Mean	3001	85	8
	Range	43		

Appendix C: User response

Table 11: Comments related to guest room lighting from common travel websites

Travel website	Ranking	No. Reviews	Notable Comments
Trip Advisor	#4 of 139 hotels in Columbus 91% liked	438	<p>"I actually enjoyed the interior as I could not tell the difference between night and day and I felt very comfortable taking a nap during the day hours w/o feeling like I was missing out on the day b/c the sun was shining through my window."</p> <p>"I preferred a room with the natural light on the street side, vs the rooms with windows facing into the center of the hotel."</p> <p>"Ask for a room that does not look into the parking garage if natural light is important to you."</p> <p>"Try to get a high floor with a city view, the interior rooms have a view of the inside of the hotel"</p>
Yelp	4/5 stars	N/A	<p>"We could not figure out the bathroom lights! After three days we still were getting stuck with the lights going out on us in the bathroom."</p> <p>"I was worried about getting an 'inner' room but the huge glass roof let in plenty of natural light."</p> <p>"The bathroom has self monitoring lighting which is huge for me. I can't stand screaming bright lights without any options for self dimming as it's the biggest pet peeve I have regarding hotel rooms. These are cool in that you can lighten up or lower down to your preference."</p>
Expedia	4.75/5 rating 98% of guests "happy"	172	"Nice uplights in the room."
Hotels.com	4.75/5	192	"Instructions for operating all electronics, including lights, were easy and evident."

Appendix D: AGI32 analysis

Model

Based on the plan (Figure 4) provided by Ardra Zinkon of a typical guest room layout and the measurements (e.g., room dimensions) collected by the PNNL Project Team (March 2014), a model was created in AGI32 to render the lighting of the entryway. This allowed for comparison between different lighting technologies, including LED, CFL, and incandescent (see Table 2 for the downlight specifications and Table 12 for horizontal and vertical illuminances values). In addition, the measured values collected by PNNL were compared with the calculated values in AGI32 (see Table 13). To check the accuracy of the architectural model used in the simulations, and to verify that the data file for the LED downlight matched the performance of the installed luminaires, illuminances were calculated at the same points as the measurement locations during the site visit. The calculated values varied from the measured values by 11% on average, which is reasonable given the uncertainties in simulating the architectural details and finishes, as well as the normal tolerances in performance between installed luminaires and representative test data. Based on these findings, the simulation model was verified for use in the relative comparisons between different downlight types. CFL and incandescent downlights were selected because they are the most frequently used lighting technology in hotels, incumbent to LED.

In the AGI32 model, the following surface reflectance conditions were specified: walls (60%), ceiling (80%), floor (10%), doors (20% - entry, closet; 30% - bathroom), opening into guestroom (1%). For the sake of comparison, all LLFs (Light Loss Factors) were set to 0.9.

Two sets of calculation points were established. The first directly copied the measurement points taken by PNNL on their March 2014 visit to the Columbus, OH. The second set of points were intended to provide average horizontal and vertical illuminances values to easily compare downlight technologies across the same space. The calculation grids were established as:

- Horizontal illuminance values on floor directly below each downlight and between;
- An average horizontal illuminance value taken from a grid of points covering the floor (1' spacing);
- Vertical illuminance values from the top and bottom of the outer wall to provide a uniformity ratio (1' spacing from 0.5' to 6.5' AFF);
- An average vertical illuminance value from a grid of points covering the outer wall with the mirror (1' spacing).

Performance

The LED downlight performs comparably to or better than the other three downlights evaluated. Looking at the AGI32 renderings in Figures 16 and 17, the Portfolio LED is very similar to both the horizontal and vertical CFLs, unlike the incandescent downlight.

Table 12: Comparison of 6" downlight fixtures using AGI32

6" Downlight			Portfolio 6" Downlight			
			LED	CFL: vertical	CFL: horizontal (lx (fc))	HALOGEN
Horizontal illuminance lx (fc)	On floor	Luminaire 1	196.0 (18.2)	189.4 (17.6)	190.5 (17.7)	266.9 (24.8)
		Between	214.2 (19.9)	223.9 (20.8)	187.3 (17.4)	305.7 (28.4)
		Luminaire 2	187.3 (17.4)	178.7 (16.6)	180.8 (16.8)	259.4 (24.1)
	On floor grid with 1' spacing	Max	214.2 (19.9)	222.8 (20.7)	194.8 (18.1)	303.5 (28.2)
		Min	146.4 (13.6)	149.6 (13.9)	139.9 (13.0)	203.4 (18.9)
		Avg	189.4 (17.6)	191.6 (17.8)	175.5 (16.3)	258.3 (24.0)
Vertical illuminance lx (fc)	On wall grid with 1' spacing	Max	139.9 (13.0)	180.8 (16.8)	138.9 (12.9)	92.6 (8.6)
		Height of Max	4.5' AFF	5.5' AFF	5.5' AFF	2.5' AFF
		Min	0	0	0	0
	On face of guest looking into mirror (1' from wall, 5' AFF)	Avg	45.2 (4.2)	57.0 (5.3)	45.2 (4.2)	26.9 (2.5)
		Max	84.0 (7.8)	125.9 (11.7)	101.2 (9.4)	15.1 (1.4)
		Min	39.8 (3.7)	59.2 (5.5)	49.5 (4.6)	9.7 (0.9)
Avg	67.8 (6.3)	101.2 (9.4)	81.8 (7.6)	12.9 (1.2)		

Table 13: Comparison of measured values collected by PNNL and calculated values, using AGI32

Point	Horizontal Illuminance		
	Measured (lx (fc))	Calculated (lx (fc))	% Difference (of calculated)
X0	137 (12.7)	146 (13.6)	7%
X1	159 (14.8)	190 (17.6)	19%
X2	204 (19.0)	210 (19.5)	3%
X3	197 (18.3)	214 (19.9)	9%
X4	183 (17.0)	203 (18.9)	11%
X5	169 (15.7)	179 (16.7)	6%
L0	143 (13.3)	142 (13.2)	-1%
L1	154 (14.3)	173 (16.1)	13%
L2	167 (15.5)	196 (18.2)	17%
L3	176 (16.4)	209 (19.4)	18%
L4	180 (16.7)	214 (19.9)	19%
L5	203 (18.9)	213 (19.8)	5%
L6	203 (18.9)	205 (19.0)	1%
L7	158 (14.7)	189 (17.6)	20%
L8	140 (13.0)	168 (15.4)	18%
L9	120 (11.1)	137 (12.7)	14%
Avg	168 (15.6)	187 (17.3)	11%

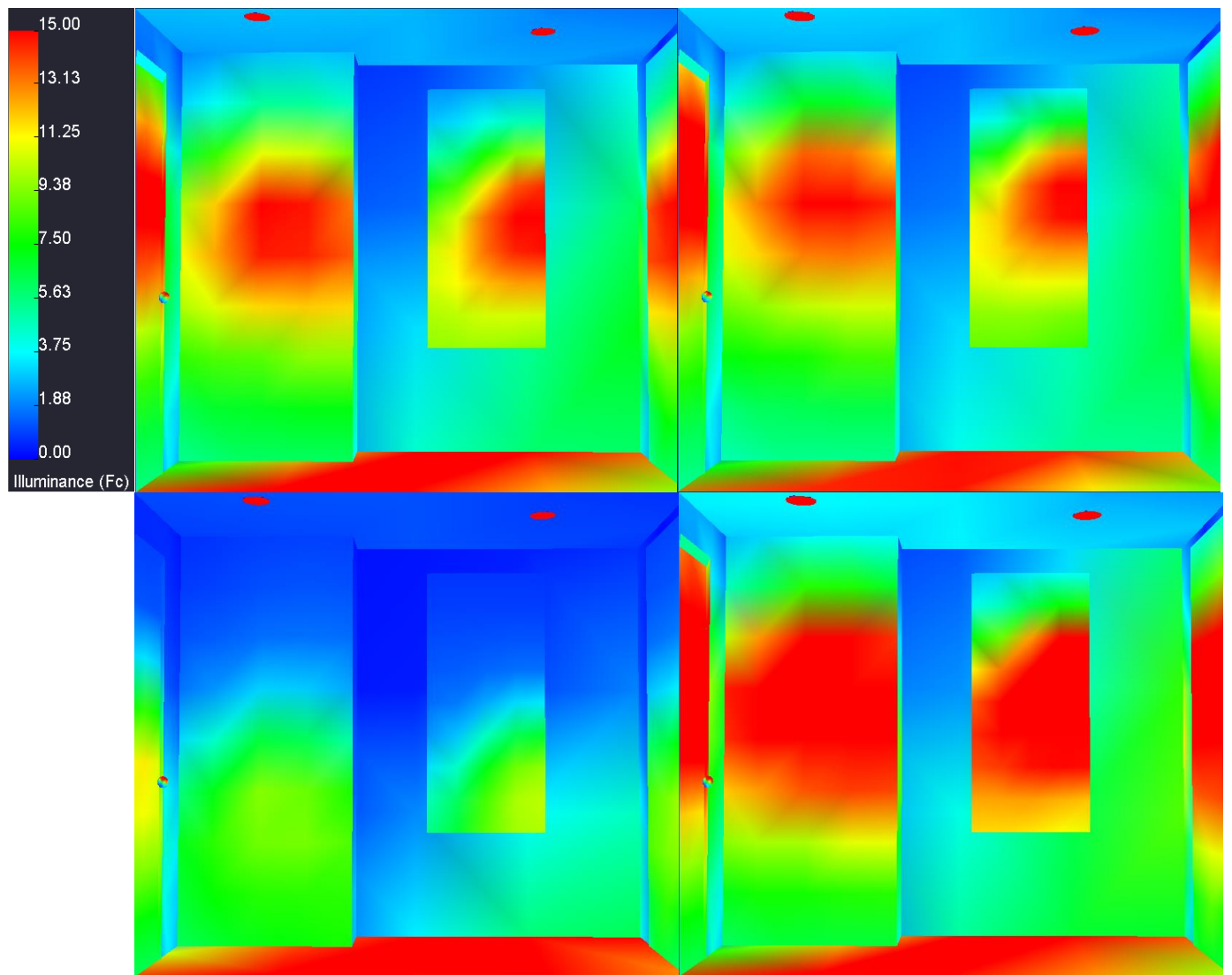


Figure 17: AGI32 pseudo-color renderings of guestroom entry (clockwise from upper left: Eaton's Cooper Lighting Business Portfolio LED, CFL – horizontal, CFL – vertical, Halogen)

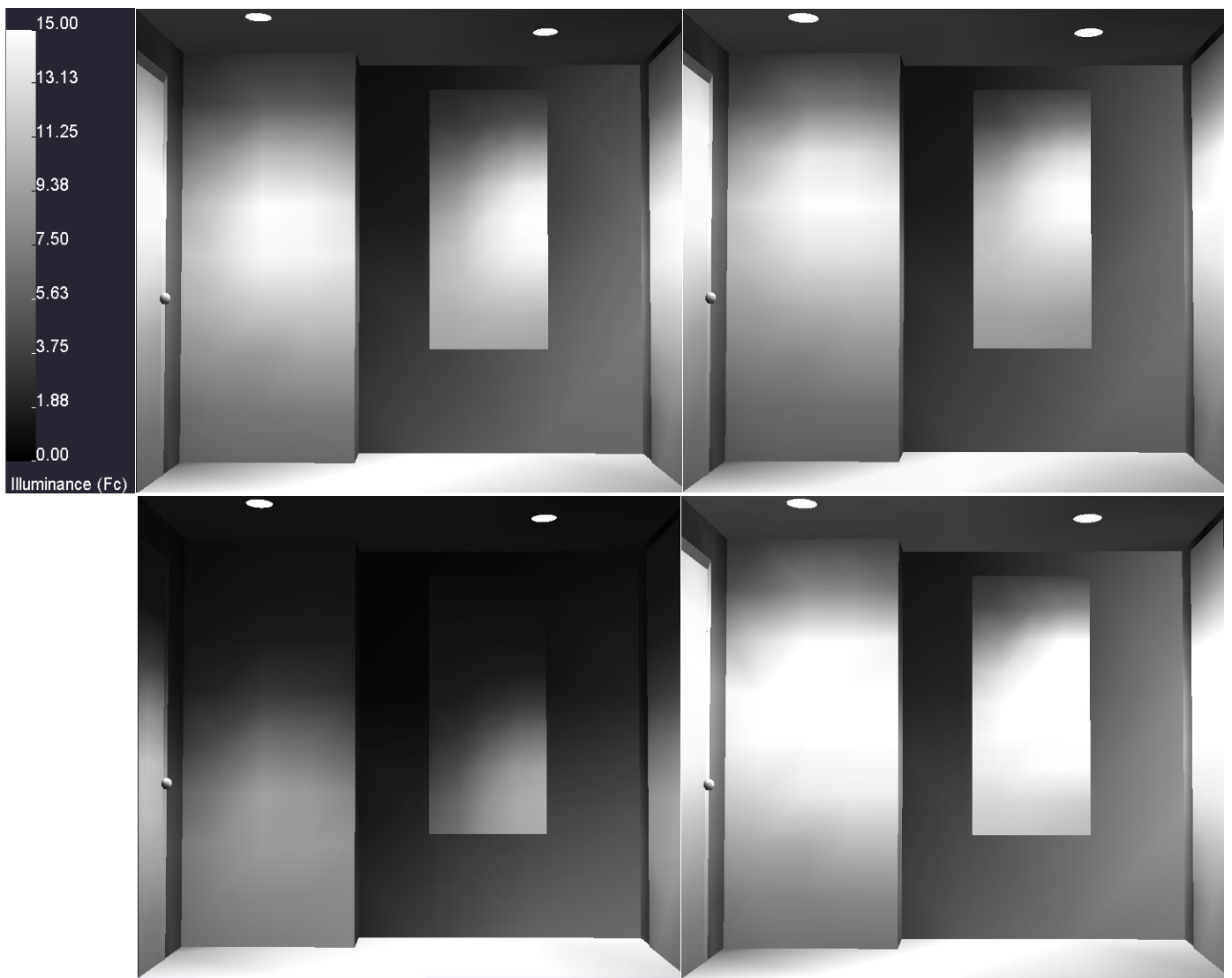


Figure 18: AGI32 greyscale renderings of guestroom entry (clockwise from upper left: Portfolio LED, CFL – horizontal, CFL – vertical, Halogen)

DESCRIPTION

High efficiency, low brightness 6" aperture medium beam reflector for use with 26W, 32W, or 42W TTT or PLT compact fluorescent lamps. The precisely formed non-imaging optical reflector ensures 60° cutoff to lens and lens image and the one piece design eliminates light leaks at the ceiling. Adjustable socket locks lamp into optimal position and cannot be disturbed by normal maintenance. Standard features include low iridescent finish on all reflector colors and venting to ensure maximum lamp life and lumen output. Optics offer unparalleled performance in glare free lighting with a smooth beam devoid of hot spots. Medium beam, wide beam, lensed, and open wall wash reflectors are interchangeable within the same housing.

SPECIFICATION FEATURES

Optical Reflector

Clear upper Alzak® reflector for maximum light output. Positive reflector mounting, without tools, pulls trim tight to ceiling. Lower spun parabolic reflector, .050 thick aluminum available in a variety of Alzak® finishes.

Lens

Choice of tempered fresnel, prismatic, diffuse, or clear glass lenses or molded prismatic acrylic, opal diffuser, or clear UV stabilized acrylic.

Trim Ring Options

Self flanged or molded white ring. Rimless trim ring accessory available

Mechanical Housing Mounting Frame

One piece precision die cast aluminum 1-1/2" deep collar accommodates varying dimensions of ceiling materials.

Universal Mounting Bracket

Accepts 1/2" EMT, C Channel, T bar fasteners, and bar hangers. Adjusts 5" vertically from above or below ceiling.

Conduit Fittings

Die cast screw tight connectors.

Junction Box

Listed for eight #12AWG (four in, four out) 90°C conductors feed through branch wiring. 1/2" and two 3/4" pry outs. Positioned to allow straight conduit runs. Access to junction box by removing reflector.

Catalog #		Type	
Project			
Comments		Date	
Prepared by			

Socket Cap

One piece vented and finned die cast aluminum cap for maximum thermal performance.

Socket

4-pin GX24q3/4 fatigue free stainless steel lamp spring ensures positive lamp retention.

Electronic Ballast with Quick Disconnect

Electronic ballast provides full light output and rated lamp life. Provides flicker free and noise free operation and starting. End of lamp life protection is standard.

Labels

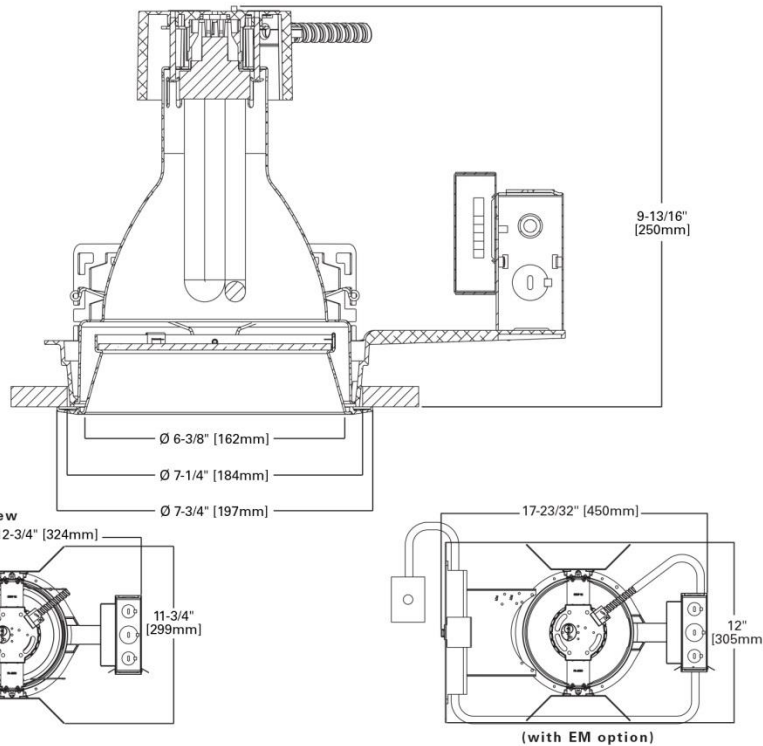
cULus listed, standard wet label. Electronic ballast housings include peel down wattage label from 42W down to 26W allowing de-rating to meet max wattage requirements. Meets IECC, ASHRAE, and Title 24 commercial standards.



**CD6013
CD6018
CD6042
6CLV142M**

13 or 18W DTT
26/32 TTT or PLT
Compact Fluorescent

6-Inch Vertical
Medium Beam Lens Downlight



ENERGY DATA	
13W DTT	
Ballast: Electronic	
120V Input Watts: 16	Line Amps: 0.13
277V Input Watts: 16	Line Amps: 0.05
18W DTT	
Ballast: Electronic	
120V Input Watts: 19	Line Amps: 0.15
277V Input Watts: 19	Line Amps: 0.07
26W TTT	
Ballast: Electronic	
120V Input Watts: 27	Line Amps: 0.23
277V Input Watts: 29	Line Amps: 0.11
32W TTT	
Ballast: Electronic	
120V Input Watts: 36	Line Amps: 0.31
277V Input Watts: 36	Line Amps: 0.13

NOTES: Accessories should be ordered separately. For additional options, please consult your Cooper Lighting Representative. Alzak is a registered trademark of Aluminum Company of America.



Specifications and dimensions subject to change without notice. Consult your representative for additional options and finishes.



ADP121212
2013-11-21 12:22:07

ORDERING INFORMATION

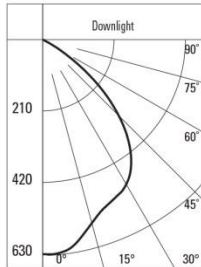
EXAMPLE: CD6042E 6CLV042M1LI

Housing	Ballast	Options	Trims	Finish	Lens	Option	Accessories
<p>CD6013=6" vertical 13W DTT Lamp CD6018=6" vertical 18W DTT Lamp CD6042=6" vertical 26/32/42 TTT lamp</p>	<p>E=120/277V 50/60 Hz Electronic 3E=347V 50/60 Hz Electronic EDR26=26W Derated label electronic EDR32=32W Derated label electronic D5LT=18W 120-277V Fifth Light (DALI Dimming) (CD6018 only) D5LT32=32W 120-277V Fifth Light (DALI) Dimming D5LT26=26W 120-277V Fifth Light (DALI) Dimming 3D5LT32=32W 347V Fifth Light (DALI) Dimming (26W Only) 3D5LT26=26W 347V Fifth Light (DALI) Dimming (26W Only) D26/32=26W or 32W 120-277V Dimming, Lutron Ecosystem D=18W 120-277V Dimming Lutron Ecosystem (CD6018 only)</p>	<p>CP=Chicago Plenum EM=Emergency Module with remote test switch ²</p>	<p>6CLV142M1=6" self flanged medium beam reflector 6CLV142M0=6" medium beam reflector with polymer trim ring</p>	<p>Alzak® Finishes LI=Specular Clear H=Semi-Specular Clear WMH=Warm Haze G=Gold WH=Wheat WHH=Wheat Haze GP=Graphite GPH=Graphite Haze B=Black Painted Finishes W=Gloss White WB=White Baffle (polymer trim ring only) BB=Black Baffle (polymer trim ring only)</p>	<p>1=Prismatic Acrylic Lens 2=Diffuse Acrylic Lens 3=Clear Acrylic Lens 1G=Prismatic Glass Lens 2G=Diffuse Glass Lens 3G=Clear Glass Lens 4G=Fresnel Glass Lens 5=Crossblade</p>	<p>WF=White Painted Flange</p>	<p>HB26=C Channel Bar Hangers, 26" Long, Pair HB50=C Channel Bar Hangers, 50" Long, Pair TRRC6=Rimless Trim Ring, White ¹ FK5=5 Amp Field Installable Fuse Kit 300V Max RMB22=Wood Joist Bar Hanger, 22" Long, Pair HSAC6=Slope Adapter for 6" Aperture Housings, Specify Slope TRMC6=CFL Metal Trim Ring ¹</p>

Notes: ¹ Order trim with polymer trim ring. ² Not available with Chicago Plenum. (Consult specification sheet for ordering information and options).

PHOTOMETRICS

Candlepower Distribution Curve



Test No. P13346
 CD6042E 6CLV142M1LI
 Lumens = 2400
 Efficiency = 45.80%
 Lamp = 32W TTT

Cone of Light

Distance Fixture to Lighted Plane	Initial Footcandles at Nadir	L/W	
5.5'	21	7'	7'
7.5'	11	8.6'	8.6'
8'	10	9.2'	9.2'
10'	6	11.6'	11.6'
12'	4	13.8'	13.8'

Candela Distribution

Degrees Vertical	Candela
0	627
5	624
15	555
25	507
35	450
45	314
55	127
65	7
75	1
85	0
90	0

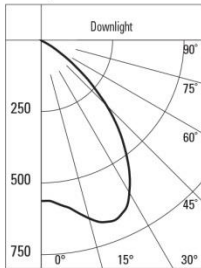
Zonal Lumen Summary

Zone	Lumens	%Fixture
0-30	450	41.0
0-40	730	66.5
0-60	1086	98.8
0-90	1099	100.0
90-180	0	0.0
0-180	1099	100.0

Luminance

Degrees	Average Candela/M ² Avg. 0° Luminance
45	21556
55	10748
65	804
75	188
85	0

Candlepower Distribution Curve



Test No. P13348
 CD6042E 6CLV142M1LI
 Lumens = 2400
 Efficiency = 51.50%
 Lamp = 32W TTT

Cone of Light

Distance Fixture to Lighted Plane	Initial Footcandles at Nadir	L/W	
5.5'	19	7.6'	7.6'
7.5'	10	10.4'	10.4'
8'	9	11.2'	11.2'
10'	6	14'	14'
12'	4	16.8'	16.8'

Candela Distribution

Degrees Vertical	Candela
0	558
5	567
15	640
25	664
35	528
45	324
55	114
65	6
75	1
85	1
90	0

Zonal Lumen Summary

Zone	Lumens	%Fixture
0-30	542	43.9
0-40	871	70.5
0-60	1221	98.8
0-90	1235	100.0
90-180	0	0.0
0-180	1235	100.0

Luminance

Degrees	Average Candela/M ² Avg. 0° Luminance
45	22243
55	9648
65	689
75	188
85	557



Specifications and dimensions subject to change without notice.
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Figure 19: Portfolio CFL vertical 6" downlight spec sheet

DESCRIPTION

High efficiency, low brightness 6" aperture lensed reflector for use with compact fluorescent lamps. The precisely formed non-imaging optical reflector ensures 60° cutoff to lens and lens image and the one piece design eliminates light leaks at the ceiling. Standard features include low iridescent finish on all reflector colors and venting to ensure maximum lamp life and lumen output. Optics offer unparalleled performance in glare free lighting with a smooth beam devoid of hot spots. Open downlight, and open wall wash reflectors are interchangeable within the same housing.

Catalog #		Type	
Project			
Comments		Date	
Prepared by			

SPECIFICATION FEATURES

Optical Reflector

Clear upper Alzak® reflector for maximum light output. Positive reflector mounting, without tools, pulls trim tight to ceiling. Lower spun parabolic reflector, .050 thick aluminum available in a variety of Alzak® finishes.

Lens

Choice of tempered Fresnel, prismatic, diffuse, or clear glass lenses or molded prismatic acrylic, opal diffuser, or clear UV stabilized acrylic.

Crossblade

Lower spun parabolic reflector with 90° louvers, .050 thick aluminum in a variety of Alzak® finishes.

Mechanical Housing Mounting Frame

One piece precision die cast aluminum 1-1/2" deep collar accommodates varying dimensions of ceiling materials.

Universal Mounting Bracket

Accepts 1/2" EMT, C Channel, T bar fasteners, and bar hangers. Adjusts 5" vertically from above or below ceiling.

Conduit Fittings

Die cast screw tight connectors.

Junction Box

Listed for eight #12AWG (four in, four out) 90°C conductors feed through branch wiring, 1/2" and two 3/4" pry outs. Positioned to allow straight conduit runs. Access to junction box by removing reflector.

Trim Ring Options

Self flanged or molded white trim ring. Rimless trim ring accessory available.

Socket Connector

One piece die cast aluminum connection allows venting for maximum thermal performance.

Rotary Lock Socket

4-pin fatigue free stainless steel lamp spring ensures positive lamp retention.

Electronic Ballast with Quick Disconnect

Electronic ballast provides full light output and rated lamp life. Provides flicker free and noise free operation and starting. End of lamp life protection is standard.

Labels

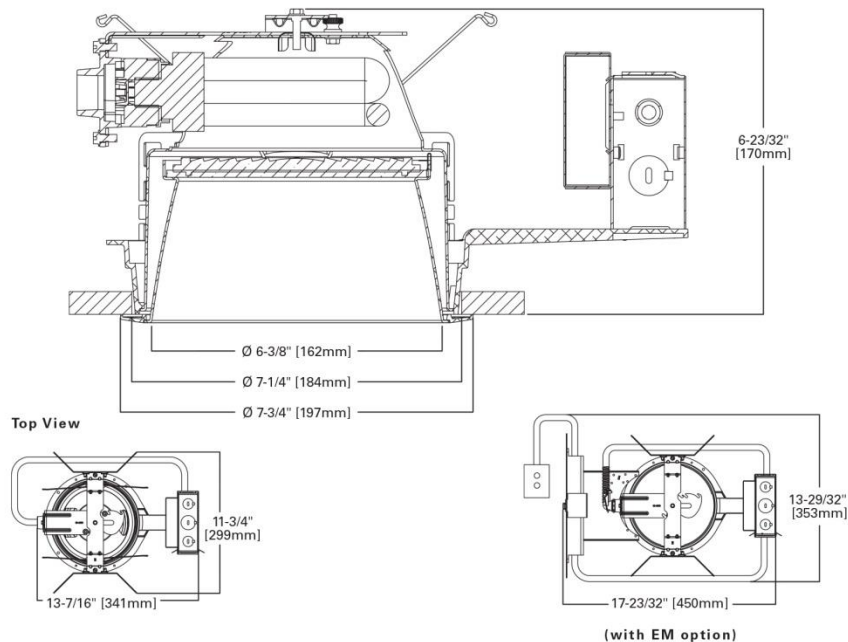
cULus listed, standard wet label. Electronic ballast housings include peel down wattage label from 42W down to 26W allowing de-rating to meet max wattage requirements. Meets IECC, ASHRAE, and Title 24 commercial standards. commercial standards.



CD6126
CD6118
CD6142
CD6113
6CLH142

13W, 18W or 26W DTT
 13W,26W,32W,42W TTT or PLT
 Compact Fluorescent

6-Inch Horizontal
 Lensed Downlight



ENERGY DATA	
13W DTT	
Ballast: Electronic	
120V Input Watts: 16	Line Amps: 0.13
277V Input Watts: 16	Line Amps: 0.05
18W DTT	
Ballast: Electronic	
120V Input Watts: 19	Line Amps: 0.15
277V Input Watts: 19	Line Amps: 0.07
26W TTT	
Ballast: Electronic	
120V Input Watts: 27	Line Amps: 0.23
277V Input Watts: 29	Line Amps: 0.11
32W TTT	
Ballast: Electronic	
120V Input Watts: 36	Line Amps: 0.31
277V Input Watts: 36	Line Amps: 0.13
42W TTT	
Ballast: Electronic	
120V Input Watts: 46	Line Amps: 0.38
277V Input Watts: 46	Line Amps: 0.17
Power Factor: >0.99	THD: <10%
Min. Starting Temperature: -18°C (0°F)	
Sound Rating: Class A Standards	

NOTES: Accessories should be ordered separately. For additional options, please consult your Cooper Lighting Representative. Alzak is a registered trademark of Aluminum Company of America.



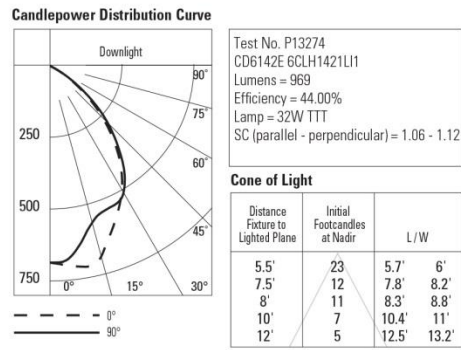
ORDERING INFORMATION

EXAMPLE: CD6142E 6CLH1421L1

Housing	Ballast	Options	Trims	Finish	Lens	Option	Accessories
<p>CD6142=6" Horizontal 26/32/42 TTT Lamp</p> <p>CD6118=6" Horizontal 18 DTT Lamp</p> <p>CD6126=6" Horizontal 26 DTT Lamp</p> <p>CD6113=6" Horizontal 13W DTT/TTT</p>	<p>E=120/277V 50/60 Hz Electronic</p> <p>3E=347V 50/60 Hz Electronic</p> <p>EDR26=26W Derated label electronic</p> <p>EDR32=32W Derated label electronic</p> <p>D5LT=18 or 26W 120-277V Fifth Light (DALI) Dimming for (CD6118 or CD6126 only)</p> <p>D5LT42=42W 120-277V Fifth Light (DALI) Dimming</p> <p>D5LT32=32W 120-277V Fifth Light (DALI) Dimming</p> <p>D5LT26=26W 120-277V Fifth Light (DALI) Dimming</p> <p>3D5LT42=42W 347V Fifth Light (DALI) Dimming</p> <p>3D5LT32=32W 347V Fifth Light (DALI) Dimming</p> <p>3D5LT26=26W 347V Fifth Light (DALI) Dimming</p> <p>3D5LT=26W 347V Fifth Light (DALI) Dimming for (CD6126 only)</p> <p>D42=42W 120-277V Dimming, Lutron Ecosystem (CD6142 only)</p> <p>D26/32=26 or 32W 120-277V Dimming, Lutron Ecosystem (CD6142 only)</p> <p>D=18 or 26W 120-277V Dimming, Lutron Ecosystem (CD6118 or CD6126 only)</p>	<p>CP=Chicago Plenum</p> <p>EM=Emergency Module with remote test switch ²</p>	<p>6CLH1421=6" wide beam reflector self flanged</p> <p>6CLH1420=6" wide beam reflector polymer trim ring</p>	<p>Aizak® Finishes</p> <p>L=Specular Clear</p> <p>H=Semi-Specular Clear</p> <p>WMH=Warm Haze</p> <p>G=Gold</p> <p>WH=Wheat</p> <p>WHH=Wheat Haze</p> <p>GP=Graphite</p> <p>GPH=Graphite Haze</p> <p>B=Black</p> <p>Painted Finishes</p> <p>W=Gloss White</p> <p>WB=White Baffle (polymer trim ring only)</p> <p>BB=Black Baffle (polymer trim ring only)</p>	<p>1=Prismatic Acrylic Lens</p> <p>2=Diffuse Acrylic Lens</p> <p>3=Clear Acrylic Lens</p> <p>1G=Prismatic Glass Lens</p> <p>2G=Diffuse Glass Lens</p> <p>3G=Clear Glass Lens</p> <p>4G=Fresnel Lens</p> <p>5=Crossblade</p>	<p>WF=White Painted Flange</p>	<p>HB26=C Channel Bar Hangers, 26" Long, Pair</p> <p>HB50=C Channel Bar Hangers, 50" Long, Pair</p> <p>TRMC6P=White Metal Trim Ring ¹</p> <p>TRRC6=Rimless Trim Ring, White ¹</p> <p>FK5=5 Amp Field Installable Fuse Kit 300V Max</p> <p>RMB22=Wood Joist Bar Hanger, 22" Long, Pair</p> <p>HSAC6=Slope Adapter for 6" Aperture Housings, Specify Slope</p> <p>TRMC6=CFL Metal Trim Ring ¹</p>

Notes: ¹Order trim with polymer trim ring. ²Not available with Chicago Plenum. (Consult specification sheet for ordering information and options).

PHOTOMETRICS



Candela Distribution

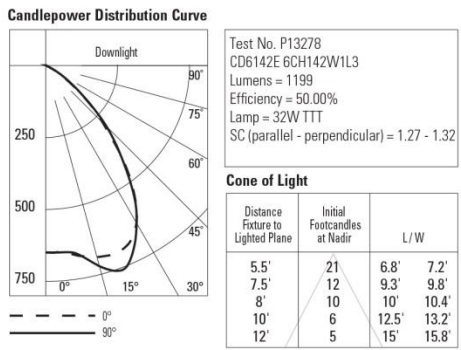
Degrees Vertical	Candela
0	679
5	692
15	682
25	555
35	427
45	263
55	102
65	6
75	1
85	0
90	0

Zonal Lumen Summary

Zone	Lumens	%Fixture
0-30	472	44.6
0-40	736	69.6
0-60	1044	98.8
0-90	1057	100.0
90-180	0	0.0
0-180	1057	100.0

Luminance

Average Candela/M ² Degrees	Avg. 0° Luminance
45	18055
55	8632
65	689
75	188
85	0



Candela Distribution

Degrees Vertical	Candela
0	646
5	646
15	685
25	679
35	529
45	277
55	95
65	5
75	1
85	0
90	0

Zonal Lumen Summary

Zone	Lumens	%Fixture
0-30	564	47.0
0-40	877	73.1
0-60	1186	98.9
0-90	1199	100.0
90-180	0	0.0
0-180	1199	100.0

Luminance

Average Candela/M ² Degrees	Avg. 0° Luminance
45	19016
55	8040
65	574
75	188
85	0



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Figure 20: Portfolio CFL horizontal 6" downlight spec sheet

DESCRIPTION

A very low brightness 6" diameter downlight for use with PAR30L (long neck). The precisely formed non-imaging reflector ensures 45° cutoff to lamp and lamp image. The modular housing system supports various downlight, wallwash, and lens reflectors.

Catalog #		Type
Project		
Comments		Date
Prepared by		

SPECIFICATION FEATURES

A ... Reflector/Baffle

Positive reflector mounting pulls trim tight to ceiling. 0.050" spun aluminum reflector. Available in a variety of Alzak® finishes. Painted white finish as well as white or black baffles.

B ... Trim Ring

Self flanged or molded white trim ring. Metal trim ring and rimless trim ring accessories available (see Options and Accessories).

C ... Socket Cap

One piece heat dissipating die-cast aluminum.

D ... Housing

Precision die-cast aluminum 1-1/2" (38mm) deep collar.

Optical assembly adjusts within the housing to accommodate ceilings up to 4 1/4" (108mm) thick.

E ... Universal Mounting Bracket

Accepts 1/2" EMT, C Channel, T bar fasteners and hanger bars. Provides 5" total adjustment.

F ... Conduit Fittings

Die-cast screw tight connectors.

G ... Junction Box

U.L. listed for four in, four out #12 at 90°C pull through branch wiring. Pry-outs for four 1/2" and two 3/4" conduits. Access to junction box by removing reflector.

H ... Socket

Medium base porcelain socket with nickel plated screw shell.

Insulation Detector

Self-resetting insulation detector opens circuit if insulation is improperly installed.

Labels

cULus listed, C.S.A. certified, damp location.

Options & Accessories

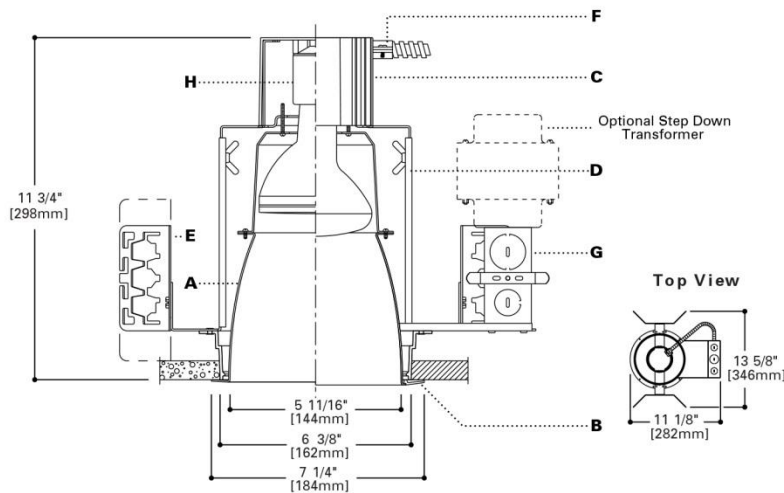
TRM=Metal Trim Rings to replace molded trim ring.
TRR=Rimless Trim Rings for minimal flange appearance in plaster ceilings.



HD6
6501/6500

75W MAX
PAR30L

6" DOWNLIGHT



NOTES:

Accessories should be ordered separately. For additional options, please consult your Cooper Lighting Representative. Alzak is a registered trademark of Aluminum Company of America.

ORDERING INFORMATION

Sample Number: Complete unit consists of housing, ballast and trim.

--	--	--	--	--	--	--

Housing

HD6: 6" Incandescent

Options

CP: Chicago Plenum

Trims

6501: Self Flanged
6500: Molded Trim Ring

Finish

B: Specular Black
G: Specular Gold
GP: Graphite
GPH: Graphite Haze
H: Semi-Specular Clear
LF: Specular Clear
W: Gloss White
WH: Wheat
WHH: Wheat Haze
WMH: Warm Haze
BB: Black Baffle (6500 only)
WB: White Baffle (6500 only)

Option

WF: White Painted Flanged (Self Flanged only)

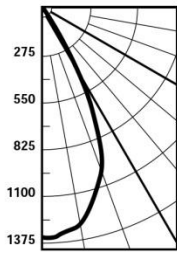
Derated Wattage Label

DR*: DeRated, Specify Wattage

Accessories

H277: Step Down Transformer, 300VA Max
HB26: C Channel Bar Hangers, 26" Long, Pair
HB50: C Channel Bar Hangers, 50" Long, Pair
TRM6: Metal Trim Ring, Specify Finish
TRR6: Rimless Trim Ring, White
FK5: 5 Amp Field Installable Fuse Kit 300V Max
RMB-22: Wood Joist Bar Hanger, 22" Long, Pair
HSA6: Slope Adapter for 6" Aperture Housings, Specify Slope

Candlepower Distribution



Test No. H22244
HD6-6500C
 Lamp = 75W
 PAR30
 Long Neck
 Flood
 Lumens = 1000
 Spacing Criteria = 0.7
 Efficiency = 81.6%

Candlepower

Deg.	CD
0	1341
5	1320
15	1122
25	687
35	89
45	7
55	0
65	0
75	0
85	0
90	0

Average Luminance

Deg.	CD/SQ M
45	604
55	0
65	0
75	0
85	0

Cone of Light

Distance to Illuminated Plane	Initial Nadir Footcandles	Beam Diameter
5'6"	44	4'6"
6'6"	32	5'6"
8'0"	21	6'6"
10'0"	13	8'0"
12'0"	9	9'6"
14'0"	7	11'6"

Beam diameter is to 50% of maximum footcandles, rounded to the nearest half-foot.
 Footcandle values are initial, apply appropriate light loss factors where necessary.

Zonal Lumen Summary

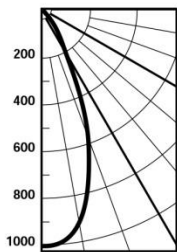
Zone	Lumens	%Lamp	%Luminaire
0-30	743	74.3	91.1
0-40	809	80.9	99.2
0-60	816	81.6	100.0
0-90	816	81.6	100.0
90-180	0	0.0	0.0
0-180	816	81.6	100.0

Coefficient of Utilization

rc	80%				70%				50%				30%				10%				0%			
	70	50	30	10	50	30	10	50	10	50	10	50	10	50	10	50	10	50	10	50	10	0		
RCR																								
0	97	97	97	97	95	95	95	91	91	87	87	83	83	82	80	78	77	75	74	73	72	71	70	
1	94	92	91	89	90	89	88	87	85	84	83	82	80	80	78	77	75	74	73	72	71	70	68	
2	91	88	86	84	87	85	83	84	81	82	80	80	80	80	78	77	75	74	73	72	71	70	66	
3	88	85	82	80	84	81	79	82	78	80	77	78	76	76	75	74	73	72	71	70	69	68	66	
4	86	82	79	76	81	78	76	79	75	78	74	77	74	74	73	72	71	70	69	68	67	66	64	
5	83	79	75	73	78	75	73	77	72	75	72	74	71	71	70	69	68	67	66	65	64	63	61	
6	81	76	73	71	76	73	70	75	70	74	70	73	69	69	68	67	66	65	64	63	62	61	59	
7	79	73	70	68	73	70	68	72	67	71	67	70	67	66	65	64	63	62	61	60	59	58	56	
8	76	71	68	65	71	67	65	70	65	69	65	68	65	64	63	62	61	60	59	58	57	56	54	
9	74	68	65	63	68	65	63	67	63	67	62	66	62	61	60	59	58	57	56	55	54	53	51	
10	72	66	63	61	66	63	61	65	61	65	61	64	60	59	58	57	56	55	54	53	52	51	49	

rc = Ceiling reflectance, rw = Wall reflectance, RCR = Room cavity ratio
 CU Data Based on 20% Effective Floor Cavity Reflectance.

Candlepower Distribution



Test No. H22243
HD6-6500C
 Lamp = 65W BR30
 Flood
 Lumens = 770
 Spacing Criteria = 0.7
 Efficiency = 69.4%

Candlepower

Deg.	CD
0	1000
5	984
15	742
25	320
35	111
45	17
55	0
65	0
75	0
85	0
90	0

Average Luminance

Deg.	CD/SQ M
45	1466
55	0
65	0
75	0
85	0

Cone of Light

Distance to Illuminated Plane	Initial Nadir Footcandles	Beam Diameter
5'6"	33	3'6"
6'6"	24	4'6"
8'0"	16	5'6"
10'0"	10	6'6"
12'0"	7	8'0"
14'0"	5	9'6"

Beam diameter is to 50% of maximum footcandles, rounded to the nearest half-foot.
 Footcandle values are initial, apply appropriate light loss factors where necessary.

Zonal Lumen Summary

Zone	Lumens	%Lamp	%Luminaire
0-30	447	58.0	83.6
0-40	518	67.3	97.0
0-60	534	69.4	100.0
0-90	534	69.4	100.0
90-180	0	0.0	0.0
0-180	534	69.4	100.0

Coefficient of Utilization

rc	80%				70%				50%				30%				10%				0%			
	70	50	30	10	50	30	10	50	10	50	10	50	10	50	10	50	10	50	10	50	10	0		
RCR																								
0	83	83	83	83	81	81	81	77	77	74	74	71	71	69	68	67	66	65	64	63	62	61	60	
1	80	78	77	76	77	76	75	74	72	72	70	69	68	67	66	65	64	63	62	61	60	59	57	
2	77	75	73	71	74	72	70	71	69	70	67	68	66	65	64	63	62	61	60	59	58	57	55	
3	75	72	69	67	71	69	67	69	66	68	65	66	64	63	62	61	60	59	58	57	56	55	53	
4	73	69	66	64	68	66	64	67	63	65	62	64	61	60	59	58	57	56	55	54	53	52	50	
5	70	66	63	61	65	63	61	64	60	63	60	62	59	58	57	56	55	54	53	52	51	50	48	
6	68	64	61	59	63	60	58	62	58	61	58	61	57	56	55	54	53	52	51	50	49	48	46	
7	66	61	58	56	61	58	56	60	56	59	55	58	55	54	53	52	51	50	49	48	47	46	44	
8	64	59	56	54	58	56	54	58	53	57	53	57	53	52	51	50	49	48	47	46	45	44	42	
9	61	56	53	51	56	53	51	56	51	55	51	55	51	50	49	48	47	46	45	44	43	42	40	
10	59	54	51	49	54	51	49	54	49	53	49	53	49	48	47	46	45	44	43	42	41	40	38	

rc = Ceiling reflectance, rw = Wall reflectance, RCR = Room cavity ratio
 CU Data Based on 20% Effective Floor Cavity Reflectance.

Figure 21: Portfolio Incandescent 6" downlight spec sheet

