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Demonstration Assessment of Light-Emitting Diode (LED) Residential Downlights and Undercabinet Lights in the Lane County Tour of Homes, Eugene, Oregon

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October 2008



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**Demonstration Assessment
of Light-Emitting Diode (LED)
Residential Downlights and Undercabinet Lights
in the Lane County Tour of Homes, Eugene, Oregon**

**Final Report prepared in support of the
U.S. DOE Solid-State Lighting
Technology Demonstration GATEWAY Program**

Study Participants:
Pacific Northwest National Laboratory
U.S. Department of Energy
Energy Trust of Oregon
Lane County Home Builders Association
Future B Homes

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Preface

This document is a report of observations and results obtained from a lighting demonstration project conducted under the U.S. Department of Energy (DOE) SSL GATEWAY Demonstration Program. The program supports demonstrations of high-performance solid-state lighting (SSL) products in order to develop empirical data and experience with in-the-field applications of this advanced lighting technology. The program seeks to demonstrate SSL products in applications that save energy, are cost effective, and maintain or improve light levels in the tested lighting application. The DOE GATEWAY Demonstration Program focuses on providing a source of independent, third-party data for use in decision-making by lighting users and professionals; this data should be considered in combination with other information relevant to the particular site and application under examination. Each GATEWAY Demonstration compares one SSL product against the incumbent technology used in that location. Depending on available information and circumstances, the SSL product may also be compared to alternate lighting technologies. Though products demonstrated in the GATEWAY program have been prescreened and tested to verify their actual performance, DOE does not endorse any commercial product or in any way guarantee that users will achieve the same results through use of these products.

Executive Summary

In August 2008 the Pacific Northwest National Laboratory (PNNL) conducted a light-emitting diode (LED) residential lighting demonstration project for the U.S. Department of Energy (DOE), Office of Building Technologies, as part of DOE's Solid-State Lighting (SSL) Technology Demonstration GATEWAY Program. Two lighting technologies, an LED replacement for lamps (bulbs) in downlights and an LED undercabinet lighting fixture, were evaluated in the demonstration which was conducted in two homes built for the 2008 Tour of Homes in Eugene, Oregon. The homes were built by the Lane County Home Builders Association (HBA) and Future B Homes. The Energy Trust of Oregon (ETO) also participated in the demonstration project.

The LED downlight product is called the LR6; it was developed by LED Lighting Fixtures Corporation (LLF) and is sold by Cree LED Lighting Solutions as a replacement for incandescent, compact fluorescent, and halogen lamps in recessed can downlights. It is a unique, integrated module with its own optics, trim, heat sink, and screw (or GU-24) base designed to allow the entire product to be installed in existing recessed downlight fixtures. The second product evaluated was Philips' eW® Profile Powercore undercabinet fixture, which was designed to mount under kitchen cabinets to illuminate the countertop and backsplash surfaces.

Quantitative and qualitative measurements of light performance and electrical power usage were taken at each site before and after initially installed halogen and incandescent lamps were replaced with the LED products. Energy savings and simple paybacks were calculated and builders who toured the homes were surveyed for their responses to the LED products.

The LED downlight product drew 12 Watts of power, reducing energy use by 82% compared to a 65W incandescent reflector lamp and by 84% compared to a 75W halogen reflector lamp. The LED undercabinet fixture drew 10 watts, cutting energy use by 83% to 90% compared to a halogen product, which was tested at two power settings – a low power setting that drew 60 watts and a high power setting that drew 105 watts.

The LED downlights consistently provided more light than the halogen and incandescent lamps in horizontal illuminance measurements at counter height and floor level. They also outperformed in vertical illuminance measurements taken on the walls, indicating better lateral dispersion of the light. The undercabinet fixture's light output was midway between the low and high power halogen undercabinet fixture light outputs (35.8 foot candle versus 13.4 fc and 53.4 fc) but it produced a more uniform light (max/min ratio of 7.0 versus 10.8).

The measured color correlated temperature (CCT) of the LED downlights correlated well with the CCT of the halogen and incandescent lights (2675 K vs. 2700 K). The color rendering of the LED downlight also correlated well at 92 CRI compared to 100 CRI for the halogen and incandescent lamps. The LED undercabinet fixture had measures of 2880 K CCT and 71 CRI compared to the 2700 K and 100 CRI scores for the halogen undercabinet fixture.

Builders who toured the homes were asked to complete a written survey regarding their perceptions of the light quality. They gave the LED downlight high marks for brightness and most felt the LEDs

were the same as or an improvement over the halogen and incandescent lamps in terms of shadows and glare. The majority gave the LED products high marks for overall visibility and improvement in home appearance and surprisingly a high number said they felt the LED products improved the homes' value (83% said this about the downlight and 75% said this about the undercabinet fixture).

The dimming performance of the LED downlight product was also evaluated because LEDs are anticipated to have better dimming capability than other high-efficiency downlight alternatives, namely CFL R-lamps. It was difficult to find the brands of dimmers that were identified by the LED downlight manufacturer as compatible with its product, however. The lamp was tested with a non-compatible dimmer and was found to be difficult to set below 50%. The lamps either didn't dim enough or turned off and they did not operate in unison. According to the builder, a compatible dimmer was found after PNNL's testing, and it is functioning satisfactorily. LED dimmer compatibility is an area for further manufacturer support and industry action.

Paybacks on the LED downlights ranged from 7.6 years (assuming electricity cost of 11 c/kWh) to 13.5 years (at 5c/kWh)^a based on product costs of \$95 per LED downlight and 3 hrs per day of usage. Paybacks on the LED undercabinet fixture in a new home ranged from 4.4 years (11c/kWh electricity) to 7.6 years (5c/kWh) based on product costs of \$140 per LED undercabinet fixture at 2 hrs per day of usage. These payback calculations do not take into account labor costs to replace burned out bulbs or fixtures, which are expected to occur much more frequently with halogen and incandescent lamps than with LED products. Paybacks will be shorter if lamps are operated more hours per day, if electricity prices go up, and/or if the initial purchase price goes down for the LED products. These products have been commercially available for less than a year; prices are expected to drop as the technology improves, as component costs decrease, and as sales and competition increase.

^a The calculations used 5 cents/kWh as the average rate for the Springfield area, and 11 cents/kWh as the national average.

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1.0 Introduction

In August 2008 the Pacific Northwest National Laboratory (PNNL) conducted a light-emitting diode (LED) residential lighting demonstration project for the U.S. Department of Energy (DOE), Office of Building Technologies, as part of DOE's Solid State Lighting (SSL) Technology Demonstration GATEWAY Program. Two lighting technologies, an LED replacement for downlight lamps (bulbs) and an LED undercabinet lighting fixture, were evaluated in the demonstration which was conducted in two homes built for the 2008 Tour of Homes in Eugene, Oregon. The homes were built by the Lane County Home Builders Association (HBA) and Future B Homes. The Energy Trust of Oregon (ETO) also participated in the demonstration project.

The LED downlight product is called the LR6; it was originally developed by LED Lighting Fixtures Corporation (LLF) and is currently sold by Cree LED Lighting Solutions as a replacement for incandescent, compact fluorescent, and halogen lamps in recessed can downlights. It is a unique, integrated module with its own optics, trim, heat sink, and screw (or GU-24) base designed to allow the entire product to be installed in existing recessed downlight fixtures. The second product tested was Philips' eW® Profile Powercore undercabinet fixture, which was designed to mount under kitchen cabinets to illuminate the countertop and backsplash surfaces.

Quantitative and qualitative measurements of light performance and electrical power usage were taken at each site before and after initially installed halogen and incandescent lamps were replaced with the LED products. Energy savings and simple paybacks were calculated and builders who toured the homes were surveyed for their responses to the LED products.

1.1 Background

A number of solid-state lighting-based or LED-based luminaires are currently being introduced into the residential market. Well-designed SSL-based applications have the potential to provide

- greater control of light dispersion
- high-quality light for residential use
- long life
- significant energy savings when compared to incandescent sources
- potentially more control flexibility (dimming) when compared to compact fluorescent sources.

Two residential applications for LEDs that currently can take advantage of these factors are residential downlights and undercabinet lights.

LEDs are a very directional light source, emitting light in one direction as opposed to most incandescent, halogen, and fluorescent lamps which are omni-directional emitters.^a Downlights (or recessed can lights) can take advantage of this inherent directionality of LEDs, minimizing light loss within the fixture. When coupled with recent improvements in LED technology that have significantly improved their efficacy, downlights have emerged as an early, attractive lighting application for LEDs, whose use can make significant energy savings possible. Similarly, LED-based undercabinet lights can also take advantage of the inherently directional nature of LEDs, delivering light to work surfaces as well as the backsplash with minimal losses within the fixtures.

Currently, many new homes use downlights or “cans” for general illumination, primarily with incandescent and halogen lamps, and less frequently with compact fluorescent light (CFL) sources. In fixtures where dimming is desired, most homes will use incandescent or halogen sources. Undercabinet fixtures in residences typically use linear fluorescent or halogen sources. In this application, incandescent and halogen sources are low cost and offer good color rendition and compatibility with the majority of installed controls, relative to the more efficient fluorescent options. LED sources have the potential for even longer life than fluorescent lamps, better light quality, and more energy savings.

LED-based lighting’s potential for long life and good light quality has kindled the interest of residential builders around the nation. This is especially true for builders who are seeking to differentiate themselves through the use of greener products and practices. The number of home builders embracing “green” has been increasing in recent years, as home buyers become more aware of energy efficiency and sustainability options.

According to the National Association of Home Builders (NAHB 2007), in 2007, more than half of NAHB’s members, accounting for more than 80% of U.S. homes built, had incorporated green practices into the development, design, and construction of new homes, that were not required by the local building codes. Features such as energy-efficient windows and appliances are now more common, which can help to ease consumer acceptance of newer techniques and technologies, including LEDs.

Residential lighting typically accounts for 15% to 20% of U.S. household electricity use, employing a mix of incandescent, fluorescent, and compact fluorescent sources. Recessed downlights (can lights) is one of the fastest growing categories in residential applications. DOE estimates more than 20 million downlights are sold in the U.S. each year, and there are at least 500 million recessed downlights installed in U.S. homes.^b Although originally intended for directional lighting, recessed downlights are now used widely for general ambient lighting in kitchens, hallways, bathrooms, and other areas of the home.

Undercabinet lighting is also a popular residential lighting application and is a premium feature in many new and remodelled consumer kitchens. It serves many purposes, ranging from illuminating the surfaces for food preparation tasks to highlighting the counter and backsplash for a more dramatic effect, to night lighting. Many of the newer fixtures use halogen sources to provide both dimming capability and dramatic effects for consumers.

^a LEDs actually emit light in a hemispherical emission pattern, but the light emission is generally referred to as directional.

^b *LED Application Series: Residential Recessed Downlights*. U.S. DOE Energy Efficiency and Renewable Energy, Building Technologies Program, Washington DC, January 2008. Available from <http://www.netl.doe.gov/ssl>.

1.2 Objectives

The objectives of the project were to examine the electrical, lighting, and economic performance of LED products in “real-world” residential downlight and undercabinet lighting applications and to compare the performance of these products with that of incandescent and halogen lamps used in the same applications. One LED downlight product was compared to a comparable halogen lamp and a comparable incandescent lamp. One LED undercabinet fixture was compared to a comparable halogen undercabinet fixture tested at two power levels, low and high. The following metrics were measured or calculated and compared for each product:

- electrical – energy usage and energy savings (both power and estimated annual kWh usage)
- lighting performance – illuminance levels (in footcandles) measured horizontally at counter height and floor height and vertically on walls; illuminance uniformity, correlated color temperature (CCT), color rendering index (CRI)
- dimmability – ability to dim in a manner that satisfies customers
- user perceptions – visibility, brightness, glare, shadows, improvement in home value
- economic performance – simple payback when used as replacement for incandescent or halogen products.

1.3 Overview of this Report

Chapter 2 provides a description of the methodology used in this demonstration project, the measurements taken, the analyses conducted, and the results obtained. Chapter 3 is a discussion of results and conclusions. Chapter 4 is references. Appendix A is a description of the two houses used as the demonstration sites, including their dimensions and electrical layouts. Appendix B is a list of the measuring equipment used. Appendix C is measured data. Appendix D is test results provided by an independent testing laboratory for the undercabinet fixture. Appendix E includes the questionnaire and builders’ perceptions about the LED products and results of the survey. Appendix F is the payback calculations. Appendix G is simulation of the LR6 in homes.

2.0 Methodology

This chapter includes a description of the site of the demonstration project, the products tested, and measurement methods.

2.1 Demonstration Site

The 2008 Eugene Tour of Homes SSL GATEWAY Demonstration Project is a joint project of the U.S. Department of Energy (DOE), Energy Trust of Oregon (ETO), Lane County Homebuilders Association (HBA), and Future B Homes of Eugene, Oregon. ETO's ENERGY STAR Homes Program has been working with Oregon-based builders to help improve the overall energy efficiency of new homes, and they had expressed interest in working with DOE on a residential demonstration of solid-state lighting.

Based on the builders' expressed interest in incorporating LED lighting into their practices, two homes located in the vicinity of Eugene were selected for this assessment with ETO's assistance. These are new homes built by experienced builders for sale to the general public; both were entries in the 2008 Eugene Tour of Homes.

Located in Lane County, Oregon, the Tour of Homes is the Home Builders Association's annual showcase of the top local builders. A 23-year tradition for the county, the 10-day tour takes place at the end of July and is intended to showcase home design ideas, the latest in home innovations, and new building techniques. The tour featured a wide variety of homes open for public viewing, from starter homes to multi-million dollar "dream homes." The 2008 tour included over 20 new homes in the cities of Eugene, Junction City, Veneta, Springfield, Coburg, and Creswell.^a

The Lane County HBA home is a showcase home constructed each year with contributions from members of the Home Builders Association of Lane County. Proceeds from the sale of the home fund HBA activities and help to promote the local building industry. The 2008 Home was designed to be a "green" showcase, with features such as ENERGY STAR qualification and Earth Advantage™ certification, roof-mounted photovoltaic panels, tankless water heaters, increased insulation values, carpeting from recycled material, and water-saving landscaping.^b The home built by Future B Homes is also an ENERGY STAR-qualified home. Detailed descriptions of the homes can be found in Appendix A. Both houses are shown in Figure 2.1.

^a A full listing of homes and descriptions can be found at: http://www.tourofhomes.com/builders_choice_home.php

^b ENERGY STAR here refers to the NW ENERGY STAR Homes Program administered by the Northwest Energy Efficiency Alliance and the Energy Trust of Oregon (<http://www.northwestenergystar.com/>). Qualified homes are up to 30% more efficient than homes built to state code. Earth Advantage is a private, non-profit certification program for homes focusing on energy efficiency, indoor air quality, environmental responsibility, and resource efficiency (<http://www.earthadvantagehomes.com>).



Lane Country HBA



Future B Homes

Figure 2.1. Lane County HBA and Future B Homes 2008 Tour of Homes Entries

2.2 Products Tested

The demonstration compared LED downlight replacement modules and undercabinet fixtures to comparable traditional halogen and incandescent products.

2.2.1 Downlights

For this project, the two participating builders used Cree LED Lighting Solutions' LR6 – a unique, integrated LED downlight module with its own optics, trim, heat sink, and screw-in base so it can function as a direct replacement for screw-based reflector lamps (bulbs) in existing recessed can fixtures (Figure 2.2 and 2.3). The LR6 module is designed to be installed in most standard 6-inch insulated contact (IC) or non-IC-rated recessed downlight housings, using either a screw-in medium base or a GU-24 base.

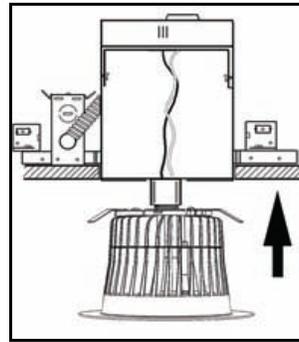


Figure 2.2. Cree LED Lighting Solutions' LR6 LED Module and Installation Instructions
Source: Cree LED Lighting Solutions



Lane County HBA



Future B Homes

Figure 2.3. Lane County HBA and Future B Homes 2008 Tour of Homes:
Kitchens (under construction)

For the Future B Homes's 2008 tour entry, the LR6 units were installed in Lightolier-brand downlight housings, and for the Lane County HBA's 2008 tour entry, the LR6 units were installed in Halo-brand downlight housings. Future B Homes installed a total of 12 Cree LR6 modules in their kitchen and dining areas. Lane County HBA installed 17 LR6 units throughout their model home, in the kitchen, dining room, living room, hallways, and bathrooms. Both homes' dimensions are shown in Appendix A.

To allow for comparisons, the downlight fixtures in the Future B Homes' kitchen and dining areas were initially installed with 75W PAR38 halogen lamps, while Lane County HBA's kitchen and living areas used 65W BR30 incandescent lamps. Downlight housings and light sources were the choices of the local electricians and builders.

2.2.2 Undercabinet Fixtures

Lane County HBA also installed four Philips' eW Profile Powercore LED undercabinet fixtures in the kitchen of their home. Philips' eW Profile Powercore is a low-profile linear LED fixture intended for undercabinet lighting, task lighting, and display case lighting (see Figure 2.4). Powered by line voltage (with a built-in power supply), it can support a run of up to 50 linear feet of fixtures on a single circuit. The fixture can be installed to illuminate work surfaces and displays in both commercial and residential settings. The fixture is available in three standard lengths: 9.25, 19.25, and 39.25 inches. The 19.25-in. units were used in the Lane County HBA home. The eW Profile Powercore LED units replaced four 24-in. three-light "Counter Attack" halogen (xenon-based) undercabinet fixtures made by CSL (Creative System Lighting, Inc.) that had been initially installed. The CSL halogen fixtures were the light sources chosen by the local electricians and builders. The CSL halogen undercabinet lights had the capability of operating at two different light levels - a high setting drawing 105 Watts per fixture and a low setting drawing about 60 Watts. Illuminance measurements were taken at both settings.



Philips' eW® Profile
Powercore LED Undercabinet Fixture



24-in. 3-light CSL "Counter Attack"
Xenon Undercabinet Fixture

Figure 2.4. Philips' s eW® Profile Powercore and CSL Counter Attack Undercabinet Fixtures
Source: Philips and CSL

2.3 Measurement Plan

Similar measurement plans were developed for each home. PNNL did a pre-test visit to the sites to assess any potential issues. One potential issue was identified regarding testing of the downlights: because both homes were still under construction, the countertops were not in and tables were not set up for the measurements, so it was difficult to take measurements at the actual task plane height. Therefore, most of the measurements were taken at floor level, although a limited set of measurements were taken at approximate counter height at both homes. All of the measurements for the downlights were taken in one visit. Measurements were taken with the halogen and incandescent lamps installed in the downlights then those lamps were replaced with the LR6 LED modules and another set of measurements were taken.

Illuminance measurements for the Future B Homes were taken over an area containing 12 luminaires, with four luminaires located in the dining area and eight in the kitchen area. The spacing for the kitchen luminaires and dining luminaires was approximately four-feet on center; both areas were at a nine-foot ceiling height.

Illuminance measurements for the HBA home were taken over two areas containing eight luminaires, with four luminaires located in the dining area and four luminaires located in the living area. The spacing for the kitchen luminaires was approximately 4 ft on center at a 9-ft ceiling height and the spacing for the living area was approximately 8 ft on center at a 17-ft ceiling height. Selected vertical illuminance measurements were also taken on the walls in the kitchen and living area of the HBA home. Table 2.1 contains details of the measurement areas.

Table 2.1. Measurement Details for GATEWAY Demonstration Homes

Location	Measurement Area	Approximate Grid Area	Approximate Grid Spacing	Measurement Height
Future B Homes	Kitchen	9 ft x 9 ft	3 ft	Floor
	Dining	10 ft x 10 ft	3 ft	Floor
Lane County HBA	Kitchen	6 ft x 6 ft	3 ft	Floor
	Living	6 ft x 12 ft	3 ft	Floor

For the Color Kinetics eW fixtures, the installation and measurements took place on separate evenings, because the halogen undercabinet fixtures were not yet installed at the time of the LR6 installation (the halogen fixtures themselves had not yet been installed). Illuminance measurements for the undercabinet fixtures were taken at the counter surface level, over a counter area measuring approximately 30 in. by 50 in. at a 36 in. counter height.

Appendix B contains a listing of the equipment used for the measurement process.

CRI and CCT data for the two LED fixture types investigated were obtained from an independent lighting test laboratory contracted by PNNL to test the fixtures. CRI and CCT data for the halogen and incandescent lamps were assumed based on manufacturers' specifications.

Consumer perceptions of the incandescent/halogen and LED lights were obtained through a questionnaire given to builders who visited the homes during the 2008 Eugene Tour of Homes (a summary of the questionnaire and results are included in Appendix F).

3.0 Results and Discussion

3.1 Electricity Usage and Savings

In the HBA home, each LR6 LED module drew roughly 82% (53 Watts) less than the 65W BR30 incandescent lamp it replaced. In the Future B Homes house, each LR6 LED module drew about 84% (63 Watts) less than the 75W PAR38 halogen lamp it replaced. Based on California’s Database for Energy Efficiency Resource (DEER) and other available usage data, kitchen and dining room downlights typically operate on average about 3 hours per day.^a At this level of daily operation, annual electrical savings are estimated to range from about 58 kWh to 69 kWh per downlight replaced with an LR6 module. Table 3.1 below provides a comparison of the energy consumption for each of the light sources.

Table 3.1. Electrical Demand and Energy Savings for Downlight Light Sources

	Lamp Watts	Hrs/day Use	Annual kWh	Energy Savings (%)
LR6 Module	12	3	13.1	
BR30	65	3	71.2	82%
PAR38	75	3	82.1	84%

The Philips LED undercabinet fixture use 10 Watts per fixture compared to the halogen undercabinet fixture, which draws 105 Watts at the high setting and 60 Watts at the low setting. Thus the LED undercabinet fixture uses 91% less energy than the halogen fixture at the high light setting and 83% less energy than the halogen fixture at the low light setting (see Table 3.2 below).

It is important to note that these are not direct comparison, because the LED undercabinet fixture did not provide the same amount of light as the halogen fixture (footcandle [fc] measurements are 35.8 fc for the LED fixture versus 13.4 fc for the low halogen and 53.4 fc for the high halogen; see lighting performance below.) At about 2 hours of use per day, which is the estimated minimum for these types of fixtures, each LED undercabinet fixture has the potential to save 69.4 kWh/yr compared to the halogen fixture at high setting and 36.5 kWh/yr compared to the halogen fixture at low setting.^b

^a <http://www.energy.ca.gov/deer/> Note that the average value is rounded to 3 hours.

^b *Lighting Efficiency Technology Report, Volume I: California Baseline.* California Energy Commission Consultant Report. September 1999. State of California.

Table 3.2. Electrical Demand and Energy Savings for Undercabinet Sources

	Lamp Watts	Hrs/day Use	Annual kWh	Energy Savings (%)
eW Powercore LEDs	10	2	7.3	
Halogen Low Level	60	2	43.8	83.3%
Halogen High Level	105	2	76.7	90.5%

3.2 Lighting Performance

3.2.1 Downlights

The LED LR6 modules improved light levels across all surveyed areas compared to both the 65W BR30 and 75W PAR38 lamps. The LED modules consistently provided higher maximum and minimum light levels, and therefore higher average light levels in both homes. In addition, the LEDs also provided slightly better light uniformity (lower uniformity ratios) than the halogen lamps – although the differences are too small to be perceivable. Table 3.3 below provides the measured and calculated values for the two homes. A complete listing of light performance data is provided in Appendix C.

Table 3.3. Illuminance Comparison at Floor

Future B Homes	Kitchen/Dining (9 ft height)			
	PAR38	LEDs		
Max light level at floor (fc)	12.4	14.2		
Min light level at floor (fc)	7.0	8.9		
Average light level (fc)	9.6	11.6		
Max/Min Ratio	1.8	1.6		
Lane County HBA	Kitchen (9 ft height)		Living (17 ft height)	
	BR30	LEDs	BR30	LEDs
Max light level at floor (fc)	10.1	12.0	3.4	4.4
Min light level at floor (fc)	8.6	10.1	2.6	3.7
Average light level (fc)	9.2	10.7	3.1	4.1
Max/Min Ratio	1.2	1.2	1.3	1.2

The LED LR6 modules also provided more light at the counter height (36 inches) or task plane level, compared to both the 65W BR30 and 75W PAR38 lamps. The LED modules consistently provided higher maximum and minimum light levels on the counter in both homes. Figure 3.1. shows the installed LR6 units in the kitchen of the Lane County HBA home.



Figure 3.1. Installed LR6 Modules at the Lane County HBA Tour Home

The LEDs provided slightly less light uniformity at the task plane level (higher uniformity ratios) than the halogen lights in the Future B Homes house and greater uniformity than the incandescent lights in the Lane County HBA home. Table 3.4 below provides the measured and calculated values for the two homes.

Table 3.4. Illuminance Comparison at Counter Height

	Future B Homes		Lane County HBA	
	PAR38	LEDs	BR30	LEDs
Max light level at counter (fc)	15.5	19.1	13.0	15.1
Min light level at counter (fc)	7.3	8.6	5.0	8.3
Average light level (fc)	12.0	14.3	9.7	12.5
Max/Min	2.1	2.2	2.6	1.8

Performance was also measured on vertical surfaces in the Lane County HBA home, and the LED modules were found to provide more vertical illuminance (more light on the walls or better lateral dispersion) than the BR30 incandescent lamps installed at the home. Table 3.5 provides the vertical illuminance measured on the east living area wall and on the south kitchen wall at the Lane County HBA home.

Table 3.5. Vertical Illuminance Comparison

Vertical Distance	Living Area East Wall		Kitchen Area South Wall	
	BR30	LEDs	BR30	LEDs
Light level at 2 ft (fc)	1.7	2.6	2.5	4.6
Light level at 4 ft (fc)	1.8	2.7	5.7	9.3
Light level at 6 ft (fc)	1.9	2.9	6.9	12.5
Light level at 8 ft (fc)	2.0	3.4	NA	NA

The color rendering index of the LR6 was tested by an independent lighting test lab and found to be 93, which also compares favorably with the incandescent and halogen CRI score of 100.^a

Aside from its light output and long life, another important aspect of LED lighting that makes it attractive to builders is its dimming capabilities. Builders were provided with Cree LED Lighting Solutions' list of LR6-compatible dimmers in preparation for the installation.^b Both builders were unable to obtain compatible dimmers at the time of installation. Future B Homes had a Lutron-brand dimmer installed as a place holder at the time of installation, while HBA used a simple on-off switch for their kitchen light control.

With the Lutron dimmer, which is not listed as a LR6 compatible dimmer by Cree LED Lighting Solutions, the LR6 units were able to reach full output, but their dimming performance was uneven and quite truncated. At the 50% setting, the light levels of the LED units were not at the 50% mark.^c In fact, they were much higher. However, when the dimmer was moved to levels lower than the 50% mark, the LR6 units had difficulty reaching levels below 50% output and quickly turned off. The LR6 units also flickered and turned off individually (in no particular sequence) rather than in unison when the dimmer was set to the lowest level. Future B Homes has ordered and installed a compatible dimmer from the dimmer families recommended as "compatible" by the manufacturer after PNNL's measurement visit and reported that it is functioning satisfactorily.

3.2.2 Undercabinet

Two types of measurements were taken for the undercabinet lighting – a horizontal measurement of lighting levels on the counter top surface and a vertical measurement on the backsplash. It was possible to make a direct comparison of the lighting performance of the LED and halogen undercabinet fixtures on the horizontal surface but it was not possible to directly compare the vertical measurements on the backsplash. This was because the LED fixtures were not installed in the same location as the halogen fixtures they replaced. The halogen fixtures had been mounted under the cabinets along the back wall. A junction box installed after the halogen fixtures were removed blocked part of the back wall so the LED fixtures had to be mounted along the front edge of the cabinets (Figure 3.2). Furthermore, the halogen fixtures had two levels of light output, whereas the LED fixtures did not.

^a CALiPER Report #07-31

^b Available from http://creelighting.com/downloads/Dimmer_Compatibility_Rev011608.pdf.

^c The PAR38 at the Future B Homes' location were dimmed to 50% setting with the installed PAR38, and this setting was marked prior to removal and installation of the LR6s.



Figure 3.2. Installed LED Undercabinet Fixture

The illuminance provided by the LED fixtures on the countertop fell in between the high and low levels of the halogen. While the LEDs could not match the higher average level provided by the halogen at the high setting, the average illuminance level provided by the LED unit exceeded IESNA recommended level (30 foot-candles) for work surfaces. Further, the LED fixtures were able to provide a more even illumination on the countertops, as evidenced by the lower uniformity ratio (7 vs. 10.8) compared to the halogen fixtures. The LED fixtures also provided a minimum light level quite close to the minimum level obtained at the high setting of the halogen fixture (Table 3.6).

Table 3.6. Illuminance Comparison of Undercabinet Fixtures

	Halogen Lo	Halogen Hi	LEDs
Max light level at counter (fc)	29.3	115.1	56.5
Min light level at counter (fc)	2.7	10.7	8.1
Average light level (fc)	13.4	53.4	35.8
Max/Min	10.9	10.8	7.0

The CCT performance of the LED undercabinet fixtures was measured at an independent testing laboratory contracted by PNNL. They reported it to be 2880 K, which compares favorably with the halogen CCT of 2700 K (or higher). The color rendering index of the eW Profile Powercore tested was reported to be 71. The independent testing data is available in Appendix D.

3.3 User Perceptions

Both Lane County HBA and Future B Homes were impressed with the performance of the LR6 LED downlight's performance. The two builders were impressed with the light output of the LED modules when compared to incandescent lamps. Although the measurable differences in the light levels were slight, both builders commented that the LED modules were brighter. They also cited instant starting and the overall positive effects of the new lights on the appearance of the illuminated areas as reasons for their high satisfaction.

The Lane County HBA representative also had a positive reaction to the Philips undercabinet luminaire, and especially noted the ability of the LED-based source to more closely approximate the “sparkle” factor of the halogen sources when compared to fluorescent sources. In fact, this “sparkle” factor has been cited by a number of builders as an important consideration in their selection of undercabinet lighting, especially if natural materials such as stone or other counter and backsplash choices that require highlighting are chosen.

A subsequent inquiry with local builders indicated a more cautious but still positive reception of the new LED technology. About two dozen builders were given a questionnaire regarding the LED light sources, and 12 responded, although only about half of the respondents saw the installed LED modules at the Future B Homes’ model home. All 12 were able to view the installed fixtures at the Lane County HBA home and were able to comment on them. The responses indicated an overall favorable impression of the LED light sources. Table 3.7 to Table 3.9 below contain a summary of the responses.

Table 3.7. Builders’ Responses to Light Qualities

Brightness, Shadow and Glare			
Light level with LEDs	More	Same	Less
Future B Homes kitchen & dining	67%	33%	0%
Lane County HBA kitchen & living	58%	25%	17%
Lane County HBA undercabinet	17%	33%	50%
Shadow amount with LEDs			
Future B Homes kitchen & dining	33%	33%	33%
Lane County HBA kitchen & living	33%	42%	25%
Lane County HBA undercabinet	17%	50%	33%
Glare amount with LEDs			
Future B Homes kitchen & dining	33%	33%	33%
Lane County HBA kitchen & living	17%	25%	58%
Lane County HBA undercabinet	17%	17%	67%

About half or more of the respondents thought that the LR6 units provided somewhat more light than the incandescent sources, as indicated in Table 3.7 above. A significant number of respondents also thought that the LR6 units were less “glary” and created less shadow than their incandescent and halogen counterparts.

A large number of builders also thought that the new light sources had a more positive impact on overall visibility and helped to improve the appearance of the illuminated area (Table 3.8). Specific to the Philips undercabinet luminaires, a number of builders commented favorably on the fact that the LED fixtures provided a lower light level (the halogen was too bright in the high setting) and a more uniform light than the halogen counterparts. Builders also commented on the fact that LEDs do not get as hot, and that they like the “sparkle” factor. More significantly, the majority thought that the new lights (both undercabinets and downlights) added to the overall value of the houses.

Table 3.8. Builders’ Responses to Appearance and Value of the LED Relative to the Conventional Alternative

Overall visibility	More	Same	Less
Future B Homes kitchen & dining	67%	33%	0%
Lane County HBA kitchen & living	50%	33%	17%
Lane County HBA undercabinet	67%	33%	0%
Improvement in home appearance			
Future B Homes kitchen & dining	67%	33%	0%
Lane County HBA kitchen & living	58%	33%	0%
Lane County HBA undercabinet	75%	25%	0%
Improvement in home value			
Future B Homes kitchen & dining	83%	17%	0%
Lane County HBA kitchen & living	83%	17%	0%
Lane County HBA undercabinet	75%	25%	0%

Builders were asked, do you prefer the old light or the new LED lights? The majority preferred the new lights as shown in Table 3.9.

Table 3.9. Builders Preference for LEDs (New)

Fixture preference	New	Old
Future B Homes kitchen & dining	67%	33%
Lane County HBA kitchen & living	67%	33%
Lane County HBA undercabinet	67%	33%

Finally, PNNL spoke with the builders during the Tour of Homes show. A number of the builders indicated their willingness to use the new light sources in their new or upcoming projects. One builder indicated that he has already sourced a number of LR6 units for his new projects, while a number of others committed to monitoring prices so that they can take advantage of the new light sources when it makes sense for them economically. Most also indicated their willingness to specify LED undercabinet products. A representative selection of their comments are provided in Appendix E. While the surveyed population probably contains a higher percentage of progressive builders, these responses indicated that the installed products are performing to their expectations.

3.4 Economic Analysis

Economic performance was evaluated by calculating the simple paybacks for the LED sources versus the incandescent sources. To calculate this, current energy and materials costs were used to calculate annual maintenance cost and energy cost.

3.4.1 Downlights

The retail price of the LR6 product varied at the time of the study from a low of \$69.99 to a high of \$149.99 or more. The price used in PNNL’s calculations is the actual “builders price” paid for multiple units from a local distributor in Portland, Oregon – \$95 per unit.

To estimate energy cost, two residential electricity rates were used: a rate local to Eugene, Oregon (5 cents per kWh) and an average national rate (11 cents per kWh). Under these rates, the LR6 LED replacement modules yielded annual energy savings of \$2.90 to \$8.71 per unit when compared to 65W incandescent BR30 lamps, and \$3.45 to \$10.35 per unit when compared to 75W halogen PAR38 lamps, based on 3 hours of use per day.^a

Because of the manufacturer’s long claimed life, the LED modules were assumed to not have to be replaced over the life of the fixture (i.e., they have zero lamp replacement cost over the course of their useful life.^b) In comparison the halogen and incandescent lamps are rated by the manufacturers to last 1000 hours for an estimated life of approximately 1 year, if operated 3 hours per day, thus their replacement cost was assumed to be \$3.50 per year for the lamp itself. Labor costs to replace the lamps (i.e., the cost of renting a ladder or hiring someone to come in and replace the lamps – a possibility with high ceilings such as the 17 foot living area at the Lane County HBA home) was not included in the calculations. The simple payback periods for the LED modules (based on their current cost and assumed operational costs of the other sources) is between 7.6 and 13.5 years when they are used in place of incandescent or halogen lamps. Table 3.10 below contains the cost calculations, assumptions, and payback results.

Table 3.10. Operating Costs and Payback Estimates for LR6 Modules

	Energy Cost/Year @ 5c/kWh	Energy Cost/Year @ 11c/kWh	Replacement lamp cost/year	Annual Operating Costs @ 5c (elec + lamp)	Annual Operating Costs @ 11c (elec. + lamp)	LEDs Payback @ 5c/kWh	LEDs Payback @ 11c/kWh
LED Module	\$ 0.66	\$ 1.45		\$ 0.66	\$ 1.45		
BR30	\$ 3.56	\$ 7.83	\$ 3.50	\$ 7.06	\$ 11.33	13.5	8.4
PAR38	\$ 4.11	\$ 9.03	\$ 3.50	\$ 7.61	\$ 12.53	12.5	7.6

Notes: See Appendix F for assumptions. The LR6 cost for this project is \$95/unit.

3.4.2 Undercabinet Lighting

Two payback scenarios were run for the undercabinet lighting: a new construction scenario and a retrofit scenario (Table 3.11 and Table 3.12). In both scenarios, the LED undercabinet fixture was compared to the halogen undercabinet fixture at both its low and the high power operation levels because those levels used different amounts of energy and thus had different annual operating costs.

In the case of new construction, the house will have undercabinet kitchen lighting so the fixture cost used in the calculation is either the cost of the halogen fixture (\$80) or the difference in cost between the LED fixture and the halogen fixture (\$140 LED fixture - \$80 halogen fixture = \$60 per unit cost for the LED fixtures). Again the LED fixtures were assumed to have zero lamp replacement cost due to their long useful life. Therefore, in the new construction scenario, the simple payback period for the LED fixtures (based on their current cost and the assumed operational costs of the other sources) is between 4.4 and 7.6 years when the LED is used instead of an incandescent or halogen lamp.

^a See Appendix F: Payback Calculations.

^b Cree LED Lighting Solutions specifies 70% lumen depreciation at 50,000 hours. At 3 hours per day, this works out to be 45.6 years. A more realistic assumption is that the modules will remain until the kitchen is remodeled, at about 7 years on average.

Table 3.11. Operating Costs and Payback Estimates for LED Undercabinet Fixtures: New Construction

	Energy Cost/Year @ 5c/kWh	Energy Cost/Year @ 11c/kWh	Replacement lamp costs/year	Annual Operating Costs @ 5c (elec + lamp)	Annual Operating Costs @ 11c (elec. + lamp)	LEDs Payback @ 5c/kWh	LEDs Payback @ 11c/kWh
eW Powercore LEDs	\$ 0.37	\$ 0.80		\$ 0.37	\$ 0.80		
CSL Xenon Low Level	\$ 2.19	\$ 4.82	\$ 6.12	\$ 8.31	\$ 10.94	7.6	5.9
CSL Xenon High Level	\$ 3.83	\$ 8.43	\$ 6.12	\$ 9.95	\$ 14.55	6.3	4.4

Notes: See Appendix F for assumptions. The LED fixture cost for this project is \$140/unit.

For the retrofit scenario, the house is assumed to start with a halogen fixture that is being replaced with the LED fixture costing \$140, so the full \$140 cost of the LED fixture is used in the calculation. Based on this unit cost and the assumed operational costs of the halogen source, the simple payback period for the LED fixture is between 10 and 17 years.

Table 3.12. Operating Costs and Payback Estimates for LED Undercabinet Fixtures: Retrofit

	Energy Cost/Year @ 5c/kWh	Energy Cost/Year @ 11c/kWh	Replacement lamp costs/year	Annual Operating Costs @ 5c (elec + lamp)	Annual Operating Costs @ 11c (elec. + lamp)	LEDs Payback @ 5c/kWh	LEDs Payback @ 11c/kWh
eW Powercore LEDs	\$ 0.37	\$ 0.80		\$ 0.37	\$ 0.80		
CSL Xenon Low Level	\$ 2.19	\$ 4.82	\$ 6.12	\$ 8.31	\$ 10.94	17.6	13.8
CSL Xenon High Level	\$ 3.83	\$ 8.43	\$ 6.12	\$ 9.95	\$ 14.55	14.6	10.2

Notes: See Appendix F for assumptions. The LED fixture cost for this project is \$140/unit.

In both Table 3.11 and 3.12 paybacks are calculated based on 2 hours per day of operation. If more hours per day of operation are assumed, payback periods will shorten considerably. Table 3.13 and Table 3.14 contain the payback calculations for retrofits assuming 4 and 6 hours of use per day.

Table 3.13. Operating Costs and Payback Estimates for LED Undercabinet Fixtures: Retrofit at 4 Hours/Day Use

	Lamp Watts	Hrs/day Use	Annual kWh	Annual Operating Costs @ 5c (elec + lamp)	Annual Operating Costs @ 11c (elec. + lamp)	LEDs Payback @ 5c/kWh	LEDs Payback @ 11c/kWh
eW Powercore LEDs	10	4	14.6	\$ 0.73	\$ 1.61		
CSL Xenon Low Level	60	4	87.6	\$ 10.50	\$ 15.76	14.3	9.9
CSL Xenon High Level	105	4	153.3	\$ 13.79	\$ 22.98	10.7	6.5

Notes: See Appendix F for assumptions. The LED fixture cost for this project is \$140/unit.

Table 3.14. Operating Costs and Payback Estimates for LED Undercabinet Fixtures: Retrofit at 6 Hours/Day Use

	Lamp Watts	Hrs/day Use	Annual kWh	Annual Operating Costs @ 5c (elec + lamp)	Annual Operating Costs @ 11c (elec. + lamp)	LEDs Payback @ 5c/kWh	LEDs Payback @ 11c/kWh
eW Powercore LEDs	10	6	21.9	\$ 1.10	\$ 2.41		
CSL Xenon Low Level	60	6	131.4	\$ 12.69	\$ 20.57	12.1	7.7
CSL Xenon High Level	105	6	230.0	\$ 17.62	\$ 31.41	8.5	4.8

Notes: See Appendix F for assumptions. The LED fixture cost for this project is \$140/unit.

4.0 Conclusions

The two LED-based products in this study demonstrated that they are viable alternatives to incandescent products in their intended applications, at the same time offering the potential for significant energy savings.

In the case of the downlight modules, the LR6 unit offers the potential to significantly reduce energy use while maintaining, if not improving, lighting performance when installed in the same residential downlight housings as a 75W PAR38 halogen or a 65W BR30 incandescent lamp (the LR6's intended targets). Their light output and general lighting performance were favorably received by both the host builders and other builders. With respect to their dimming performance, the issues of compatibility and appropriate application still require some attention by the manufacturer, including possibly more technical support to users.^a

In the case of the Philips eW Profile LED Powercore undercabinet fixtures, they were able to meet or exceed required task lighting levels as required by the Illuminating Engineering Society of North America (IES), while offering a potential energy savings of up to 90% when compared to halogen fixtures used in the same application. In addition, their ability to render the “sparkle” factor desired by builders and customers, as well as their ability to operate coolly were favorably received by builders surveyed.

With respect to energy use, each of the LED downlight modules used in this particular study uses 63 Watts less power than the 75W PAR38, and 53 Watts less power than the 65W BR30 they replaced, providing the potential for between an 82% and 84% reduction in annual energy consumption. The Philips eW Profile LED Powercore undercabinet fixture offers the potential of a 83% to 90% annual energy reduction when compared to halogen fixtures in the same residential application, depending on the setting.

The LED sources received favorable reception from the builders who had the opportunity to compare them against incandescent and halogen sources. Close to half of the surveyed builders thought that LED-based fixtures added to the overall value of the houses, and a number indicated their willingness to use the new light sources where it makes sense for them economically. While the survey population probably contains a higher percentage of progressive builders, these responses indicated that the installed products are performing to their expectations.

One area where the LED alternatives need to improve is cost (and they are expected to in the near future). Despite the significant reduction in annual energy consumption and maintenance cost that they can offer, the high upfront cost of these LED products and of LED products in general can be a significant barrier to their adoption, especially in the price-sensitive environment of the residential market. In choosing between a halogen lamp, an incandescent lamp, a CFL, or a LED downlight module, the simple payback of the LED downlight module used in this study would be over 7 years. To meet a simple payback of 3 years or less, the cost of an LED module would need to be less than half of the current cost.

^a A more comprehensive way to address this issue of compatibility is for the industry to agree on a dimming standard.

Similarly, it does not yet make sense on a solely economic basis to retrofit existing halogen and incandescent undercabinet fixtures, as the payback periods for these can be more than 10 years, especially in a low-use scenario. However, the picture is much better for replacement with LEDs at higher usage and higher electricity rates, or in the case of new construction, where only the incremental cost of the LED products, not the whole fixture cost, needs to be taken into account. At the national average electricity cost of 11 cents per kWh, the payback period for the eW Profile LED Powercore 19.25-in. fixture is currently under 5 years.

With lower product costs and possibly higher electricity rates, LEDs will certainly find favorable reception in the near future with more progressive builders and builders seeking more “green” options. Additionally, LED products with dimming capabilities can better compete, especially in applications where the baseline technology includes dimming options, as these are currently dominated by incandescent and halogen sources. As previously noted, with the rapid advancements in LED efficacy and a reduction in the cost of semi-conductors, the payback of any LED luminaire installation can be expected to improve in the future. Utility incentive programs could also help bring the initial costs down for consumers even sooner.

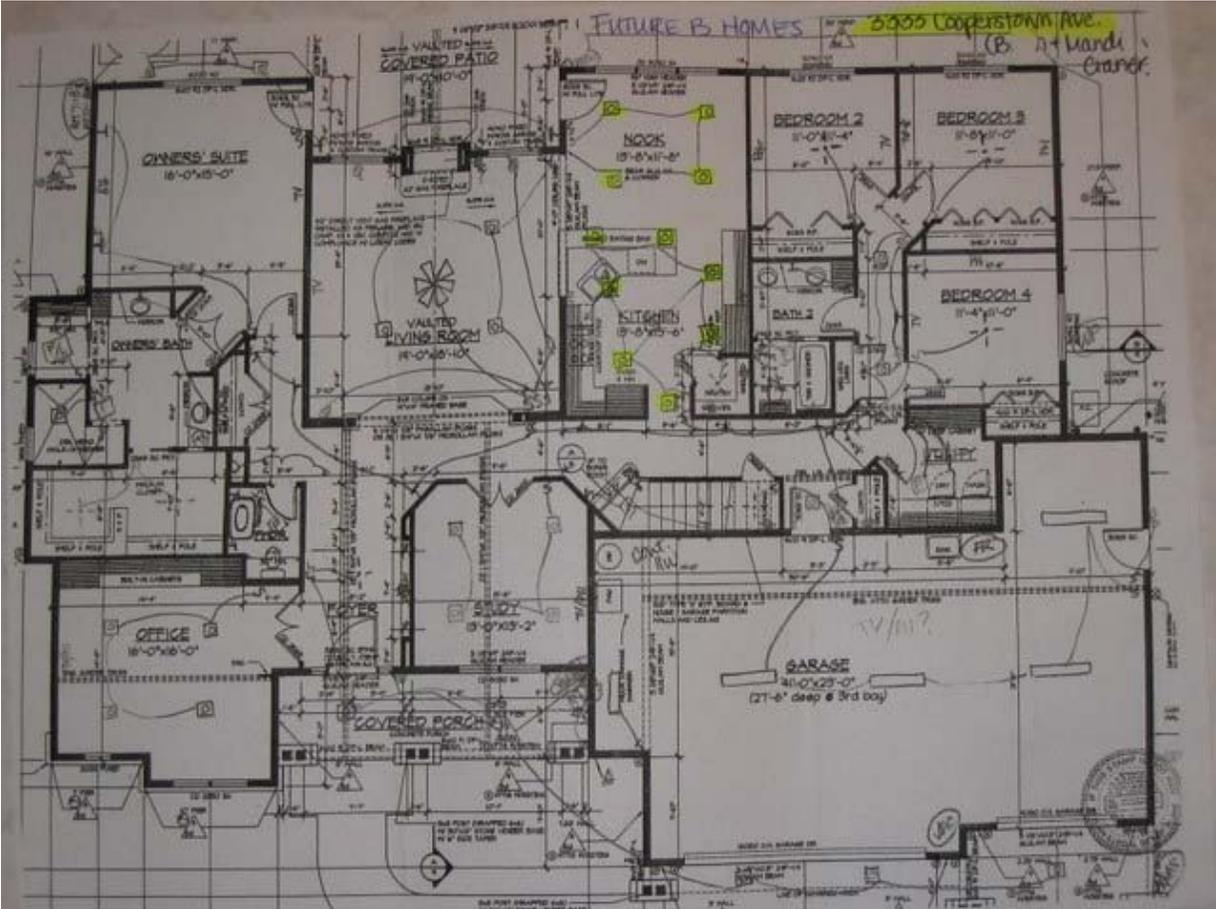
Appendix A
Demonstration Homes

Appendix A

Demonstration Homes

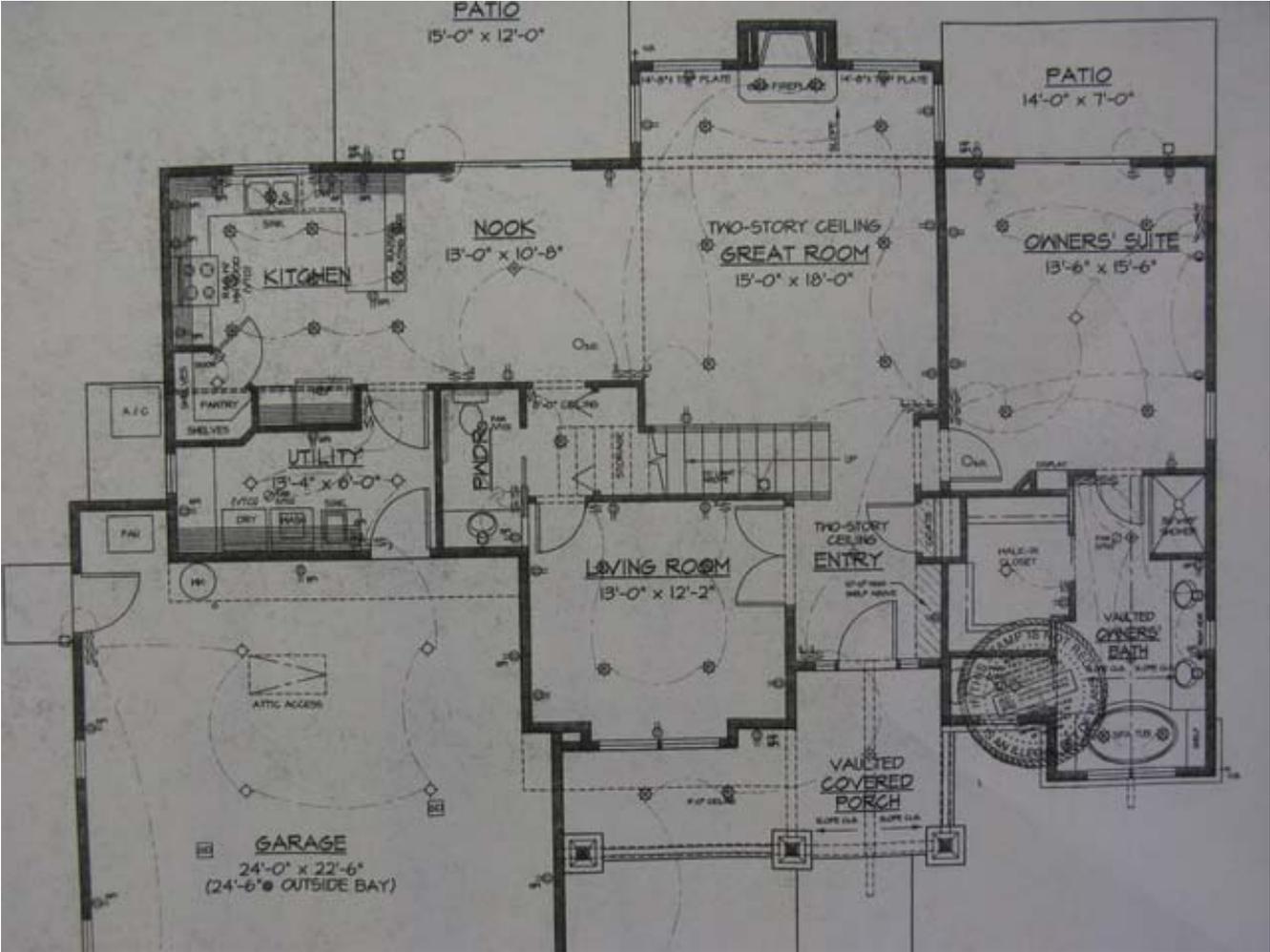
Builder	Future B Homes
Address	3333 Cooperstown Ave Eugene, OR
Type	Detached 2-story single family home with attached garage
Size	4127 Square feet
Rooms	5 Bedrooms, 3 ½ baths
Notable features	NW ENERGY STAR Certified
Year built	2008

Floor Plan:



Builder	Home Builders Association of Lane County (d.b.a Homebuilders Construction Company)
Address	2598 17 th Street Springfield, OR
Type	Detached 2-story single family home with attached garage
Size	2208 Square feet
Rooms	4 Bedrooms, 2 ½ baths
Notable features	NW ENERGY STAR and Earth Advantage certified, photovoltaic panels.
Year built	2008

Floor Plan, 1st floor:



Appendix B

Measurement Equipment & Conditions

Appendix B

Measurement Equipment & Conditions

Date: June 11 & 12, 2008

Time: 9:45 PM – 2:30 AM

Temperature: 70 F

Conditions: Indoor, controlled conditions

Illuminance Meter	Minolta Illuminance Meter, Model T-1
Chroma Meter	Konica Minolta Chroma Meter, Model CL-200
Power Meter	N/A
Temperature Meter	Honeywell T8812

Appendix C

Illuminance-Level Measurement Data

Appendix C

Illuminance-Level Measurement Data

Illuminance Level Measurements: Raw Data - HBA Home

Downlight Kitchen Floor (fc)

	BR30	LR6
	9.5	10.4
	9	10.6
	10.1	12
	8.9	10.2
	8.6	10.1
Average	9.2	10.7
Max	10.1	12.0
Min	8.6	10.1
Max/Min	1.2	1.2

Downlight Living Space (fc)

	BR30	LR6
	2.7	3.8
	2.9	4
	2.8	3.8
	2.6	3.7
	3	4
	3.1	4.1
	3.2	4.2
	3	4
	3.2	4.2
	3.4	4.4
	3.4	4.3
	3.2	4.1
	3.3	4.2
	3.4	4.3
	3.4	4.4
	3.3	4.2
	3.2	4
	3.2	4.2
	3.3	4.2
	3.3	4
Average	3.1	4.1
Max	3.4	4.4
Min	2.6	3.7
Max/Min	3.4	1.2

Downlight Kitchen Counter (fc)

	BR30	LR6
	11.3	14.2
	11.2	14.5
	13.0	14.3
	12.6	13.8
	9.3	11.2
	13.0	14.7
	12.5	15.1
	11.3	14.6
	10.9	13.7
	8.8	11.7
	9.5	12.4
	9.9	13.0
	9.5	13.1
	9.4	12.8
	6.9	10.4
	6.9	10.6
	7.0	10.5
	6.2	9.3
	5.0	8.3
Max light level at counter (fc)	13.0	15.1
Min light level at counter (fc)	5.0	8.3
Avg light level (fc)	9.7	12.5
Max/Min	2.6	1.8

HBA Home: Undercabinet (lx)

	Hg Low	Hg High	LED			
	154	594	279			
	232	920	501			
	275	1100	608			
	292	1150	570			
	212	1080	464			
	130	830	350			
	110	509	378			
	153	328	335			
	181	557	279			
	188	730	189			
	181	752	298			
	139	726	429			
	88	600	510			
	56	401	604			
	80	239	592			
	91	322	540			
	97	374	595			
	89	395	597			
	73	360	542			
	54	298	415			
	47	212	344			
	77	177	244			
	97	277	147			
	96	350	203			
	86	372	256			
	63	329	402			
	29	252	500			
	114	115	550			
	249	249	87			
	293	391	116			
	315	963	148			
	269	1239	271			
	233	1220	350			
	56	1132	410			
				Halogen Lo	Halogen Hi	LEDs
Max light level at counter	315.0	1239.0	608.0	29.3	115.1	56.5
Min light level at counter	29.0	115.0	87.0	2.7	10.7	8.1
Average light level	144.1	574.8	385.4	13.4	53.4	35.8
Max/Min	10.9	10.8	7.0	10.9	10.8	7.0

Illuminance Level Measurements: Raw Data - Future B Homes

Downlight

Kitchen & Dining Room Floor (fc)

	75W R38	LR6
	10	11
	11.6	12.9
	11.7	13.6
	11	12.9
	10.5	12.7
	12.2	14.2
	12.4	14.2
	12	13.4
	9.3	10.5
	7.2	9.7
	9.6	11.2
	10.6	11.8
	9.7	11.1
	7.2	9.4
	8.2	10.4
	10.4	12.4
	11.1	13.2
	10.6	12.6
	8.3	10.8
	7.3	8.9
	8.4	10.1
	8.1	10.5
	9.2	12.4
	7.1	10.6
	8.5	11.6
	7	9.6
Average	9.6	11.6
Max	12.4	14.2
Min	7	8.9
Max/Min	1.8	1.6

Downlight

Counter Height (fc)

	75W R38	LR6
	7.3	8.6
	9.7	10.4
	11.5	12.1
	11.5	13.8
	11.3	14.7
	11.5	14.5
	13.1	15.1
	15.5	17.1
	14.1	18.9
	14.8	19.1
	14.6	17.3
	13.3	16.7
	14.5	15.1
	9.9	11.2
	10.2	12.2
	9.3	11.4
Average	12.0	14.3
Max	15.5	19.1
Min	7.3	8.6
Max/Min	2.1	2.2

Appendix D

Test Results for Philips eW® Profile Powercore Undercabinet Fixture from Independent Laboratory



LUMINAIRE TESTING LABORATORY, INC.

SUSTAINING
MEMBER
of the
IESNA

905 Harrison Street · Allentown, PA 18103 · 610-770-1044 · Fax 610-770-8912 · www.LuminaireTesting.com

LTL NUMBER: 13714 DATE: 08-27-2008
PREPARED FOR: PACIFIC NORTHWEST NATIONAL LABORATORY/BATTELLE
CATALOG NUMBER: CALIPER 08-89
LUMINAIRE: EXTRUDED ALUMINUM HOUSING WITH FORMED PLASTIC ENDS, FROSTED PLASTIC ENCLOSURE.

LAMPS: 10 WHITE LEDS
LED POWER SUPPLY: ONE UNMARKED LED POWER SUPPLY
ELECTRICAL VALUES: 120.0VAC, 0.0828A, 9.89W
LUMINAIRE EFFICACY: 28.0 LUMENS/WATT
NOTE: THIS TEST WAS PERFORMED USING THE CALIBRATED PHOTODETECTOR METHOD OF ABSOLUTE PHOTOMETRY.*
VERTICAL TEST DATA WAS ACQUIRED IN 1/2 DEGREE INCREMENTS.

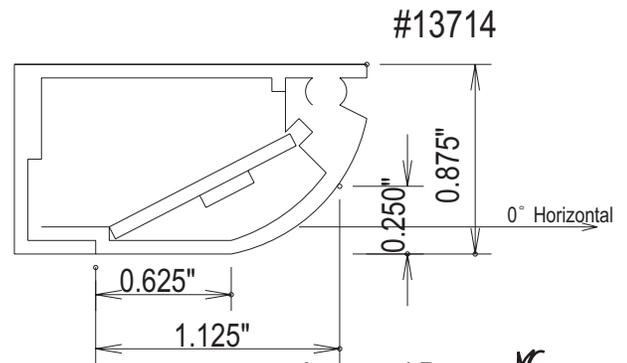
LUMINAIRE STANDARD CANDELA DISTRIBUTION

VER ANG	LATERAL ANGLE										ZONAL LUMEN SUMS
	0.0	22.5	45.0	67.5	90.0	112.5	135.0	157.5	180.0		
0	98	98	98	98	98	98	98	98	98		
5	100	100	99	99	98	97	95	94	94	9	
15	104	103	100	97	94	90	87	85	83	26	
25	104	102	98	92	87	81	74	70	67	40	
35	101	98	92	83	76	67	58	53	51	47	
45	93	91	83	71	61	50	42	38	36	48	
55	82	78	70	55	42	32	27	22	20	42	
65	70	64	52	37	22	17	12	9	7	31	
75	57	51	36	18	8	6	4	3	3	21	
85	22	19	15	7	1	1	1	1	1	8	
90	13	11	8	4	0	0	0	0	0		
95	8	7	5	2	0	0	0	0	0	3	
105	3	2	2	0	0	0	0	0	0	1	
115	1	1	0	0	0	0	0	0	0	0	
125	0	0	0	0	0	0	0	0	0	0	
135	0	0	0	0	0	0	0	0	0	0	
145	0	0	0	0	0	0	0	0	0	0	
155	0	0	0	0	0	0	0	0	0	0	
165	0	0	0	0	0	0	0	0	0	0	
175	0	0	0	0	0	0	0	0	0	0	
180	0	0	0	0	0	0	0	0	0	0	

ZONAL LUMEN SUMMARY DATA IN MAJOR ZONES

ZONE	LUMENS	%FIXT
0-30	75	27.23
0-40	123	44.31
0-60	213	76.94
0-90	273	98.61
90-120	4	1.33
90-130	4	1.35
90-150	4	1.37
90-180	4	1.39
0-180	277	100.00

TOTAL LUMEN OUTPUT: 277
CIE CLASSIFICATION TYPE: DIRECT
DIMENSION NORMAL TO 0-DEG PLANE: 19.000"
DIMENSION PARALLEL TO 0-DEG PLANE: 1.125"



Approved By: MG

*DATA WAS ACQUIRED USING THE CALIBRATED PHOTODETECTOR METHOD OF ABSOLUTE PHOTOMETRY. A UDT MODEL #211 PHOTODETECTOR AND UDT MODEL #S370 OPTOMETER COMBINATION WERE USED AS A STANDARD. A SPECTRAL MISMATCH CORRECTION FACTOR WAS EMPLOYED BASED ON THE SPECTRAL RESPONSIVITY OF THE PHOTODETECTOR AND THE SPECTRAL POWER DISTRIBUTION OF THE TEST SUBJECT.

TESTING WAS PERFORMED IN ACCORDANCE WITH IES LM-79-08.

TEST ANGULAR INCREMENTS AND REPORT FORMATTING WAS BASED ON IES LM-41-98 AND LM-46-04.



LUMINAIRE TESTING LABORATORY, INC.

SUSTAINING MEMBER of the IESNA

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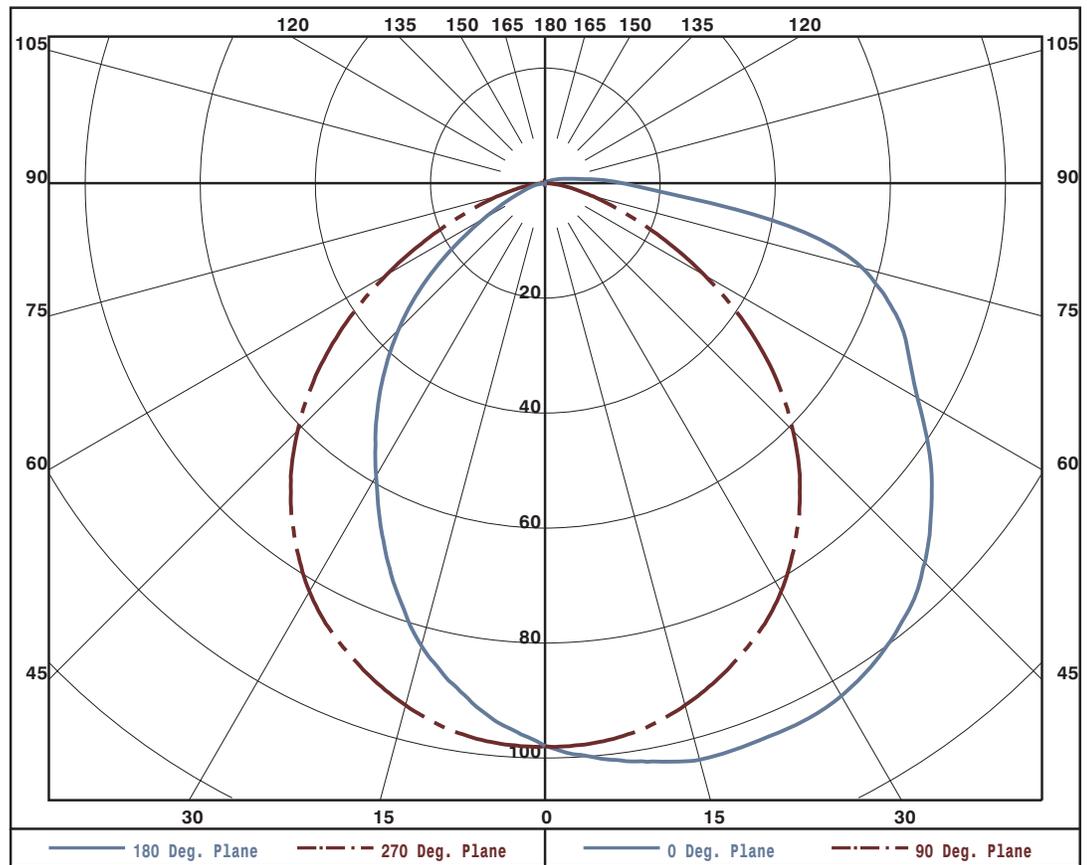
LTL NUMBER: 13714

DATE: 08-27-2008

PREPARED FOR: PACIFIC NORTHWEST NATIONAL LABORATORY/BATTELLE

5 DEG LUMEN VALUES	LUMENS
0-5	2
5-10	7
10-15	11
15-20	15
20-25	19
25-30	21
30-35	23
35-40	24
40-45	24
45-50	24
50-55	22
55-60	20
60-65	17
65-70	14
70-75	12
75-80	9
80-85	5
85-90	3
90-95	2
95-100	1
100-105	1
105-110	0
110-115	0
115-120	0
120-125	0
125-130	0
130-135	0
135-140	0
140-145	0
145-150	0
150-155	0
155-160	0
160-165	0
165-170	0
170-175	0
175-180	0

LUMINANCE IN CANDELA PER SQUARE METER				
VER ANG	LATERAL ANGLE			
	0-DEG	45-DEG	90-DEG	
0	7104	7104	7104	
45	7861	7329	6252	
55	7847	7204	5355	
65	8110	6722	3814	
75	8769	6383	2288	
85	5269	4389	1191	





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LTL NUMBER: 13714

DATE: 08-27-2008

PREPARED FOR: PACIFIC NORTHWEST NATIONAL LABORATORY/BATTELLE

5 DEGREE LUMINAIRE CANDELA DISTRIBUTION

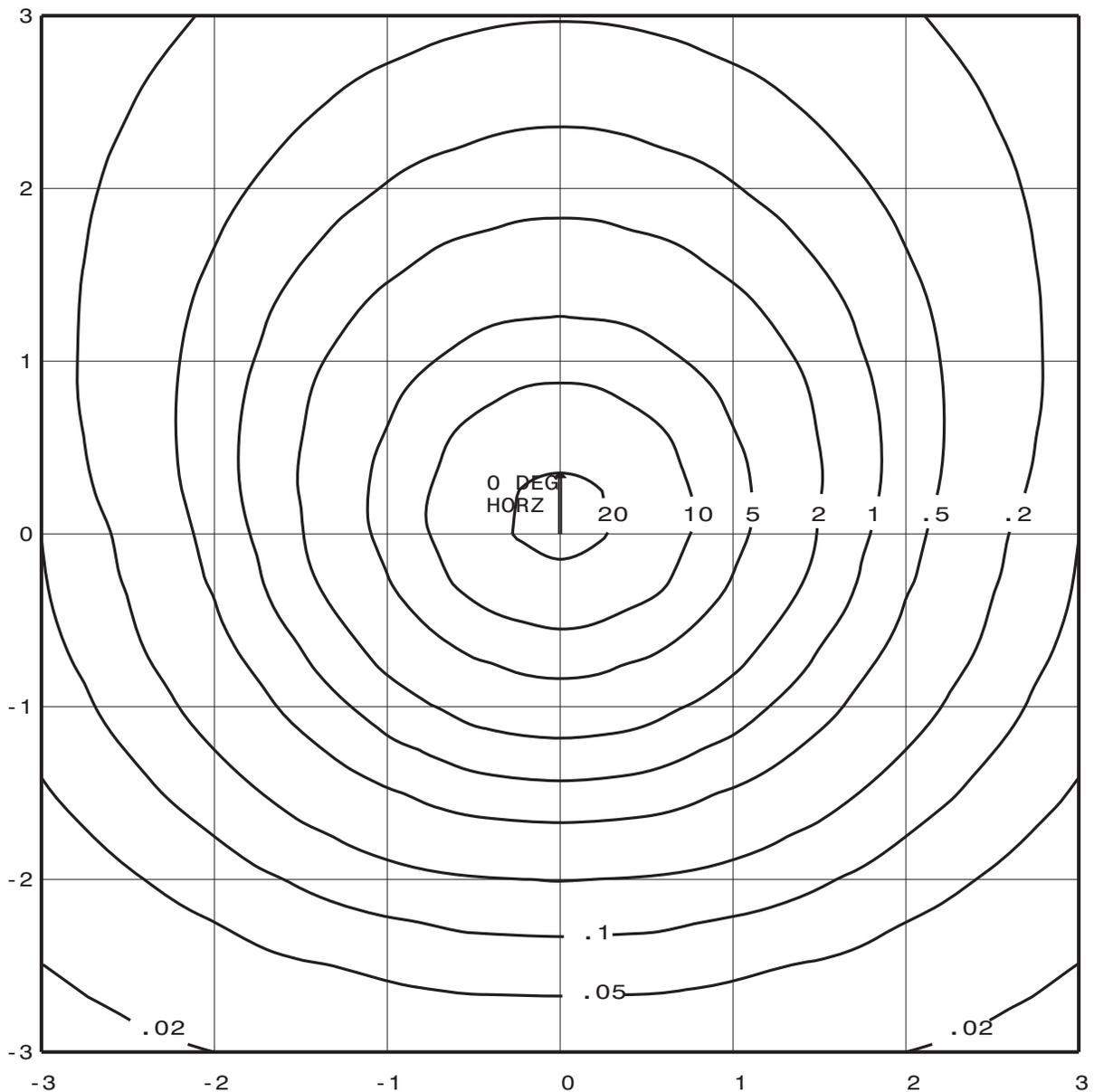
Table with columns: VER ANG, LATERAL ANGLE (0.0, 22.5, 45.0, 67.5, 90.0, 112.5, 135.0, 157.5, 180.0) and rows of candela values.

THIS TEST WAS CONDUCTED USING PHOTOMETRY TECHNIQUES ACCORDING TO STANDARD IES PROCEDURES. THE USER MUST THEREFORE USE CAUTION IN THE FOLLOWING SITUATIONS: 1) THIS TEST WAS PERFORMED USING A SPECIFIC BALLAST/LAMP COMBINATION. EXTRAPOLATION OF THESE DATA FOR OTHER BALLAST/LAMP COMBINATIONS MAY PRODUCE ERRONEOUS RESULTS. 2) THIS TEST WAS CONDUCTED IN A CONTROLLED LABORATORY ENVIRONMENT WHERE THE AMBIENT TEMPERATURE WAS HELD AT 25°C ±1°C. FIELD PERFORMANCE MAY DIFFER PARTICULARLY IN REGARDS TO CHANGE IN LUMINOUS OUTPUT AS A RESULT OF DIFFERENCE IN AMBIENT TEMPERATURE AND METHOD OF MOUNTING THE LUMINAIRE.



ISOFOOTCANDLE CONVERSION FACTORS FOR SELECTED MOUNTING HEIGHTS

MOUNTING HEIGHT	1'	1.5'	2'	2.5'	3'
MULTIPLIER	4.00	1.78	1.00	0.64	0.44



LTL REPORT NUMBER 13714-ISOFOOTCANDLE VALUES ARE BASED ON A MOUNTING HEIGHT OF 2', WITH THE LUMINAIRE LOCATED AT 0,0. ISOFOOTCANDLE VALUES ARE CALCULATED FROM THE DIRECT CONTRIBUTION FROM THE LUMINAIRE ONLY. WALL, CEILING, AND FLOOR CONTRIBUTION IS NOT INCLUDED.



LUMINAIRE TESTING LABORATORY, INC.

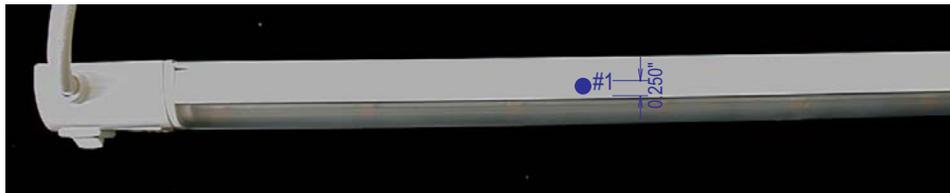
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IESNA

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LTL NUMBER: 13714 DATE: 08-27-2008
PREPARED FOR: PACIFIC NORTHWEST NATIONAL LABORATORY/BATTELLE
CATALOG NUMBER: CALIPER 08-89
LUMINAIRE: EXTRUDED ALUMINUM HOUSING WITH FORMED PLASTIC ENDS, FROSTED PLASTIC ENCLOSURE.
LAMPS: 10 WHITE LEDS
LED POWER SUPPLY: ONE UNMARKED LED POWER SUPPLY
PROCEDURE: ALL TESTING WAS PERFORMED IN THE LTL PHOTOMETRIC TESTING LABORATORY WITH A CONTROLLED THERMAL ENVIRONMENT OF $25.0^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$. THERMOCOUPLE LEADS WERE ATTACHED TO TWO LOCATIONS ON THE LAMP (SEE DIAGRAM BELOW). TEMPERATURE MEASUREMENTS WERE ACQUIRED USING A YOKOGAWA 2423A THERMOMETER

DATA:

	TEMPERATURE
LOCATION #1 ON LUMINAIRE	36.3°C
LOCATION #2 ON LUMINAIRE	46.2°C



"OFF" POWER ELECTRICAL READINGS: 120.0VAC, 0.00A, 0.00W



LTL Number: 13715

Date: 08-28-2008

Prepared For: Pacific Northwest National Laboratory/Battelle

PNNL Catalog Number: CALiPER 08-89

Luminaire: Extruded aluminum housing with formed plastic ends, frosted plastic enclosure.

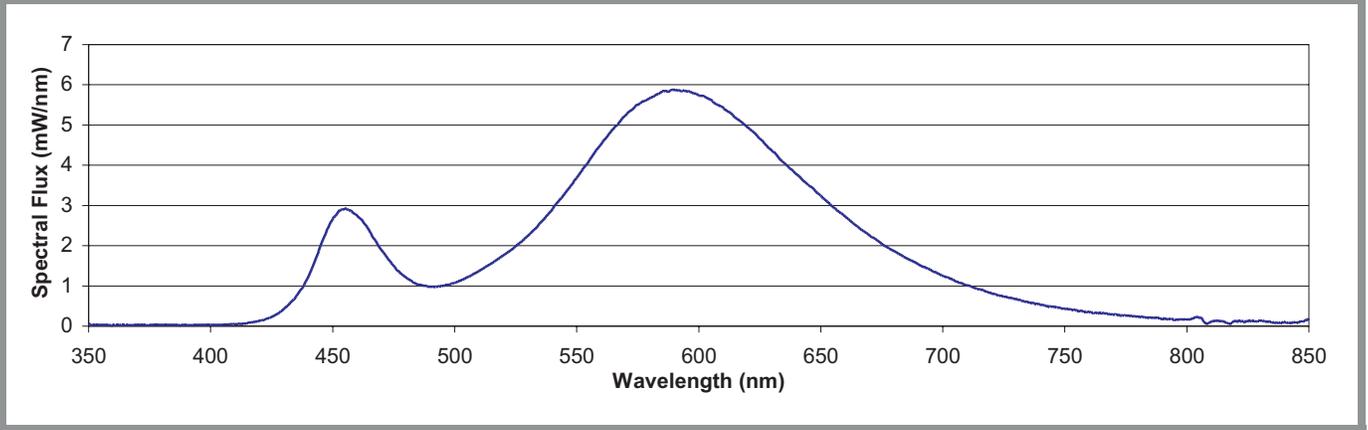
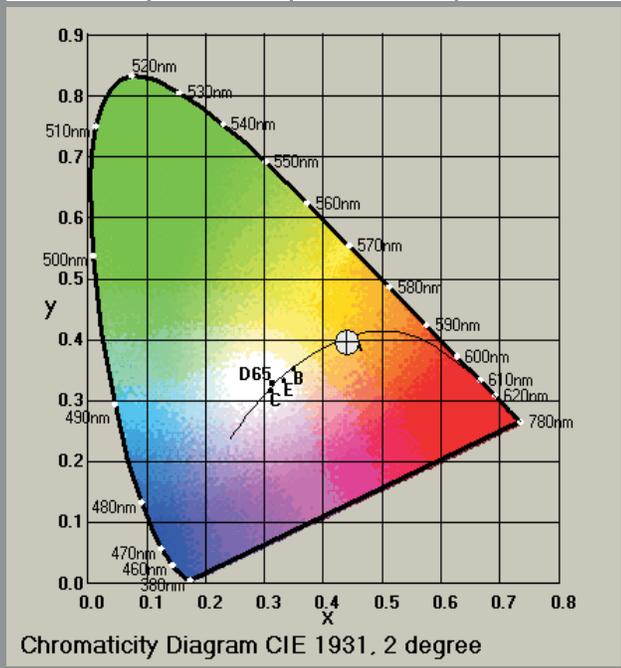
Lamp: 10 White LEDs

LED Power Supply: One unmarked LED power supply

Lamp Efficacy: 28.4 Lumens/Watt

Lamp Arc Voltage	Lamp Current	Lamp Watts	Frequency
120.0VAC	0.08290A	9.863W	60Hz
Radiant Flux mW	Luminous Flux lumen	Corr. Color Temperature K	Color Rend. Index Ra
881.6222	280.5882	2881	71.3
Chroma x	Chroma y	Chroma u	Chroma v
0.4402	0.3964	0.2561	0.3459

Wavelength in nm	Spectral Flux in mW/nm	Wavelength in nm	Spectral Flux in mW/nm
350	0.0686	610	5.4325
360	0.0253	620	4.9504
370	0.0273	630	4.3608
380	0.0290	640	3.7805
390	0.0238	650	3.2406
400	0.0309	660	2.7274
410	0.0444	670	2.2562
420	0.1229	680	1.8637
430	0.4284	690	1.5371
440	1.2283	700	1.2492
450	2.6636	710	1.0085
460	2.7479	720	0.8146
470	1.8942	730	0.6686
480	1.2099	740	0.5366
490	0.9800	750	0.4307
500	1.0776	760	0.3460
510	1.3735	770	0.2839
520	1.7626	780	0.2294
530	2.2496	790	0.1774
540	2.9028	800	0.1665
550	3.6848	810	0.1056
560	4.5226	820	0.1306
570	5.2411	830	0.1369
580	5.6647	840	0.0961
590	5.8757	850	0.1935
600	5.7331		



Appendix E

Questionnaire of Builders' Perception of LED Lighting

Appendix E

Questionnaire of Builders' Perception of LED Lighting

Lighting Questionnaire

Alternative types of light fixtures (LEDs) were recently installed in the HBA and Future B homes for the 2008 Tour of Homes. The U.S. Department of Energy is interested in your opinions of these new products and has constructed a brief questionnaire to obtain your feedback. The questionnaire is entirely voluntary. Your responses will be aggregated with those of others via computer and no individual responses or other identification will be reported.

1. Did you notice that new lighting fixtures were used in the kitchen and dining room at the Future B home?

Yes No

2. Did you notice that new fixtures were used in the kitchen and dining room, and also under cabinets at the HBA home?

Kitchen/Dining: Yes No **Under Cabinet:** Yes No

**NOTE: Answer Q3-Q9 ONLY IF YES IN Q1 and/or Q2.
Put an "X" in the appropriate column.**

Questions: Appearance	More	About the Same			Less
	1	2	3	4	5
3. Do you feel that the LED light fixtures provide more, less, or just the right amount of light compared to what you are used to?					
Future B Home: Kitchen Dining					
HBA Home: Kitchen/Dining					
HBA Home: Under Cabinet					
4. Do you feel that the LED light fixtures create more, less or about the same amount of shadows?					
Future B Home: Kitchen Dining					
HBA Home: Kitchen/Dining					
HBA Home: Under Cabinet					
5. Do you feel that the new LED light fixtures create more, less or about the same amount of glare?					
Future B Home: Kitchen Dining					
HBA Home: Kitchen/Dining					
HBA Home: Under Cabinet					

Questions: Value	Positive Impact				
	Neutral (No impact)			Negative Impact	
	1	2	3	4	5
6. Do you notice that the new LED lighting had a positive, negative, or neutral impact on overall visibility in the area where they were installed?					
Future B Home: Kitchen Dining					
HBA Home: Kitchen/Dining					
HBA Home: Under Cabinet					
7. Do you feel the new LED light fixtures have had a positive, negative, or neutral impact on the overall <u>appearance</u> of the homes?					
Future B Home: Kitchen Dining					
HBA Home: Kitchen/Dining					
HBA Home: Under Cabinet					
8. Do you feel the new LED light fixtures have a positive, negative, or neutral impact on the overall <u>value</u> of the homes?					
Future B Home: Kitchen Dining					
HBA Home: Kitchen/Dining					
HBA Home: Under Cabinet					

Question: Preference	New	About the Same			Old
	1	2	3	4	5
9. When all things are considered, do you prefer the new light LED fixtures that were installed or do you prefer the fixtures you currently use?					
Future B Home: Kitchen Dining					
HBA Home: Kitchen/Dining					
HBA Home: Under Cabinet					

10. Explain why do you prefer the light fixtures you selected in the last question? (Skip if no preference.)

a. New (LED) fixtures

b. Old fixtures

11. Do you plan to offer any of the alternative LED fixtures in the homes you build in the future? (circle one)

Yes No Maybe

12. Please indicate current lamp/fixture types you are using (incandescent, CFL, or LEDs):
 Kitchen: Dining: Under Cabinet:

Any other comments?

Thank you for your time!

Tallied Results:

Brightness, Shadow and Glare						
Light level with LEDs	More	Same	Less	Total		
Future B Homes kitchen & dining	4	2				6
Lane County HBA kitchen & living		7	3	2		12
Lane County HBA undercabinet		2	4	6		12
Shadow amount with LEDs						
Future B Homes kitchen & dining		2	2	1	1	6
Lane County HBA kitchen & living		4	5	2	1	12
Lane County HBA undercabinet		2	6	2	2	12
Glare amount with LEDs						
Future B Homes kitchen & dining		2	2	2		6
Lane County HBA kitchen & living		2	3	5	2	12
Lane County HBA undercabinet		2	2	6	2	12
Visibility, Appearance and Value						
Overall visibility	More	Same	Less	Total		
Future B Homes kitchen & dining	3	1	2			6
Lane County HBA kitchen & living	4	2	4	2		12
Lane County HBA undercabinet	6	2	4			12
Improvement in home appearance						
Future B Homes kitchen & dining	2	2	2			6
Lane County HBA kitchen & living	5	2	4	1		12
Lane County HBA undercabinet	6	3	3			12
Improvement in home value						
Future B Homes kitchen & dining	3	2	1			6
Lane County HBA kitchen & living	6	4	2			12
Lane County HBA undercabinet	7	3	2			12
Fixture preference	New	Old	Total			
Future B Homes kitchen & dining	4	2				6
Lane County HBA kitchen & living	8	4				12
Lane County HBA undercabinet	8	4				12

Appendix F

Payback Calculations and Assumptions

Appendix F

Calculations and Assumptions

Annual Operation Costs & Savings Downlights:

	Lamp Watts	Unit Cost	Hrs/day Use	Annual kWh	Cost of Electricity	Cost of Electricity	Energy Cost/Year @ 5c/kWh	Energy Cost/Year @ 11c/kWh	Energy Savings (%)
LR6 Module	12	\$ 95.00	3	13.1	0.05	0.11	\$ 0.66	\$ 1.45	
BR30	65	\$ 3.50	3	71.2	0.05	0.11	\$ 3.56	\$ 7.83	82%
PAR38	75	\$ 3.50	3	82.1	0.05	0.11	\$ 4.11	\$ 9.03	84%

Payback Calculations Assumptions, Downlights:

Replacement lamp life @ 1050 hours, average cost \$3.50

LR6: life at 50,000 hours; LR6 “builder cost” of \$95

Average Eugene electricity cost: 5cents/kWh, national electricity cost: 11 cents/kWh;

	Lamp Watts	Unit Cost	Hrs/day Use	Annual kWh	Cost of Electricity	Cost of Electricity	Energy Cost/Year @ 5c/kWh	Energy Cost/Year @ 11c/kWh	Replacement lamp costs/year	Annual Operating Costs @ 5c (elec + lamp)	Annual Operating Costs @ 11c (elec. + lamp)	LEDs Payback @ 5c/kWh	LEDs Payback @ 11c/kWh
LED Module	12	\$ 95.00	3	13.1	0.05	0.11	\$ 0.66	\$ 1.45		\$ 0.66	\$ 1.45		
BR30	65	\$ 3.50	3	71.2	0.05	0.11	\$ 3.56	\$ 7.83	\$ 3.50	\$ 7.06	\$ 11.33	14.8	9.6
PAR38	75	\$ 3.50	3	82.1	0.05	0.11	\$ 4.11	\$ 9.03	\$ 3.50	\$ 7.61	\$ 12.53	13.7	8.6

Annual Operation Costs & Savings, Undercabinets:

	Lamp Watts	Unit Cost	Hrs/day Use	Annual kWh	Cost of Electricity	Cost of Electricity	Energy Cost/Year @ 5c/kWh	Energy Cost/Year @ 11c/kWh	Energy Savings (%)
eW Powercore LEDs	10	\$ 140.00	2	7.3	0.05	0.11	\$ 0.37	\$ 0.80	
CSL Halogen Low Level	60	\$ 80.00	2	43.8	0.05	0.11	\$ 2.19	\$ 4.82	83.3%
CSL Halogen High Level	105	\$ 80.00	2	76.7	0.05	0.11	\$ 3.83	\$ 8.43	90.5%

Payback Calculations Assumptions, Undercabinets:

Replacement lamp life @2000 hours, average cost \$5.60 for 35w T4 G8 C 120v Halogen

eW: life at 50,000 hours; MSRP of \$140

Average Eugene electricity cost: 5cents/kWh, national electricity cost: 11 cents/kWh;

New Construction Case – 2 hours/day use:

	Lamp Watts	Unit Cost	Hrs/day Use	Annual kWh	Cost of Electricity	Cost of Electricity	Energy Cost/Year @ 5c/kWh	Energy Cost/Year @ 11c/kWh	Replacement lamp costs/year	Annual Operating Costs @ 5c (elec + lamp)	Annual Operating Costs @ 11c (elec. + lamp)	LEDs Payback @ 5c/kWh	LEDs Payback @ 11c/kWh
eW Powercore LEDs	10	\$ 140	2	7.3	0.05	0.11	\$ 0.37	\$ 0.80		\$ 0.37	\$ 0.80		
CSL Halogen Low Level	60	\$ 80	2	43.8	0.05	0.11	\$ 2.19	\$ 4.82	\$ 6.12	\$ 8.31	\$ 10.94	7.6	5.9
CSL Halogen High Level	105	\$ 80	2	76.7	0.05	0.11	\$ 3.83	\$ 8.43	\$ 6.12	\$ 9.95	\$ 14.55	6.3	4.4

New Construction Case – 4 hours/day use:

	Lamp Watts	Unit Cost	Hrs/day Use	Annual kWh	Cost of Electricity	Cost of Electricity	Energy Cost/Year @ 5c/kWh	Energy Cost/Year @ 11c/kWh	Replacement lamp costs/year	Annual Operating Costs @ 5c (elec + lamp)	Annual Operating Costs @ 11c (elec. + lamp)	LEDs Payback @ 5c/kWh	LEDs Payback @ 11c/kWh
eW Powercore LEDs	10	140	4	14.6	0.05	0.11	\$ 0.73	\$ 1.61		\$ 0.73	\$ 1.61		
CSL Halogen Low Level	60	80	4	87.6	0.05	0.11	\$ 4.38	\$ 9.64	\$ 6.12	\$ 10.50	\$ 15.76	6.1	4.2
CSL Halogen High Level	105	80	4	153.3	0.05	0.11	\$ 7.67	\$ 16.86	\$ 6.12	\$ 13.79	\$ 22.98	4.6	2.8

Retrofit Case – 4 hours/day use

	Lamp Watts	Unit Cost	Hrs/day Use	Annual kWh	Cost of Electricity	Cost of Electricity	Energy Cost/Year @ 5c/kWh	Energy Cost/Year @ 11c/kWh	Replacement lamp costs/year	Annual Operating Costs @ 5c (elec + lamp)	Annual Operating Costs @ 11c (elec. + lamp)	LEDs Payback @ 5c/kWh	LEDs Payback @ 11c/kWh
eW Powercore LEDs	10	\$ 140.00	4	14.6	0.05	0.11	\$ 0.73	\$ 1.61		\$ 0.73	\$ 1.61		
CSL Halogen Low Level	60	\$ 80.00	4	87.6	0.05	0.11	\$ 4.38	\$ 9.64	\$ 6.12	\$ 10.50	\$ 15.76	14.3	9.9
CSL Halogen High Level	105	\$ 80.00	4	153.3	0.05	0.11	\$ 7.67	\$ 16.86	\$ 6.12	\$ 13.79	\$ 22.98	10.7	6.5

Appendix G

Simulations of the LR6 in Homes

Appendix G

Simulation of the LR6 in Homes

Simulation Results for Future B Homes' Home

Luminaire Schedule							
Label	Lumens	Description	LDD	LLD	BF	LLF	Watts
LR6	647	A2_B1-05	1	1	1	1	11.5

Calculation Summary									
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min	# Pts	CV
Workplane-Entire Space	Illuminance	Fc	14.76	20.09	1.76	8.39	11.41	72	0.22
Counter_Top_1	Illuminance	Fc	13.31	19.9	2.05	6.49	9.71	51	0.28
Counter_2_Top	Illuminance	Fc	9.64	13.65	2.65	3.64	5.15	18	0.33
Floor_Planar_1	Illuminance	Fc	10.64	14.3	5.4	1.97	2.65	66	N.A.

Luminaire Schedule							
Label	Lumens	Description	LDD	LLD	BF	LLF	Watts
75PAR-H-FL25-120	-1	1	0.63	1	0.63	75	

Calculation Summary									
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min	# Pts	CV
Workplane-Entire Space	Illuminance	Fc	21.17	59.71	0.7	30.24	85.3	72	0.74
Counter_Top_1	Illuminance	Fc	17.93	56.3	0.9	19.92	62.56	51	0.57
Counter_2_Top	Illuminance	Fc	11.12	32.03	1.48	7.51	21.64	18	0.75
Floor_Planar_1	Illuminance	Fc	16.33	31.2	3.6	4.54	8.67	66	N.A.

Luminaire Schedule							
Label	Lumens	Description	LDD	LLD	BF	LLF	Watts
Lightolier PAR38	1050	B7780CLW	1	1	1	1	75

Calculation Summary									
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min	# Pts	CV
Workplane-Entire Space	Illuminance	Fc	23.55	52.19	0.29	81.21	179.97	72	0.58
Counter_Top_1	Illuminance	Fc	19.78	47.65	0.26	76.08	183.27	51	0.52
Counter_2_Top	Illuminance	Fc	13.93	34.06	1.09	12.78	31.25	18	0.7
Floor_Planar_1	Illuminance	Fc	18.45	29.7	5.1	3.62	5.82	66	N.A.

Simulation Results for HBA of Lane County's Home

Luminaire Schedule							
Label	Description	Lumens	LDD	LLD	BF	LLF	Watts
LR6andLR6C	A2_B1-05	647	1	1	1	1	11.5
eW_Profile_Powercore	523-000027-01	275	1	1	1	1	10.1
Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
Kitchen Workplane	Illuminance	Fc	15.7	43.9	3.1	5.06	14.16
Living Room Workplane	Illuminance	Fc	5.29	6.3	3.9	1.36	1.62
Living Room Floor_Planar	Illuminance	Fc	4.44	5.3	2.6	1.71	2.04
Kitchen Floor_Planar	Illuminance	Fc	10.41	20.2	4.5	2.31	4.49
Counters_1_Counter Top	Illuminance	Fc	24.21	38.4	17.2	1.41	2.23

Luminaire Schedule							
Label	Description	Lumens	LDD	LLD	BF	LLF	Watts
65W R Flood Lamp		-1	1	0.625	1	0.625	0
ITL57565	LIH22	320	1	1	1	1	60
Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
Kitchen Workplane	Illuminance	Fc	14.23	54.8	1.8	7.91	30.44
Living Room Workplane	Illuminance	Fc	4.5	5.3	3.2	1.41	1.66
Living Room Floor_Planar	Illuminance	Fc	3.8	4.7	2.1	1.81	2.24
Kitchen Floor_Planar	Illuminance	Fc	8.98	20.1	3	2.99	6.7
Counters_1_Counter Top	Illuminance	Fc	25.6	52.5	15	1.71	3.5

Luminaire Schedule							
Label	Description	Lumens	LDD	LLD	BF	LLF	Watts
ITL57565	LIH22	320	1	1	1	1	60
IC2-24B-65BR30	IC2-24B-WH	725	1	1	1	1	65.4
Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
Kitchen Workplane	Illuminance	Fc	16.35	53.7	1.1	14.86	48.82
Living Room Workplane	Illuminance	Fc	6.07	7.5	4	1.52	1.88
Living Room Floor_Planar	Illuminance	Fc	5.14	6.6	2.7	1.9	2.44
Kitchen Floor_Planar	Illuminance	Fc	11.05	25.3	2.3	4.8	11
Counters_1_Counter Top	Illuminance	Fc	28.69	52.3	17.7	1.62	2.95

Luminaire Schedule							
Label	Description	Lumens	LDD	LLD	BF	LLF	Watts

ITL57565	LIH22	320	1	1	1	1	60
IC2-24W-65BR30	IC2-24W-WH	725	1	1	1	1	65
Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
Kitchen Workplane	Illuminance	Fc	18.55	54.7	1.8	10.31	30.39
Living Room Workplane	Illuminance	Fc	6.95	8.5	4.7	1.48	1.81
Living Room Floor_Planar	Illuminance	Fc	5.89	7.5	3.1	1.9	2.42
Kitchen Floor_Planar	Illuminance	Fc	12.63	27.9	3.2	3.95	8.72
Counters_1_Counter Top	Illuminance	Fc	31.23	53.4	20.7	1.51	2.58

Luminaire Schedule							
Label	Description	Lumens	LDD	LLD	BF	LLF	Watts
ITL57565	LIH22	320	1	1	1	1	60
IC2-27C-65BR30	IC2-27C-WH	725	1	1	1	1	65
Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
Kitchen Workplane	Illuminance	Fc	20.3	54.2	1.4	14.5	38.71
Living Room Workplane	Illuminance	Fc	8.39	10.8	5.7	1.47	1.89
Living Room Floor_Planar	Illuminance	Fc	7.14	9.1	3.6	1.98	2.53
Kitchen Floor_Planar	Illuminance	Fc	14.26	30.5	2.8	5.09	10.89
Counters_1_Counter Top	Illuminance	Fc	33.84	53.4	21.8	1.55	2.45

Luminaire Schedule							
Label	Description	Lumens	LDD	LLD	BF	LLF	Watts
ITL57565	LIH22	320	1	1	1	1	60
IC2-250-65BR30	IC2-250-WH	725	1	1	1	1	65.1
Calculation Summary							
Label	CalcType	Units	Avg	Max	Min	Avg/Min	Max/Min
Kitchen Workplane	Illuminance	Fc	19.21	56	2.3	8.35	24.35
Living Room Workplane	Illuminance	Fc	6.81	8.1	4.8	1.42	1.69
Living Room Floor_Planar	Illuminance	Fc	5.73	7	3.2	1.79	2.19
Kitchen Floor_Planar	Illuminance	Fc	12.87	27.3	4.3	2.99	6.35
Counters_1_Counter Top	Illuminance	Fc	31.78	54.4	21.9	1.45	2.48

