LED Linear Retrofit Solutions and Advanced Lighting Control Systems for Small Commercial Retail Applications

ET Project Number: ET13PGE8131

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Issued: June 9, 2015
ACKNOWLEDGEMENTS

Pacific Gas and Electric Company’s Emerging Technologies Program is responsible for this project. It was developed as part of Pacific Gas and Electric Company’s Emerging Technology – Technology Introduction Support program under internal project number ET13PGE8131. The California Lighting Technology Center conducted this technology evaluation for Pacific Gas and Electric Company with overall guidance and management from Jeff Beresini. For more information on this project, contact JLBd@pge.com.

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# Abbreviations and Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AGi32</td>
<td>Lighting Design Software by Lighting Analysts</td>
</tr>
<tr>
<td>ALCS</td>
<td>Advanced Lighting Control System</td>
</tr>
<tr>
<td>CALCTP</td>
<td>California Advanced Lighting Controls Training Program</td>
</tr>
<tr>
<td>DLC</td>
<td>DesignLights Consortium</td>
</tr>
<tr>
<td>IRR</td>
<td>Internal Rate of Return</td>
</tr>
<tr>
<td>L70</td>
<td>70% of initial lumen output</td>
</tr>
<tr>
<td>LCA</td>
<td>Lifecycle Cost Analysis</td>
</tr>
<tr>
<td>LED</td>
<td>Light-emitting Diode</td>
</tr>
<tr>
<td>Lm</td>
<td>Lumen</td>
</tr>
<tr>
<td>LPD</td>
<td>Lighting Power Density</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>QPL</td>
<td>Qualified Product List</td>
</tr>
<tr>
<td>SMD</td>
<td>Surface-mount Device</td>
</tr>
<tr>
<td>T8</td>
<td>Tubular linear fluorescent lamp with 1” diameter</td>
</tr>
<tr>
<td>Title 24</td>
<td>California Building Energy Efficiency Standards</td>
</tr>
<tr>
<td>W</td>
<td>Watt</td>
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EXECUTIVE SUMMARY

GOAL & OBJECTIVES
The goal of this project is to evaluate the performance of LED linear retrofit solutions combined with advanced lighting controls in small to mid-size retail businesses. The key objectives are to identify and evaluate commercial products; design and install selected systems in a retail store; assess the quantitative performance in terms of photometry, energy, economics, and assess qualitative performance through feedback from the installation team and end users.

PROJECT DESCRIPTION
Linear fluorescent lamps account for 83 percent of installed lamps in the California commercial sector per a lighting market characterization performed in 2014. LED lighting products are receiving attention for their potential to replace fluorescent lighting, reduce energy use and improve lighting quality in a variety of indoor commercial applications, including offices, classrooms and retail stores. LED alternatives to linear fluorescent lighting products fall into three main categories: linear retrofit lamp solutions, linear retrofits for troffers and dedicated luminaires. This evaluation focuses on LED linear retrofit kits paired with advanced lighting control systems (ALCS) in retail applications.

To evaluate the performance of LED linear retrofit kits paired with ALCS, the project team partnered with a local retailer, Watermelon Music located in Davis, Ca., and installed a retrofit lighting system including ALCS designed to meet IES recommended light levels for retail applications. Measurement and verification of the system was conducted to quantify its photometric performance and the energy savings of the approach. System performance comparisons were made between the fluorescent lighting system that was in place when the site was selected (referred to as 'as-is'), the ‘as-is’ system after it was re-lamped (referred to as ‘re-lamped’), the LED retrofit lighting system with no controls, and the LED retrofit combined with multiple control strategies enabled by the ALCS. Energy savings were derived from measured energy use obtained during each phase of the demonstration.

Qualitative lighting system performance feedback was collected by surveying the installation team and lighting system end users. The installation team survey focused on ease of installation for the evaluated technologies in general, as well as demonstration site-specific questions regarding the design, procurement, installation, and commissioning process. The end user survey focused on determining their level of satisfaction with the lighting system performance with respect to task plane light levels, object appearance under the lighting system, visible flicker, glare, uniformity and controllability.

RESULTS

The photometric performance of the LED linear retrofit kits combined with the ALCS fulfilled the design goals of meeting IES recommended minimum light levels, providing equivalent or higher light levels than the as-is lighting system, and adhering to Title 24 requirements for retail spaces. As an example, Table 1 provides the average horizontal and vertical light level measurements for general retail areas. The as-is and re-lamped fluorescent systems were not equipped with dimming controls. The LED system is controlled by a fully commissioned ALCS system with the following control strategies deployed: scheduling, task tuning, occupancy and daylight harvesting.

**Table 1: Average Illuminance Measurements for General Retail Areas**

<table>
<thead>
<tr>
<th>Measurement Type</th>
<th>IES Recommended Value, fc</th>
<th>T8 Fluorescent As-Is, fc</th>
<th>T8 Fluorescent Re-lamped, fc</th>
<th>LED and ALCS, fc</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_h$, At Grade, Up</td>
<td>N/A*</td>
<td>39.7</td>
<td>57.7</td>
<td>53.2</td>
</tr>
<tr>
<td>$E_v$, 3', N</td>
<td>15</td>
<td>17.5</td>
<td>21.9</td>
<td>20.4</td>
</tr>
<tr>
<td>$E_v$, 3', E</td>
<td>15</td>
<td>18.3</td>
<td>22.1</td>
<td>20.4</td>
</tr>
<tr>
<td>$E_v$, 3', S</td>
<td>15</td>
<td>17.1</td>
<td>21.1</td>
<td>19.4</td>
</tr>
<tr>
<td>$E_v$, 3', W</td>
<td>15</td>
<td>19.6</td>
<td>25.5</td>
<td>24.3</td>
</tr>
<tr>
<td>$E_v$, 5', N</td>
<td>15</td>
<td>20.5</td>
<td>25.6</td>
<td>25.6</td>
</tr>
<tr>
<td>$E_v$, 5', E</td>
<td>15</td>
<td>23.6</td>
<td>28.3</td>
<td>25.3</td>
</tr>
<tr>
<td>$E_v$, 5', S</td>
<td>15</td>
<td>19.8</td>
<td>27.7</td>
<td>22.5</td>
</tr>
<tr>
<td>$E_v$, 5', W</td>
<td>15</td>
<td>24.0</td>
<td>32.1</td>
<td>29.6</td>
</tr>
</tbody>
</table>

*IES recommended value for horizontal surfaces 2.5’ above the finished floor is 40 fc.

To determine the incremental savings of each stage of the lighting retrofit, Watermelon Music was retrofitted in multiple phases. The as-is 32 Watt, four-lamp T8 fluorescent system was re-lamped one-to-one with 32 Watt T8 fluorescent lamps to collect baseline energy use for both as-is and re-lamped lighting strategies. There was a 14.7% increase in energy use as a result of re-lamping because the as-is lighting operated with burnt-out or degraded lamps.

The re-lamped fluorescent lighting system was retrofitted with the LED linear retrofit solution. Two retrofit kit solutions were installed per fixture to fulfill the design goals. The use of the LED system with no controls resulted in a decrease of 6.9% energy use as compared to the re-lamped fluorescent lighting system.

Pairing the LED system with the fully commissioned ALCS reduced the annual energy use by an additional 25.2%. The following incremental savings are based on the assumption that each ALCS control strategy would be added to a system with the strategies above it in the table already implemented.
### Table 2: Incremental Savings of Lighting System Strategies Implemented at Watermelon Music

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Calculated Annual Energy Use (kWh)</th>
<th>Annual Savings per Strategy (kWh)</th>
<th>Incremental Savings per Strategy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T8 Fluorescent – As-Ix</td>
<td>19,207</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>T8 Fluorescent – Re-lamp</td>
<td>22,035</td>
<td>-2,828</td>
<td>-14.7%</td>
</tr>
<tr>
<td>LED – No Controls</td>
<td>20,520</td>
<td>1,515</td>
<td>6.9%</td>
</tr>
<tr>
<td>Scheduling</td>
<td>19,049</td>
<td>1,470</td>
<td>7.2%</td>
</tr>
<tr>
<td>Task Tuning</td>
<td>13,197</td>
<td>5,853</td>
<td>30.7%</td>
</tr>
<tr>
<td>Occupancy</td>
<td>15,000</td>
<td>-1,804</td>
<td>-13.7%</td>
</tr>
<tr>
<td>Daylight Harvesting</td>
<td>15,356</td>
<td>-356</td>
<td>-2.4%</td>
</tr>
</tbody>
</table>

Based on the end user feedback, the installation of the LED and ALCS control strategies of scheduling, task tuning and occupancy sensing had little to no impact on their perception of the lighting system. However, as installed, the daylight harvesting control strategy resulted in the ALCS system being manually overridden by the store owner to increase light output of the electric lighting system in order to achieve the desired light levels in the daylit area of the store. This manual override of the system resulted in an increase in energy use as compared to the LED and ALCS system with scheduling, task tuning and occupancy strategies implemented as shown in Table 2.

Design and commissioning process limitations were identified during the ALCS occupancy and daylight harvesting implementation process. Sensor location and sensitivity settings determined during the design and installation phase of the project are critical to the success of occupancy and daylight harvesting control strategies. Improper design, installation or commissioning of the system will result in lost energy savings. These are typically caused by a manual override of the ALCS system to increase the light output. Additional analysis of the energy use data logs indicate very high occupancy during store hours and significant occupancy during after store hours. This after-hours lighting energy use enabled by auto-ON occupancy sensing also contributed to the decrease in energy savings as compared to the task tuned system controlled by a time schedule only.

The store owner identified the ability to maintain and control the store’s lighting system themselves as, “Very important. We do different things in our space and need the ability to make our lighting work for us.”

The installation team followed the LED and ALCS manufacturer wiring diagrams and recommendations, and the lighting system performed as designed. No safety issues were reported. Based on their experience, the installation team unanimously recommends LED products for future end users, citing cost savings and ease of installation as two main reasons. Three of the four surveyed installers would recommend ALCS to future end users, and one installer replied that they would maybe recommend it to future end users. Of those who responded that they would recommend ALCS systems reasons cited were ease of...
operation, easy to install and energy savings, as well as the options it provides to the system owner.

Lifecycle cost analyses (LCA) were performed to determine the simple payback, incremental net present value (NPV) and internal rate of return (IRR) of the Watermelon Music demonstration retrofit. The analyses are based on the installation labor, material costs and calculated annual energy use of the lighting systems.

Simple payback is the initial investment divided by the annual savings experienced as a result of the investment, and is the number of years required to pay for the investment with the project savings. The incremental NPV is provided to determine if the retrofit lighting technology will have a positive or negative cash flow for the 15-year lifecycle analyzed. IRR estimates the growth of investment options, with the highest IRR being most likely to return ‘strong growth’. To determine the IRR, an assumed finance rate of 8% and reinvestment rate of 3% are used. An assumed inflation rate of 4% is used for LCA calculations.

Table 3: Economic Analysis for LED and ALCS Retrofit Scenarios at Watermelon Music

<table>
<thead>
<tr>
<th>Technology</th>
<th>Simple Payback</th>
<th>Incremental NPV</th>
<th>IRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T8 Fluorescent, As-Is vs. LED</td>
<td>NaN</td>
<td>-$38,619</td>
<td>-16%</td>
</tr>
<tr>
<td>T8 Fluorescent, Re-lamp vs. LED</td>
<td>71</td>
<td>-$30,038</td>
<td>-8%</td>
</tr>
<tr>
<td>LED vs. LED and ALCS</td>
<td>27</td>
<td>-$16,401</td>
<td>-2%</td>
</tr>
<tr>
<td>T8 Fluorescent, As-Is vs. LED and ALCS</td>
<td>67</td>
<td>-$55,019</td>
<td>-8%</td>
</tr>
<tr>
<td>T8 Fluorescent, Re-Lamp vs. LED and ALCS</td>
<td>37</td>
<td>-$46,438</td>
<td>-5%</td>
</tr>
</tbody>
</table>

Scenarios in Table 3 returning a simple payback of NaN (not a number) are investments that will never result in a return on the initial cost. A negative incremental net present value at the end of the 15 year evaluation cycle further supports this by requiring a negative interest rate (IRR) for the investment to break even.

Recommendations

To achieve increased demand among small- and medium-sized commercial retail applications for emerging LED and ALCS products, it is recommended that an incentive structure adhering to Total Resource Cost (TRC) requirements defined by the California Public Utilities Commission (CPUC) be developed to enable customers to implement retrofit lighting systems. It is recommended that design, installation and commissioning verification steps be systematically defined to ensure the ALCS system is performing as designed in order to optimize photometric performance and energy savings. To guarantee a successful installation it is recommended that the ALCS system be installed by a California Advanced Lighting Controls Training Program (CALCTP) certified installer.

ALCS technology limitations identified during this field demonstration support the recommendation for additional research, development and education in the design, installation and commissioning of occupancy and daylight harvesting control strategies.

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2 Internal Rate of Return. [www.investopedia.com](http://www.investopedia.com), January 2015.
Metric limitations identified during the photometric performance evaluation of this demonstration support the recommendation for the development of alternate design practices. End user feedback expressed satisfaction with the photometric performance of the as-is system, the re-lamp system and the LED light system. However, when anecdotally asked to pick their ‘favorite’ light system the store employees identified to the re-lamped system and LED light system with no controls. Table 1 provides average light levels for the re-lamped system as compared to IES recommended light levels for specialty retail applications. The average measured light level (footcandles) for vertical illuminance in general areas are 29%-53% ‘over lit’ as compared to the IES recommended light levels.
INTRODUCTION

The evaluation of an LED linear retrofit solution paired with an advanced lighting control system (ALCS) at a small retailer in Davis, California includes the measurement and verification of the LED performance and energy reduction over the baseline T8 linear fluorescent system, evaluation of the LED linear retrofit solution integration with advanced lighting control systems, measurement and verification of energy use reduction achieved with the retrofit and addition of advanced controls, and the qualitative end user feedback related to the demonstration.

Figure 1 provides the lighting plan for the small retailer selected for evaluation in this study. This site is provided by the owners of Watermelon Music in Davis, California.

Figure 1: Lighting Plan of Watermelon Music, Davis, California
BACKGROUND

Fluorescent lamps account for 80 percent of installed lamps per a national market characterization performed in 2010. LED lighting products are receiving attention for their potential to replace fluorescent lighting, reduce energy use and improve lighting quality in a variety of indoor commercial applications, including offices, classrooms and retail stores. LED alternatives to fluorescent lighting products fall into three main categories: linear replacement lamp solutions, fixture retrofit solutions and dedicated luminaires. This evaluation focuses on LED linear retrofit kits paired with advanced lighting control systems (ALCS) in retail applications.

Stand-alone lighting control technologies and strategies reduce energy use, however the largest potential energy savings are achieved through the integration of multiple stand-alone control technologies and strategies. Energy savings for lighting control strategies are dependent on factors such as space type and occupant behavior. A recent study estimates lighting control energy savings as below based on these factors.

- Daylighting Controls: 17% to 38%
- Personal Tuning: 10% to 50%
- Occupancy Controls: 8% to 38%
- Institutional Tuning: 18% to 53%
- Combined Multiple Types of Controls: 19% to 56%

Advanced lighting control systems (ALCS) enable stand-alone light sources and control technologies to work in tandem by equipping each control point (light source, sensors, switches) with a network access point. Through this network, manufacturer specific software integrates the control points to optimize lighting performance and energy use reduction of the system through strategies such as scheduling, task tuning, occupancy sensing and daylight harvesting.

LIGHT SOURCE OVERVIEW

Fluorescent and LED technologies emit light in different, distinct ways. Fluorescent lamps rely on the phosphor-coated glass tube filled with low-pressure argon gas to act as a conductive pathway for electric discharge created during the start-up process. The charge continuously vaporizes a small amount of mercury present in the tube. This vaporized mercury, or plasma, emits photons in the ultra-violet (UV) range that is converted to visible light as it encounters the phosphor coating. This method of light emission results in a diffuse source that is prevalent in form factors common in commercial and residential applications.

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LED is a solid-state technology, meaning it does not utilize a gas like fluorescent. Instead, the semi-conductor diode conducts electrons from the positive (p) to the negative (n) junction, or through the p-n junction. When the electron flows through the p-n junction the emitted energy is in the form of a photon equal to that of the energy gap created by the valence band and conduction band as shown in Figure 3. LED linear retrofit solutions incorporate multiple, directional light sources into a linear form factor through varied optical design strategies. The directional nature of LED technology often increases the intensity of the LED retrofit solution as compared to incumbent fluorescent.

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LINEAR LED PRODUCT CATEGORIES

LED alternatives to linear fluorescent lighting products fall into three main categories: linear replacement lamp solutions, fixture retrofit solutions and dedicated luminaires. Lighting product categories are defined by the DesignLights Consortium (DLC). Qualifying products based on the DLC definitions are compiled in the DLC Qualified Product List (QPL).

Emerging product categories for linear lighting retrofit solutions are divided into replacement lamp solutions and fixture retrofit solutions.

REPLACEMENT LAMP SOLUTIONS

Replacement lamp solutions contain three sub-categories of product types:

1. **Linear Replacement Lamps**: Designed to replace four-foot fluorescent lamps (T12, T8 and T5). Products in this category do not require mechanical or electrical changes to the fixture and can operate off an existing fluorescent ballast (electronic only). These lamps are also referred to as ‘Plug-n-Play’ solutions.

2. **Lamp-style Retrofit Kits, External Driver**: Designed to replace four-foot fluorescent lamps (T12, T8 and T5). Products in this category do require mechanical or electrical changes to the fixture to replace the ballast with the provided external driver. This product category uses existing lamp holders but does not operate off an existing fluorescent ballast.

3. **Lamp-style Retrofit Kits, Internal Driver**: Designed to replace four-foot fluorescent lamps (T12, T8 and T5). Products in this category do require mechanical or electrical changes to the fixture to bypass the ballast and provide line voltage directly to lamp. This solution does not operate off an existing fluorescent ballast.
**Fixture Retrofit Solutions**

Fixture retrofit solutions contain two sub-categories of product types:

4. **Integrated-Style Retrofit Kits**: Fixture retrofit kits for 2x4, 2x2 and 1x4 fixture form factors. Kits replace all reflectors and optical components of the existing fixture.

5. **Linear-Style Retrofit Kits**: Fixture retrofit kits for 2x4, 2x2 and 1x4 fixture form factors. Kits are tube- or strip-shaped and do not operate using existing lamp holders for electrical or mechanical purposes. Kits do not replace the reflector or optical components of the existing fixture.

**Building Code Changes**

Since July 1, 2014 in California, more lighting retrofit projects are considered alterations and must comply with the 2013 version of California’s Building Energy Efficiency Standards (Title 24). Under the previous regulations, lighting system alterations that replaced, removed or reinstalled more than 50% of an enclosed space’s luminaires required compliance with the standards. Since the 2013 version of Title 24 was implemented, altering just 10% of the luminaires in a building will make the project subject to Title 24 regulation.  

In most cases, replacing linear fluorescent lamps with linear LED lamps requires making modifications that are considered an alteration by Title 24 standards. In some cases, no modifications are needed to the existing luminaire housing, wiring or other components; these replacements are not considered alterations under Title 24.

Most retrofits will qualify as alterations, including those that require the ballast to be disconnected and replaced with an LED driver and those that require disconnecting the fluorescent ballast and wiring the tombstones directly to line voltage. Replacing or relocating entire luminaires may also require other lighting system upgrades to bring the system into compliance with the newest standards.

Under Title 24, Part 6, linear LED lamp installation is not recognized as converting a luminaire from linear fluorescent to LED technology, so the luminaire type will not change for Title 24 compliance purposes. The same is true for some LED retrofit kits; the rated wattage of the luminaire does not change, and the same rated (linear fluorescent) wattage still applies for lighting power allowances. As the luminaires are still classified as linear fluorescent, they must also comply with the lighting control requirements for fluorescent lighting systems.

Title 24 updates to lighting alteration requirements are expected for the 2016 code cycle. Refer to the most recent California Energy Commission (CEC) published language for updates.

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EMERGING PRODUCT

LINEAR LED RETROFIT SOLUTIONS

Replacing existing linear fluorescent lamps with linear LED retrofit solutions requires minimal new hardware, but this strategy also presents some unique installation challenges. Based on the particular product being considered, this approach typically requires changing the electrical wiring, replacing the ballast with an external driver, or altering the existing lamp holders (or “tombstones”) to accommodate the new lamp.

Tests of LED replacement lamps, retrofit solutions and dedicated luminaires show that while their performance continues to improve, limitations remain. For instance, LED replacement lamps vary greatly in their ability to dim without perceivable flicker. Linear LED retrofit solutions demonstrate a wide range of performance characteristics, making the retrofit process more complicated than a simple exchange based on the stated manufacturer specifications.

LUMINOUS OUTPUT

Additional LED replacement lamps or retrofit solutions may be needed to deliver luminous output equivalent to that of the existing fluorescent lamps. This decreases the potential energy savings of retrofitting. This additional lighting may not be required for retrofits in spaces that are over lit or those that introduce task lighting to supplement general lighting.

Lighting design best practices and guidelines published by the Illuminating Engineering Society (IES) should be used to determine if additional lamps or luminaires may be needed based on the tasks performed in the space.

SYSTEM EFFICACY

The efficacy, or the amount of light produced per watt of power consumed, is not dramatically higher for tested linear LED replacement lamps than it is for linear fluorescent lamps. Still, recent studies show that LED retrofit kits and dedicated luminaires are somewhat more efficacious.

Figure 4 shows luminaire efficacy and luminous output for a cross section of evaluated LED and linear fluorescent products. As the table indicates, tested T8 LED lamps are nearly 10% more efficacious, on average, than the tested fluorescent T8 lamps. LED troffers are 44% more efficacious than fluorescent luminaires.

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Linear LED replacement lamps incorporate multiple, directional light sources into a linear form factor through varied optical design strategies. As a result, linear LED and linear fluorescent lamps installed in the same troffer can produce different light distribution patterns, as illustrated by plots A – D in Figure 5.
Plots A, B and C depict the light distribution patterns of three different linear LED replacement lamps while figure D shows a “batwing” distribution of a fluorescent lamp. The lamps were installed in one-lamp, ceiling-mounted luminaires for testing.

Plot A indicates the light distribution of a linear LED lamp with a diffuser, plot B corresponds to a lamp with 32 high-intensity LEDs, and plot C to a lamp with a total of 360 surface-mount device (SMD) LEDs.

The distribution characteristics of LED lamps can increase brightness (and glare) to an uncomfortable degree as compared to linear fluorescent lamps. Installing a luminaire reflector and optical lens optimized for the LED replacement lamp’s distribution can achieve a "batwing" fluorescent distribution pattern and improve uniformity.

**OPTICS AND DESIGN**

Retrofit kits and fixture replacements can provide better light distribution than linear LED replacement lamps because they are able to better integrate the LED source(s) with the structure of the troffer and optical elements. The lensing for most current troffers consists of diffuser surfaces with linear details, frosted diffusers or parabolic louvers. Older, prismatic lenses may not pair well with linear LED lamps and can produce distracting patterns.

FIGURE 6: TYPICAL LENSES USED IN LINEAR FLUORESCENT AND LED APPLICATIONS

LIFETIME AND COST COMPARISON

Long product lifetime is an advantage of LED-based lighting technologies. An industry metric for specifying length of dependable service for LED lamps is “lumen maintenance.” Current methods for measuring and projecting the lumen maintenance of LED light sources are outlined in IES LM-80 and IES TM-21, respectively. IES LM-84 and IES TM-28 address useful lamp life and incorporate system factors such as thermal management.

Traditional lamps are typically measured in hours to lamp failure, but because LEDs last longer than traditional light sources and depreciate more slowly, their useful life is measured in the hours they can maintain at least 70% of their initial lumen output. This is known as “L70.” The DLC requirement for the useful life of tubular LEDs is an L70 equal to or greater than 50,000 hours, or a practical lifespan of roughly 16 years.\(^\text{11}\) This is about twice the life of the average fluorescent tube, although some long-life fluorescent lamps now offer comparable lifetimes.

A long lifespan is a critical factor when calculating the cost-effectiveness of LED replacement lamps. Current prices for linear LED replacement lamps vary considerably, from $30 to over $100 per lamp, while fluorescent tubes cost $2 to $10 per lamp.

\(^{11}\) Product life based on 12 hours of operation per day, 255 days per year.
INSTALLATION CHALLENGES

Replacing existing linear fluorescent lamps with linear LED retrofit solutions requires minimal new hardware, but this strategy also presents some unique installation challenges. Fluorescent lamps are supplied electricity through a ballast that regulates electrical current to the lamps and supplies sufficient starting voltage for them. LED technology uses an electronic driver to provide the proper voltage and current for LED operation. For this reason, new electrical or mechanical components and rewiring are often necessary to make the existing fixture compatible with the new lamps. The electrical incompatibilities between linear fluorescent and linear LED retrofit solutions constitute the most important safety issue facing retrofit LED technology.

The majority of LED replacement lamps with internal or integrated drivers require line voltage be supplied directly to the lamp holders, bypassing the fluorescent ballast. Internal driver LED lamps may be either single- or double-ended, with power running to one or both ends, respectively.

Linear LED replacement lamps, or ‘Plug-n-Play Lamps’, incorporate a driver into the lamp. This allows the LED replacement lamp to utilize existing fluorescent ballasts with no additional rewiring required. With these products, the LED replacement lamp bi-pins connect directly to the existing G13 lamp holders (or “tombstones”). The thermal performance of the technology must be evaluated while installed in-situ to ensure lamp life will not be compromised with the driver components exposed to temperatures potentially outside manufacturer rating and/or operating recommendations. The thermal management section of this report provides more detail.

Lamp-style retrofit kits with external or remote drivers differ still, and require their driver be connected to either the existing tombstone, or directly to the lamp, while using the tombstone merely for stability.

Another electrical wiring point of interest is whether the lamp holder is shunted for instant start fluorescent ballasts or un-shunted for rapid start ballasts. Generally, lamp-style retrofits that receive electricity through the lamp holder require un-shunted lamp-holders to operate as intended by the manufacturer. To ensure operation over the lifetime of the LED product, it is recommended that new lamp holders be sold and installed as part of the retrofit kit.

Fixture retrofit solutions typically provide the required mechanical and/or electrical components needed as part of the product. Manufacturer recommendations should be followed to ensure safe operation.
All these factors concerning electrical architecture increase the complexity of the retrofit process and raise safety concerns. The fact that many LED replacement lamps connect through the bi-pin tombstone can create confusion for future maintenance workers who might attempt to replace lamps with an incorrect linear LED retrofit solution, or a traditional fluorescent lamp.

Installing a fluorescent lamp into a retrofitted lamp holder with unregulated line voltage modifications introduces a potential hazard for the installation team.

Proper documentation and labeling of LED retrofit solution is crucial to avoid such hazards and protect the safety of maintenance staff and end users after retrofitting. Manufacturers require this step in the installation of a retrofit system.

**THERMAL MANAGEMENT**

The ability of an LED retrofit solution to manage heat affects its performance, longevity and safety. The form factor of the linear tube lamp presents certain constraints on thermal management. Innovative lamp manufacturers employ a number of solutions for thermal management, including improved drivers, forced convection methods, improved heat sink designs, and advanced materials.

To select suitable LED retrofit solutions for existing troffers, facility personnel should consider the solutions’ thermal performance in that specific troffer, with careful attention paid to how the lamp is built to manage heat.

Dedicated LED luminaires and integrated-style retrofit kits utilize the fixture housing to provide thermal management for the LEDs. Similarly, LED linear-style retrofit kits utilize the optical reflector and mechanical elements as thermal conductors. Although some linear replacement lamp products successfully manage the heat generated by LEDs, the inherent differences in these mechanical architectures place the dedicated luminaire and the retrofit kits at an advantage when it comes to thermal management.
Current methods for measuring and projecting the lumen maintenance of LED light sources are outlined in *IES LM-80* and *IES TM-21*, respectively. This approach is specifically focused on the LED component and does not include in-situ thermal considerations for other system components. *IES LM-84* and *IES TM-28* address useful system life and incorporates system factors such as thermal management. It is recommended that these test reports be referenced when evaluating products for installation.

**Advanced Lighting Control Systems**

Advanced lighting control systems (ALCS) enable stand-alone light sources and control technologies to work in tandem by equipping each control point (light source, sensors, switches) with a network access point. Through this network, manufacturer specific software integrates the control points to optimize lighting performance and energy use reduction of the system through strategies such as scheduling, task tuning, occupancy sensing and daylight harvesting.

**Assessment Objective**

The objective of evaluating LED replacement lamps paired with advanced lighting controls at a small retailer in Davis, California is to verify the energy use reduction over the baseline T8 linear fluorescent system, evaluate the LED integration with advanced lighting control systems, verify the energy use reduction achieved by using advanced controls, and collect the qualitative end user feedback related to the demonstration.

**Technology Selection**

The retrofit lighting system was selected based on reviewing commercially available LED Linear Retrofit options, advanced lighting control systems and directional LED lamps. To identify light source products that meet existing utility requirements, the qualified product list (QPL) maintained by the DesignLights Consortium (DLC) was used to limit the search field.

QPL products must meet a number of stringent criteria, including benchmarks for light output (lumens), efficacy (lumens per watt), correlated color temperature (CCT), color rendering index (CRI), power factor, total harmonic distortion (THD), warranty, and safety certification. To qualify for inclusion on the QPL, tubular LED lamps must have documented safety certification, system efficacy of at least 100 lm/W, lumen maintenance (L70) of greater than or equal to 50,000 hours, and a five-year warranty.

At the time of the lighting design, the DLC categorized all tube-style LED products as “linear replacement lamps,” even if safety organizations classify them as retrofit kits. This was due to the common need to perform electrical or mechanical alterations to existing luminaires for proper installation. Only fully-integrated “insert-style” kits were eligible under the DLC’s retrofit kit categories. Currently, DLC is considering proposed categories as described in the Background section of this report.
Products identified as high-performing were evaluated for appropriateness in the demonstration site for replacing the 32 Watt, four-lamp T8 fluorescent system, CFL downlights and halogen track lighting. The retrofit lighting system for the selected demonstration site was designed with lighting design software (AGi32) utilizing the recommended practices from the Illuminating Engineering Society’s *The Lighting Handbook, Tenth Edition*. The *Lighting for Retail Applications* chapter was referenced to identify target applications and tasks for specialty retailers with specific lighting requirements. Illuminance (E) values in foot-candles are provided for horizontal (h) and vertical (v) surfaces at the specified height above finished floor (AFF) in Table 4.

<table>
<thead>
<tr>
<th>Task</th>
<th>(E_h )@floor</th>
<th>(E_h) at 2.5’ AFF</th>
<th>(E_h) at Task Plane</th>
<th>(E_v) @ 5’ AFF</th>
<th>(E_v) @ 3’ AFF</th>
<th>(E_v) @ 5’ AFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>-</td>
<td>40</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Circulation</td>
<td>15</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sales Counter</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

In order to maintain existing light levels per the store owner’s request, initial light level measurements were used with the Table 1 values to finalize the lighting design. Current Title 24 requirements were referenced during the design process, using the provided allowable power densities for the demonstration space type in Table 140.6\textsuperscript{12}.

The Cree UR product was selected for evaluation. Two Cree UR kits were installed per fixture to achieve lighting design requirements. The Cree UR product does not utilize existing lamp holders, but instead is energized with direct wiring from the driver as shown in Figure 8. Under the emerging categories, this product is classified as a Linear-Style Retrofit Kit. LED solutions were also selected for the downlight and track lighting applications. Details are provided in Table 5.

Advanced lighting control systems were evaluated for use in the demonstration by reviewing product literature of commercialized systems. Mandatory requirements for the system included the ability to continuously dim the lighting based on the following inputs: store and holiday schedule, task tuning, occupancy/vacancy and daylighting.

Table 5 contains the retrofit lighting system specification. Detailed specifications for all products are provided in Appendix 1.

<table>
<thead>
<tr>
<th>Manufacturer/Type</th>
<th>Model</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cree Downlight</td>
<td>CR6-800L-27K-12-E26</td>
<td>3</td>
</tr>
<tr>
<td>Cree 2’ LED Kit</td>
<td>UR2-24-36L-40K-10V-FD</td>
<td>6</td>
</tr>
<tr>
<td>Cree 4’ LED Kit</td>
<td>UR2-48-45L-40K-10V-FD</td>
<td>82</td>
</tr>
<tr>
<td>Cree A-Lamp</td>
<td>BA19-08027OMF-12DE26-2U100</td>
<td>9</td>
</tr>
<tr>
<td>Sylvania PAR-30 Lamp</td>
<td>LED15PAR30/DIM/P/930/FL40</td>
<td>37</td>
</tr>
<tr>
<td>Soraa MR-16 Lamp</td>
<td>MR16 MR16-50-B01-12-830-25-95</td>
<td>4</td>
</tr>
<tr>
<td>Encelium</td>
<td>Advanced Lighting Control System</td>
<td>-</td>
</tr>
</tbody>
</table>
Based on the demonstration site space and use type, the allowable lighting power density (LPD) as defined by Title 24 is 1.5 Watts per square foot. The selected technologies result in an LPD of 1.29, or a 14% reduced load from the Title 24 baseline. The ALCS system provides the required controls based on Title 24 for retail spaces.¹³

**TEST METHODOLOGY**

The test methodology includes the test plan and instrumentation required to characterize the demonstration site for both pre- and post-retrofit lighting systems. The photometric characterization, energy use characterization and qualitative feedback from the installation team and end users of the lighting systems are provided in the results section of this report.

**INSTALLATION AND COMMISSIONING**

The installation and commissioning process is to be observed and documented to evaluate the implementation of LED products and ALCS systems process. Observation of the installation and commissioning processes is augmented with the survey of the installation team. Survey questions are provided in Appendix 2.

**PHOTOMETRIC CHARACTERIZATION**

The photometric performance of the pre- and post-retrofit lighting systems are characterized utilizing the recommended practices from the Illuminating Engineering Society’s *The Lighting Handbook, Tenth Edition* as a guideline. The *Lighting for Retail Applications* chapter was referenced to identify target applications and tasks for Specialty Retailers with specific lighting requirements.

Illuminance data and luminance mapping was collected for circulation areas, sales counters, and general retail applications. The data is compared to recommended retail illuminance target values in *The Lighting Handbook* and luminance uniformity goals to evaluate the photometric performance of the installed system.

Instrumentation used to gather illuminance data and luminance mapping is provided in Table 6.

<table>
<thead>
<tr>
<th>TABLE 6: PHOTOMETRIC CHARACTERIZATION INSTRUMENTATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
</tr>
</tbody>
</table>

ENERGY USE CHARACTERIZATION

The Advanced Lighting Control System (ALCS) Measurement and Verification Guidelines (Appendix 3) document provided by PG&E was used to develop a best-practice methodology for the energy use monitoring portion of this demonstration. The specified energy-use monitoring system allows for determination of the energy use reduction attributed to the baseline scenario and each control strategy implemented by the ALCS.

The pre-retrofit lighting system installed at the site was re-lamped to eliminate lamp degradation as a variable in the energy use analysis. The new lamps were “burnt-in” for 100 hours without switching before the demonstration site returned to typical use of the system, allowing for the lamps to stabilize and defective lamps to be replaced. The baseline energy use monitoring of the re-lamped system was monitored for no less than two weeks, or 14 days, in duration.

After the installation of the tubular LED lamps and ALCS, each of the following control strategies were monitored in periods no less than 14 days in duration.

1. **Strategy 1:** Scheduled, Full Output: Lighting system operating per the customer’s operating schedule at full light output.
2. **Strategy 2:** Scheduled + Tuned: Lighting system operating per the customer’s operating schedule at the desired task-tuned light level.
3. **Strategy 3:** Scheduled + Tuned + Occupancy Control: Lighting system operating per the customer’s operating schedule at the desired task-tuned light level with occupancy sensor control enabled.
4. **Strategy 4:** Scheduled + Tuned + Occupancy Control + Daylight Control: Lighting system operating per the customer’s operating schedule at the desired task-tuned light level with occupancy sensor control and daylight control enabled.

Continuous energy use data for each monitoring period was collected at a logging interval of one minute.
SITE ASSESSMENT

An initial assessment of the selected site was conducted to gather as-built electrical design details, including the tracing and confirmation of the lighting circuitry. Figure 9 provides the lighting plan for the small retailer selected for evaluation in this study. This site is provided by the owners of Watermelon Music in Davis, California.

Circuit tracing identified circuits with loads outside the monitoring zone, and allowed for the lighting load of the first floor to be separated from the lighting load of the second floor which was not retrofitted. Figure 10 shows the electrical panels containing the lighting circuits selected for retrofit. Figure 11 depicts which lighting loads correspond to each circuit.
Figure 10: Electrical panel A and B at Watermelon Music
The lighting loads selected for retrofit at Watermelon Music are described in Table 7 and Figure 11.

**TABLE 7: ELECTRICAL PANEL LABELS AND TRACED LIGHTING LOADS**

<table>
<thead>
<tr>
<th>Panel and Circuit Label</th>
<th>Zone Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>3A</td>
<td>Restrooms</td>
</tr>
<tr>
<td>7A</td>
<td>Entryway/Cashier</td>
</tr>
<tr>
<td>9A</td>
<td>Front Door – Track Lighting</td>
</tr>
<tr>
<td>13A</td>
<td>Store Floor – Ambient Lighting</td>
</tr>
<tr>
<td>15A</td>
<td>Store Floor – Ambient Lighting</td>
</tr>
<tr>
<td>17A</td>
<td>Store Floor – Track Lighting</td>
</tr>
<tr>
<td>19A</td>
<td>Store Floor – Track Lighting</td>
</tr>
<tr>
<td>23A</td>
<td>Store Floor – Track Lighting</td>
</tr>
<tr>
<td>25A</td>
<td>Front Window Lighting</td>
</tr>
<tr>
<td>1B</td>
<td>Store Floor – Ambient Lighting</td>
</tr>
<tr>
<td>11B</td>
<td>Secondary Space</td>
</tr>
</tbody>
</table>

**FIGURE 11: LIGHTING LOADS BY CIRCUIT AT WATERMELON MUSIC**
MEASUREMENT AND VERIFICATION INSTRUMENTATION

Revenue grade metering equipment was selected as appropriate for installation at the project site. The accuracy of revenue grade metering equipment meets the accuracy requirements of the ANSI C12.1 standard when used with Continental Control System current transformers rated for IEEE C57.13 class 0.6 accuracy. Table 8 lists the equipment used at the Watermelon Music demonstration site.

Specifications with wiring diagrams are provided in Appendix 4.

**TABLE 8: INSTALLED MONITORING EQUIPMENT**

<table>
<thead>
<tr>
<th>Monitoring Equipment Type</th>
<th>Model</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC Power Measurement Device</td>
<td>WattNode RWNB-3Y-208-P</td>
<td>8</td>
</tr>
<tr>
<td>Current Transformers</td>
<td>CCS CTL-1250</td>
<td>21</td>
</tr>
<tr>
<td>Data Logger</td>
<td>HOBO UX120-017M</td>
<td>7</td>
</tr>
</tbody>
</table>

Measurement and verification equipment was installed at Watermelon Music on May 29, 2014. The equipment was configured to collect lighting energy use data in one minute intervals, as shown in Figures 12 and 13.

**FIGURE 12: INSTALLATION SCHEMATIC OF ENERGY LOGGING EQUIPMENT**
QUALITATIVE FEEDBACK

A survey was developed and deployed to capture the installation team and end user feedback with respect to the new lighting system. The installation team was surveyed during the retrofit process, and the end users were surveyed after the system was fully deployed and they had experienced the full set of features evaluated in this study. A sample of the survey given is included in Appendix 2.
RESULTS

Results of the installation, commissioning, photometric characterization, energy use characterization and qualitative feedback are provided in this section.

INSTALLATION PROCESS

Prior to the installation of the LED and advanced lighting control system, the design team and installation team reviewed all product specification sheets and wiring diagrams (Appendix 1) to ensure the system would perform as designed.

The installation team retrofitted each existing light fixture with application appropriate LED products and the ALCS control unit from Encelium. Lighting circuitry was updated to allow for the most effective energy monitoring per retrofit lighting zones shown in Figure 14.

The installation of the LED and ALCS system required five days, working nights only, to accommodate the demonstration site so they could remain open for business.
Figure 15: Installation of LED and ALCS Products

Figure 16: Installation of LED Downlight and Track Lighting Products
The installation team installed the occupancy and daylight harvesting sensors per the design documents provided by the ALCS manufacturer.

![ALCS Sensor Layout - Occupancy and Daylight Harvesting](image)

**FIGURE 17: ALCS SENSOR LAYOUT – OCCUPANCY AND DAYLIGHT HARVESTING**

The installation team followed the LED and ALCS manufacturer wiring diagrams and recommendations, and the lighting system performed as designed. No safety issues were reported.

![Watermelon Music with LED Lighting System at Full Output](image)

**FIGURE 18: WATERMELON MUSIC WITH LED LIGHTING SYSTEM AT FULL OUTPUT**
COMMISSIONING PROCESS

After the installation team completed retrofitting the demonstration site, a commissioning agent from the ALCS manufacturer (Encelium) commissioned the system to operate using their standard ‘Start-Up’ process. Start-up documents created by the lighting designer/customer are provided in Appendix 5.

During the Start-Up process, the Encelium system is programmed with controller IDs and locations to allow for dynamic control changes to be made by the store owner in the future. The Encelium field technician provided a system tutorial to the system owner and the CLTC project team to allow for system changes to be made in the future as needed.

Control Strategy 1 was implemented by the Encelium field technician after the Start-Up process. Strategies 2, 3 and 4 were commissioned by CLTC staff with technical support from Encelium as needed. Descriptions of the control strategies are provided in the ‘Energy Use Characterization’ section of this report.

To implement strategy 2, CLTC staff and the store owner identified the minimum acceptable light levels for the first floor by dimming each lighting zone to IES recommended light levels. When store owner identified areas being ‘too dim’, light levels were increased until light levels were satisfactory. After all zones were dimmed to the identified light level, the whole store was commissioned.

To implement strategy 3, Encelium remotely commissioned the system to incorporate the occupancy sensor inputs to lower light levels during periods of vacancy. Additionally, lights will now turn on to the task tuned level when occupancy is detected during unscheduled periods of time increasing safety and functionality of the space.

To implement strategy 4, Encelium remotely activated the daylight sensor input to lower the electrical light contribution in zones where the daylight contribution allowed for the task tuned light levels to be achieved.
Figure 19: Watermelon Music General Area - Fully Commissioned

Figure 20: Watermelon Music Entry/Daylight Area - Fully Commissioned
PHOTOMETRIC CHARACTERIZATION

Pre- and post-retrofit illuminance data and luminance mapping is provided for circulation areas, feature displays and general retail. Appendix 6 contains complete illuminance and luminance measurement data.

ILLUMINANCE MEASUREMENTS

Illuminance data is provided for points of measurement (shown in red in Figure 22) in the general retail, sales counter and circulation areas. Pre-retrofit data includes illuminance measurements for as-is store conditions and re-lamped store conditions. Post-retrofit illuminance data was collected for the fully commissioned LED system and ALCS system. All measurements were taken after dark.
Measurement location (general retail, sales counter, and circulation) refers to the space use at the time of measurement, however due to the dynamic nature of the product displays and circulation areas it is assumed that all areas of the store will be used for multiple purposes over the lifetime of the lighting system. Over the course of the project, feature displays, for example, were moved on the store sales floor. Illuminance measurement type (E) includes information designating the measurement plane (h, horizontal; v, vertical), distance above finished floor and direction of illuminance sensor (North [N], East [E], West [W], and South [S]).

### Table 9: Average Illuminance Measurements for General Retail Areas

<table>
<thead>
<tr>
<th>Measurement Type</th>
<th>Recommended Value, fc</th>
<th>Pre-Retrofit As-Is, fc</th>
<th>Pre-Retrofit Re-lamped, fc</th>
<th>Post Retrofit, fc</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{v}$ At Grade, Up</td>
<td>-</td>
<td>39.7</td>
<td>57.7</td>
<td>53.2</td>
</tr>
<tr>
<td>$E_{v}$ 3', N</td>
<td>15</td>
<td>17.5</td>
<td>21.9</td>
<td>20.4</td>
</tr>
<tr>
<td>$E_{v}$ 3', E</td>
<td>15</td>
<td>18.3</td>
<td>22.1</td>
<td>20.4</td>
</tr>
<tr>
<td>$E_{v}$ 3', S</td>
<td>15</td>
<td>17.1</td>
<td>21.1</td>
<td>19.4</td>
</tr>
<tr>
<td>$E_{v}$ 3', W</td>
<td>15</td>
<td>19.6</td>
<td>25.5</td>
<td>24.3</td>
</tr>
<tr>
<td>$E_{v}$ 5', N</td>
<td>15</td>
<td>20.5</td>
<td>25.6</td>
<td>25.6</td>
</tr>
<tr>
<td>$E_{v}$ 5', E</td>
<td>15</td>
<td>23.6</td>
<td>28.3</td>
<td>25.3</td>
</tr>
<tr>
<td>$E_{v}$ 5', S</td>
<td>15</td>
<td>19.8</td>
<td>27.7</td>
<td>22.5</td>
</tr>
</tbody>
</table>
### TABLE 10: AVERAGE ILLUMINANCE MEASUREMENTS FOR CIRCULATION AREAS

<table>
<thead>
<tr>
<th>Measurement Type</th>
<th>Recommended Value, fc</th>
<th>Pre-Retrofit As-Is, fc</th>
<th>Pre-Retrofit Relamped, fc</th>
<th>Post Retrofit, fc</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{\text{h}}$, At Grade, Up</td>
<td>15</td>
<td>41.3</td>
<td>52.3</td>
<td>46.0</td>
</tr>
<tr>
<td>$E_{\text{v}}$, 3', N</td>
<td>-</td>
<td>22.4</td>
<td>28.6</td>
<td>23.2</td>
</tr>
<tr>
<td>$E_{\text{v}}$, 3', E</td>
<td>-</td>
<td>20.0</td>
<td>25.4</td>
<td>19.2</td>
</tr>
<tr>
<td>$E_{\text{v}}$, 3', S</td>
<td>-</td>
<td>10.4</td>
<td>13.9</td>
<td>9.5</td>
</tr>
<tr>
<td>$E_{\text{v}}$, 3', W</td>
<td>-</td>
<td>14.8</td>
<td>18.8</td>
<td>15.7</td>
</tr>
<tr>
<td>$E_{\text{v}}$, 5', N</td>
<td>5</td>
<td>28.1</td>
<td>36.7</td>
<td>29.8</td>
</tr>
<tr>
<td>$E_{\text{v}}$, 5', E</td>
<td>5</td>
<td>25.6</td>
<td>31.8</td>
<td>21.8</td>
</tr>
<tr>
<td>$E_{\text{v}}$, 5', S</td>
<td>5</td>
<td>13.8</td>
<td>16.3</td>
<td>11.3</td>
</tr>
<tr>
<td>$E_{\text{v}}$, 5', W</td>
<td>5</td>
<td>16.7</td>
<td>24.5</td>
<td>18.9</td>
</tr>
</tbody>
</table>

### TABLE 11: AVERAGE ILLUMINANCE MEASUREMENTS FOR SALES COUNTER AREA

<table>
<thead>
<tr>
<th>Measurement Type</th>
<th>Recommended Value, fc</th>
<th>Pre-Retrofit As-Is, fc</th>
<th>Pre-Retrofit Relamped, fc</th>
<th>Post Retrofit, fc</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{\text{h}}$, At Grade, Up</td>
<td>30</td>
<td>58.1</td>
<td>67.5</td>
<td>66.3</td>
</tr>
</tbody>
</table>
**Luminance Measurements**

Luminance mapping and luminance ratio calculations (luminaire-adjacent compared to luminaire) are provided for points of measurement shown in red in Figure 23. Pre-retrofit data includes luminance mapping for as-is store conditions and re-lamped store conditions with luminance. Post-retrofit luminance mapping is collected for the fully commissioned LED system and ALCS system. All luminance mapping photos were taken after dark.
The summary of the pre- and post-retrofit luminance ratios for luminaire-adjacent surfaces to the luminaire are provided in Table 12. The IES recommended maximum luminance ratio for maintaining visual comfort is provided for comparison.
### Table 12: Watermelon Music Luminance Ratios

<table>
<thead>
<tr>
<th>Measurement Location</th>
<th>Recommended Max Luminance Ratio(^{14}), (1:__)</th>
<th>Pre-Retrofit, As-Is (1:__)</th>
<th>Pre-Retrofit Re-lamp, (1:__)</th>
<th>Post-Retrofit, (1:__)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – General Retail</td>
<td>20</td>
<td>84</td>
<td>65</td>
<td>56</td>
</tr>
<tr>
<td>2 – Display Area</td>
<td>20</td>
<td>153</td>
<td>78</td>
<td>137</td>
</tr>
<tr>
<td>3 – General Retail</td>
<td>20</td>
<td>459</td>
<td>800</td>
<td>74</td>
</tr>
<tr>
<td>4 – Display Area</td>
<td>20</td>
<td>80</td>
<td>88</td>
<td>63</td>
</tr>
<tr>
<td>5 – General Retail</td>
<td>20</td>
<td>79</td>
<td>111</td>
<td>57</td>
</tr>
<tr>
<td>6 – General Retail</td>
<td>20</td>
<td>92</td>
<td>119</td>
<td>95</td>
</tr>
<tr>
<td>7 – General Retail</td>
<td>20</td>
<td>133</td>
<td>144</td>
<td>156</td>
</tr>
<tr>
<td>8 – Display Area</td>
<td>20</td>
<td>319</td>
<td>609</td>
<td>671</td>
</tr>
<tr>
<td>9 – Display Area</td>
<td>20</td>
<td>608</td>
<td>522</td>
<td>735</td>
</tr>
<tr>
<td>10 – Display Area</td>
<td>20</td>
<td>312</td>
<td>264</td>
<td>359</td>
</tr>
<tr>
<td>11 – General Retail</td>
<td>20</td>
<td>75</td>
<td>124</td>
<td>151</td>
</tr>
</tbody>
</table>

For measurement location 1, luminance mapping images and calculations are provided for pre-retrofit as-is, pre-retrofit re-lamped and post-retrofit scenarios. Luminance mapping for all locations is provided in Appendix 6.

\(^{14}\) Table 12.5. IES Handbook, 10\(^{th}\) Edition.
PRE-RETROFIT, AS-IS

FIGURE 25: LOCATION 1, LUMINAIRE-ADJACENT LUMINANCE MAPPING FOR PRE-RETROFIT AS-IS

FIGURE 26: LOCATION 1, LUMINAIRE LUMINANCE MAPPING FOR PRE-RETROFIT AS-IS
PRE-RETROFIT, RE-LAMPED

FIGURE 27: LOCATION 1, LUMINAIRE-ADJACENT LUMINANCE MAPPING FOR PRE-RETROFIT RE-LAMPED

FIGURE 28: LOCATION 1, LUMINAIRE LUMINANCE MAPPING FOR PRE-RETROFIT RE-LAMPED
POST-Retrofit LED, FULLY COMMISSIONED

**Figure 29:** Location 1, Luminaire-Adjacent Luminance Mapping for Post-Retrofit

**Figure 30:** Location 1, Luminaire Luminance Mapping for Post-Retrofit
ENERGY USE CHARACTERIZATION

Monitored energy-use results are provided in Table 13 by source type (T8 fluorescent, LED) and advanced lighting control strategy (Scheduling, Task Tuning, Occupancy, Daylight Harvesting). The calculated annual energy use assumes average daily energy use derived from the monitored energy use is applicable to each day the store is open for a year of operation. The store is open 360 days per year and closed for 5 holidays a year (New Year’s Day, Fourth of July, Labor Day, Thanksgiving, Christmas Day).

**Table 13: Energy Use Monitoring Summary**

<table>
<thead>
<tr>
<th>Lighting Strategy</th>
<th>Monitoring Period</th>
<th>Number of Days</th>
<th>Total Energy Use (kWh)</th>
<th>Average Daily Energy Use (kWh)</th>
<th>Calculated Annual Energy Use (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T8 Fluorescent - As-Is</td>
<td>5/29/14 to 7/14/14</td>
<td>46</td>
<td>2,454.2</td>
<td>53.4</td>
<td>19,207</td>
</tr>
<tr>
<td>T8 Fluorescent - Re-lamp</td>
<td>7/22/14 to 11/3/14</td>
<td>104</td>
<td>6,365.7</td>
<td>61.2</td>
<td>22,035</td>
</tr>
<tr>
<td>LED No Controls</td>
<td>11/8/14 to 11/16/14</td>
<td>9</td>
<td>513.0</td>
<td>57.0</td>
<td>20,520</td>
</tr>
<tr>
<td>LED with Scheduling</td>
<td>11/18/14 to 12/3/14</td>
<td>16</td>
<td>846.6</td>
<td>52.9</td>
<td>19,049</td>
</tr>
<tr>
<td>LED with Scheduling and Task Tuning</td>
<td>12/5/14 to 1/4/14</td>
<td>29</td>
<td>1,063.1</td>
<td>36.7</td>
<td>13,197</td>
</tr>
<tr>
<td>LED with Scheduling, Task Tuning and Occupancy</td>
<td>1/6/2015 to 2/5/2015</td>
<td>31</td>
<td>1,291.7</td>
<td>41.7</td>
<td>0</td>
</tr>
<tr>
<td>LED with Scheduling, Task Tuning, Occupancy and Daylight Harvesting</td>
<td>2/6/2015 to 2/23/2015</td>
<td>17</td>
<td>725.2</td>
<td>42.7</td>
<td>15,356</td>
</tr>
</tbody>
</table>
Based on the calculated annual energy use for each strategy in Table 13, the incremental savings for each control strategy compared to the previous strategy are provided in Table 14. The fully commissioned ALCS saves 25.2% over the LED lighting system with no controls. Load profiles for each baseline and ALCS control scenario are provided in the following sections.

**Table 14: Incremental Savings per Lighting Strategy**

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Calculated Annual Energy Use (kWh)</th>
<th>Annual Savings per Strategy (kWh)</th>
<th>Incremental Savings per Strategy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T8 Fluorescent – As-Is</td>
<td>19,207</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>T8 Fluorescent – Re-lamp</td>
<td>22,035</td>
<td>-2,828</td>
<td>-14.7%</td>
</tr>
<tr>
<td>LED – No Controls</td>
<td>20,520</td>
<td>1,515</td>
<td>6.9%</td>
</tr>
<tr>
<td>Scheduling</td>
<td>19,049</td>
<td>1,470</td>
<td>7.2%</td>
</tr>
<tr>
<td>Task Tuning</td>
<td>13,197</td>
<td>5,853</td>
<td>30.7%</td>
</tr>
<tr>
<td>Occupancy</td>
<td>15,000</td>
<td>-1,804</td>
<td>-13.7%</td>
</tr>
<tr>
<td>Daylight Harvesting</td>
<td>15,356</td>
<td>-356</td>
<td>-2.4%</td>
</tr>
</tbody>
</table>
**Baseline Energy Use**

The load profile and energy use for as-is fluorescent, re-lamped fluorescent and LED baseline scenarios are included in this section.

**Linear Fluorescent – As Is**

Over the duration of May 29, 2014 to July 14, 2014, the lighting system used 2,454 kWh of energy. The store was closed on July 4, 2014. This day is omitted in the calculations to determine the annual energy use of this system. The average daily energy use is 53.4 kWh. Based on the store being open 360 days per year, this results in a calculated annual energy use of 19,207 kWh.

![T8 Fluorescent As-Is - Baseline](image-url)

**Figure 31: Fluorescent As-Is Baseline Load Profile**
The lighting system was re-lamped on July 15, 2014 and new lamps operated continuously for 100 hours to stabilize. After this ‘burn-in’ period, energy use was monitored between July 22, 2014 and November 3, 2014 the system used 6,367 kWh of energy. The store was closed on September 1, 2014. This day is omitted in the calculations to determine the annual energy use of this system. The average daily energy use is 61.2 kWh. Based on the store being open 360 days per year, this results in a calculated annual energy use of 22,035 kWh.

**Figure 32: Fluorescent Re-lamped Baseline Load Profile**
LED WITH NO CONTROLS

The LED lighting system was installed between November 3, 2014 and November 7, 2014. Between November 8, 2014 and November 16, 2014, the lighting system used 513 kWh of energy. This is equivalent to an average of 57 kWh per day. Based on the store being open 360 days per year, this results in a calculated annual energy use of 20,520 kWh.

**FIGURE 33: LED WITH NO CONTROLS BASELINE LOAD PROFILE**
ADVANCED LIGHTING CONTROLS

The load profile and energy consumption for the post-retrofit lighting system per ALCS control strategy is included in this section.

SCHEDULING

The scheduling feature in the ALCS was deployed on November 17, 2014. Between November 18, 2014 and December 3, 2014, the lighting system used 846.6 kWh of energy. This is equivalent to 52.9 kWh per day on average. Based on the store being open 360 days per year, this results in a calculated annual energy use of 19,049 kWh.
SCHEDULING AND TASK TUNING

The task tuning feature in the ALCS was added to the existing control strategy on December 4, 2014. Between December 5, 2014 and January 4, 2014, the lighting system used 1,063 kWh of energy. The store was closed for two holidays (December 25, January 1) during this period. After removing these days, the average daily use was 36.7 kWh. Based on the store being open 360 days per year, this results in a calculated annual energy use of 13,197 kWh.

**Figure 35: LED Load with ALCS Control - Scheduling and Task Tuning**
The occupancy sensing feature in the ALCS was added to the existing control strategies on January 5, 2015. Between January 6, 2015 and February 5, 2015, the lighting system used 1,291 kWh of energy. This is equivalent to an average of 41.7 kWh per day. Based on the store being open 360 days per year, this results in a calculated annual energy use of 15,000 kWh.

**Figure 36: LED Load with ALCS Control – Scheduling, Task Tuning and Occupancy Sensing**
SCHEDULING, TASK TUNING, OCCUPANCY SENSING AND DAYLIGHT HARVESTING

The daylight harvesting feature in the ALCS was added to the existing control strategies on February 6, 2015. Between February 7, 2015 and February 23, 2015, the lighting system used 725 kWh of energy. This is equivalent to an average of 42.7 kWh per day. Based on the store being open 360 days per year, this results in a calculated annual energy use of 15,356 kWh.

**Figure 37:** LED Load with ALCS Control - Scheduling, Task Tuning, Occupancy and Daylight Harvesting
QUALITATIVE FEEDBACK

Results of the installation team and end user survey are provided below. The survey addresses both general questions about the technology and demonstration specific questions.

INSTALLATION TEAM - GENERAL FEEDBACK

What is the name of your organization?
1. Country Bear Electric
2. Country Bear Electric
3. Country Bear Electric
4. Sedillo Company, Inc.

What is your position/title at the organization?
1. General Journeyman Electrician
2. Electrician
3. Owner
4. General Building Contractor

What is your age bracket: <25 25-34 35-44 45-54 55+
1. 25-34
2. 55+
3. 55+
4. 45-54

How important is the lighting in your home to you?
SCALE: -3 = Not Important at All / 0 = Indifferent / 3 = Incredibly Important

-3 -2 -1 0 1 2 3
1. 3
2. 3
3. 3
4. 3
Important is the lighting at your place of work to you?

SCALE: $\begin{array}{cccccc}
-3 & -2 & -1 & 0 & 1 & 2 & 3 \\
1. & 3 \\
2. & 3 \\
3. & 0 \\
4. & 2
\end{array}$

What type of lighting do you typically install in retail applications?

Sources: ________________________________________________________
(Source Examples: Linear fluorescent, LED, Halogen)

1. LED
2. LED, fluorescent
3. Used to be fluorescent, now it is LED
4. All

Controls: _______________________________________________________
(Control Examples: A/B Switching, Advanced Controls)

1. A/B Switching
2. A/B Switching and advanced controls
3. Normal A/B switching, and now advanced controls
4. Occupancy sensors, code compliant switching

Have you installed tubular LED products in previous projects? Yes / No
If yes, how many projects? _____

1. Yes, 15
2. No
3. Yes, 4
4. Yes, 2

Have you installed advanced lighting control products in previous projects? Yes / No
If yes, how many projects? _____

1. Yes, 5
2. Yes, 4-5
3. Yes, 5-6
4. No
Based on your experience with tubular LED products, would you recommend them to future customers? Yes / No

Please describe reason: ___________________________

1. Yes, savings in cost of maintenance and energy usage; quality of light
2. Yes, installs quick and energy efficient
3. Yes, easy
4. Yes, energy savings, quality of light, easy retrofit

Based on your experience with advanced lighting control products, would you recommend them to future customers? Yes / No

Please describe reason: ___________________________

1. Yes, ease of operation
2. Yes, easy install
3. Yes, options, saves energy
4. Maybe

**INSTALLATION TEAM - DEMONSTRATION SPECIFIC FEEDBACK**

How long did the installation of the tubular LED product take in each luminaire? _______ (man minutes)

1. 20 minutes
2. 30-40 minutes
3. ~20 minutes
4. N/A

Were specialized tools required for the installation of the tubular LEDs or advanced controls? Yes / No
If yes, please list tools: ___________________________

1. No
2. No
3. No
4. N/A

Were wiring diagrams provided by the manufacturer for the installation of the tubular LED product? Yes / No
If yes, were they accurate? Yes / No
If yes, were they helpful? Yes / No

1. Yes, Yes, Yes
2. No
3. Yes, Yes, Yes
4. Yes, Yes, Yes

If no, please describe your experience: _________________________________________________________________

1. N/A
2. Easy
3. N/A
4. N/A
Have you received specialized training on Advanced Lighting Control Systems?  
Yes / No

If yes, what program or manufacturer provided the training?

1. Yes, Leviton
2. Yes, on job training
3. Yes, seminar in Sacramento by Leviton
4. No, requested information on programs from CLTC

If yes, was it helpful for this installation?

1. Not sure
2. N/A
3. General Idea
4. N/A

Is the installation team performing the acceptance testing?  
Yes / No

If no, who is performing the acceptance testing?  
______________________________

1. N/A
2. Ask General Contractor
3. N/A
4. N/A

If no, has the installation team coordinated with the acceptance tester per Title 24 requirements?  
Yes / No

If no, please describe reason:  
________________________________________________________

1. N/A
2. No
3. N/A
4. N/A

What would you change about the installation process?

1. Nothing, it works great
2. No
3. No
4. Payment structure with PG&E, design changes better communicated to install team
END USER – GENERAL FEEDBACK

What type of end user are you? Store Owner/Store Employee/Customer/Lighting Designer
1. Store Owner
2. Store Employee
3. Store Employee
4. Customer
5. Customer

What is your age bracket? <25 25-34 35-44 45-54 55+
1. 45-54
2. 25-34
3. 25-34
4. 35-44
5. 25-34

How important is the lighting in your home to you? Very important
1. Very important
2. Important, yes, 10
3. Moderate
4. 10
5. Important

How important is the lighting at your place of work to you? Very important
1. Very important
2. Important, yes, 10
3. Important
4. 10
5. Important

END USER – DEMONSTRATION SPECIFIC FEEDBACK

What time are you typically in the store? (Circle all ranges that apply)

Before 8 AM  8 AM to 10 AM  10 AM to Noon  Noon to 2 PM  2 PM to 4 PM  4 PM to 6 PM  6 PM – 8 PM  After 8 PM
1. 8 AM to 8 PM
2. 10 AM to 8 PM
3. 10 AM to 8 PM
4. 2 PM to 6 PM
5. 2 PM to 4 PM
How important is the lighting at your place of work/shopping to you?  
SCALE:  
-3 = Not Important at All / 0 = Indifferent / 3 = Incredibly Important

1. 2
2. 3
3. 0
4. 3
5. 1

Respondent 1:  
Please compare the new lighting system to your previous lighting system:  
SCALE:  
-3 = Worse than before / 0 = Indifferent / 3 = Major improvement

Color of Light    -3 -2 -1 0 1 2 3  
Light Level at Task Planes    -3 -2 -1 0 1 2 3  
Object Appearance    -3 -2 -1 0 1 2 3  
Light Flickering    -3 -2 -1 0 1 2 3  
Glare    -3 -2 -1 0 1 2 3  
Light Level Uniformity    -3 -2 -1 0 1 2 3  

Store Owner Only  
Light Controllability    -3 -2 -1 0 1 2 3

Please rate your satisfaction with the lighting in each space type:  
SCALE:  
-3 = Worse than before / 0 = Indifferent / 3 = Major improvement

Sales floor    -3 -2 -1 0 1 2 3  
Cash Register    -3 -2 -1 0 1 2 3  
Restroom    -3 -2 -1 0 1 2 3  
Instrument Repair Room    -3 -2 -1 0 1 2 3  
Storage    -3 -2 -1 0 1 2 3  

Respondent 2:  
Please compare the new lighting system to your previous lighting system:  
SCALE:  
-3 = Worse than before / 0 = Indifferent / 3 = Major improvement

Color of Light    -3 -2 -1 0 1 2 3  
Light Level at Task Planes    -3 -2 -1 0 1 2 3  
Object Appearance    -3 -2 -1 0 1 2 3  
Light Flickering    -3 -2 -1 0 1 2 3  
Glare    -3 -2 -1 0 1 2 3  
Light Level Uniformity    -3 -2 -1 0 1 2 3  

Store Owner Only  
Light Controllability    -3 -2 -1 0 1 2 3
Please rate your satisfaction with the lighting in each space type:
SCALE: -3 = Worse than before / 0 = Indifferent / 3 = Major improvement

<table>
<thead>
<tr>
<th>Space Type</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales floor</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Cash Register</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Restroom</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Instrument Repair Room</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Storage</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Respondent 3:
Please compare the new lighting system to your previous lighting system:
SCALE: -3 = Worse than before / 0 = Indifferent / 3 = Major improvement

<table>
<thead>
<tr>
<th>Space Type</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color of Light</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Light Level at Task Planes</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Object Appearance</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Light Flickering</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Glare</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Light Level Uniformity</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

**Store Owner Only**

<table>
<thead>
<tr>
<th>Light Controllability</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
</table>

Please rate your satisfaction with the lighting in each space type:
SCALE: -3 = Worse than before / 0 = Indifferent / 3 = Major improvement

<table>
<thead>
<tr>
<th>Space Type</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales floor</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Cash Register</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Restroom</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Instrument Repair Room</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Storage</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Respondent 4: N/A
Respondent 5: N/A
**Respondent 1:**
Rate your familiarity with the following concepts:
SCALE: A= I can describe the use and function / B= heard of it / C= No knowledge

<table>
<thead>
<tr>
<th>Concept</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED lighting</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Institutional/Task Tuning</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Scheduling</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Occupancy Sensing</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Daylight Harvesting</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Demand Response</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>

**Respondent 2:**
Rate your familiarity with the following concepts:
SCALE: A= I can describe the use and function / B= heard of it / C= No knowledge

<table>
<thead>
<tr>
<th>Concept</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
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<td>LED lighting</td>
<td>A</td>
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<td>C</td>
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<td>C</td>
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<tr>
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<td>B</td>
<td>C</td>
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</tr>
<tr>
<td>Daylight Harvesting</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Demand Response</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>

**Respondent 3:**
Rate your familiarity with the following concepts:
SCALE: A= I can describe the use and function / B= heard of it / C= No knowledge

<table>
<thead>
<tr>
<th>Concept</th>
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<th>B</th>
<th>C</th>
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</thead>
<tbody>
<tr>
<td>LED lighting</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Institutional/Task Tuning</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Scheduling</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Occupancy Sensing</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Daylight Harvesting</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Demand Response</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>

**Respondent 4:**
Rate your familiarity with the following concepts:
SCALE: A= I can describe the use and function / B= heard of it / C= No knowledge

<table>
<thead>
<tr>
<th>Concept</th>
<th>A</th>
<th>B</th>
<th>C</th>
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</thead>
<tbody>
<tr>
<td>LED lighting</td>
<td>A</td>
<td>B</td>
<td>C</td>
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<tr>
<td>Institutional/Task Tuning</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Scheduling</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Occupancy Sensing</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Daylight Harvesting</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Demand Response</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
</tbody>
</table>
Respondent 5:
Rate your familiarity with the following concepts:
SCALE: A= I can describe the use and function / B= heard of it / C= No knowledge

- LED lighting: A B C
- Institutional/Task Tuning: A B C
- Scheduling: A B C
- Occupancy Sensing: A B C
- Daylight Harvesting: A B C
- Demand Response: A B C

Do you have any additional feedback regarding the new lighting system? If so, what?
**Respondent 1:** The thing I like the least is my inability to lower/turn off lights at closing time.
**Respondent 2:** All for saving money. Interested in energy savings.
**Respondent 3:** Manual override is essential otherwise the physical light switches are a waste of resources; in other working switches would be great.
**Respondent 4:** Book area dark before, better than before. Lighting should be bright for retail.
**Respondent 5:** No response.

If answered yes to Store Owner:

How important is it to you that you maintain your business’ lighting system yourself?

1. Very important. We do different things in our space and need the ability to make our lighting work for us.

What is your typical monthly electric utility bill?

- <$100
- $100-$150
- $151-$200
- $201-$250
- $251-$300
- $301-$350
- $351-$400
- >$400

What role do utilities play when making lighting design choices? Some role.

Are you aware of incentives programs of your energy provider? Yes/No

Do you participate in utility incentive programs outside of this demonstration? Yes/No
DEMONSTRATION COSTS

Installation and material costs incurred over the duration of the demonstration were collected from the contractor. For analysis, lump sum costs for LED and ALCS systems received from the contractor were separated based on the breakdown of the initial quotation of the systems. Estimated and final costs are provided in Appendix 7.

TABLE 15: WATERMELON MUSIC DEMONSTRATION COST SUMMARY

<table>
<thead>
<tr>
<th>Material Cost ($)</th>
<th>Installation Labor ($)</th>
<th>Total Initial Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Retrofit, As Is</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Pre-Retrofit, Re-lamp</td>
<td>$1,008</td>
<td>$1,313</td>
</tr>
<tr>
<td>LED</td>
<td>$17,006</td>
<td>$7,850</td>
</tr>
<tr>
<td>ALCS</td>
<td>$18,574</td>
<td>$10,540</td>
</tr>
<tr>
<td>ALCS and LED</td>
<td>$35,580</td>
<td>$18,390</td>
</tr>
</tbody>
</table>

EVALUATIONS

Evaluations of the LED and ALCS lighting system with respect to the product implementation, photometric performance, energy use reduction, qualitative feedback and lifecycle cost analysis are provided in this section.

PRODUCT IMPLEMENTATION

The installation team followed the LED and ALCS manufacturer wiring diagrams and recommendations, and the lighting system performed as designed. No safety issues were reported.

Design and commissioning process limitations were identified during the ALCS occupancy and daylight harvesting implementation process. Sensor location and sensitivity settings determined during the design and installation phase of the project are critical to the success of occupancy and daylight harvesting control strategies. Improper design, installation or commissioning of the system will result in lost energy savings. These lost energy savings were caused by a manual override of the ALCS system to achieve increase the light output at Watermelon Music. Ideally, the system owner will leverage the lighting designer or customer support team for the ALCS system to optimize functionality and energy savings.

PHOTOMETRIC PERFORMANCE

The photometric performance of the LED lamps paired with ALCS met the design goal of providing equivalent or greater light levels for all area types in the retail application. For the applications and locations measured, the light levels provided by the pre-retrofit system were greater than the recommended light levels.

Luminance ratios were calculated for ‘luminaire-adjacent’ compared to the ‘luminaire-luminous opening’. Overall, lighting at the demonstration site exceeded the recommended
luminance ratios necessary to maintain ‘visual comfort’ for both pre- and post-retrofit lighting systems. As the recommended practice is not specific to Retail Applications, this metric may be considered as a way to compare system performance pre- and post-retrofit; but not appropriate to use as a tool to evaluate the performance of the lighting system specific to the tasks required in the commercial retail establishments.

For the general retail areas, the LED source as compared to the T8 fluorescent pre-retrofit system provided reduced luminance in some areas and increased luminance in others. The ALCS system is able to accommodate store owner lighting preferences via task tuning control resulting in an application-appropriate lighting system. For the display areas on the perimeter of the store, the track light upgrade from halogen to LED lamps resulted in higher luminance ratio.

Combining the measured performance with the positive survey responses with respect to ‘light levels’ and ‘glare’, the overall photometric performance of the demonstrated system is determined to be improved as compared to the pre-retrofit system.

With respect to the ALCS impact on photometric performance, the scheduling, task tuning and occupancy sensing strategies had little to no impact on the store end users. However, with the daylight harvesting control strategy, the store owner manually increased the electric lighting each morning to achieve the desired light levels in the daylit area of the store.

**ENERGY USE REDUCTION**

The energy use reduction achieved by installing LED lamps and ALCS in a retail application vary by strategy, space type and occupant use pattern. Comparing the pre-retrofit as-is lighting system to the LED system with no controls, there is a 6.8% increase in annual energy use. This is due to the as-is system operating with burnt-out lamps that had not been replaced at the time of the study. However, comparing the pre-retrofit re-lamped system to the LED system with no controls there is a 6.9% annual energy use reduction. For applications where light levels can be reduced, as opposed to where light levels were matched, energy savings will be greater.

The combination of LED lighting and a fully commissioned control system reduced the annual energy use by an additional 25.2%. Each strategy used by the ALCS contributed to this overall energy savings. Incremental savings are based on the assumption that each strategy would be layered over other previously implemented strategies. Scheduling increased annual energy savings by 7.2% compared to the LED lighting system. With both scheduling and task tuning implemented, the ALCS system resulted in 35.7% annual energy use savings. This was the largest savings the ALCS system achieved at the demonstration site evaluated in this assessment.

Adding occupancy control capabilities to the demonstration site resulted in a decrease in energy savings of 13.7%. This decrease is attributed to the ALCS occupancy sensing commissioning process. The intended strategy was to add occupancy control to the existing task tuned system. Energy load profiles in the results section depict an increase in the maximum lighting load during periods of occupancy, indicating that the task tuning strategy was overridden during these periods resulting in increased lighting energy use. Further analysis of the energy use data logs indicate very high occupancy during store hours and significant occupancy during after store hours. This after hours energy use due to occupancy sensing also contributes to the decrease in energy savings.
Adding daylight harvesting capabilities to the demonstration site resulted in an additional decrease in annual energy savings of 2.4% as compared to the previous control strategy using scheduling, task tuning and occupancy sensing. This decrease in energy savings is also contributed to the commissioning process, as the store owner determined the light levels in the daylight zone to be ‘inadequate’. Based on this assessment, the ALCS system was manually overridden when the store opened for the day. This resulted in a higher energy use than anticipated.

**QUALITATIVE FEEDBACK**

Based on their experience, the installation team unanimously recommends LED products for future end users, citing perceived cost savings and ease of installation as two main reasons. Three of the four surveyed installers would recommend ALCS to future end users, and one installer replied that they would ‘maybe’ recommend it to future end users. Of those who responded that they would recommend ALCS systems, reasons cited were ease of operation, easy to install and energy savings, as well as the options it provides to the system owner.

The majority of end users agree that the quality of light and light levels were either the same or improved for all applications in the store. However, light controllability was defined as slightly worse than the previous system by the store owner.

One surveyed employee reported less than satisfied performance with respect to ‘glare’ of the LED system as compared to the pre-retrofit lighting system. All other surveyed end users did not report any issues with ‘glare’.

The store owner identified the ability to maintain the store’s lighting system themselves as “Very important. We do different things in our space and need the ability to make our lighting work for us.”

**LIFECYCLE COST ANALYSES**

Lifecycle cost analyses (LCA) were performed to determine the simple payback, incremental net present value (NPV) and internal rate of return (IRR) of the Watermelon Music demonstration retrofit. The LCA is based on the installation labor and material costs incurred during the course of the installation provided in the results section and Appendix 7.

Simple payback is the initial investment divided by the annual savings experienced as a result of the investment, and is the number of years required to pay for the investment with the project savings. The incremental NPV is provided to determine if the retrofit lighting technology will have a positive or negative cash flow for the 15 year lifecycle analyzed. IRR estimates the growth of investment options, with the highest IRR being most likely to return ‘strong growth’.\(^{15}\) To determine the IRR, an assumed finance rate of 8% and reinvestment rate of 3% are used. An assumed inflation rate of 4% is used for LCA calculations.

\(^{15}\) Internal Rate of Return. [www.investopedia.com](http://www.investopedia.com). January 2015.
Labor and material costs for replacing light sources are included at the lamp/luminaire’s manufacturer-provided rated life. Based on typical retail lighting use of 11.5 hours a day for 360 days a year, LED products with a life equal to or greater than 50,000 hours are expected to require replacement every 12 years. Linear fluorescent T8 lamps with an estimated useful life of 24,000 hours are expected to require replacement every 6 years in the retail application. A prevailing wage estimated at $125 per hour is used for lifecycle maintenance labor calculations. Based on feedback from the installation team, it is assumed that each fixture takes 30 minutes to install LED and ALCS components. It is estimated to take 15 minutes to install/re-lamp fluorescent luminaires.

For the energy cost calculations an average total rate of $0.21/kWh was selected based on PG&E A-1 rate schedule for commercial customers. This energy rate is used with the calculated annual energy use during the monitoring task of the demonstration. No rebates were included in this analysis.

The following technology scenarios are compared, with the first technology serving as the incumbent lighting system that is upgraded to the second lighting system:

- Pre-Retrofit, As-Is vs. LED
- Pre-Retrofit, Re-lamp vs. LED
- LED vs. LED and ALCS
- Pre-Retrofit, As-Is vs. LED and ALCS
- Pre-Retrofit, Re-lamp vs. LED and ALCS

<table>
<thead>
<tr>
<th>Technology</th>
<th>Simple Payback</th>
<th>Incremental NPV</th>
<th>IRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T8 Fluorescent, As-Is vs. LED</td>
<td>NaN</td>
<td>-$38,619</td>
<td>-16%</td>
</tr>
<tr>
<td>T8 Fluorescent Re-lamp vs. LED</td>
<td>71</td>
<td>-$30,038</td>
<td>-8%</td>
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<tr>
<td>LED vs. LED and ALCS</td>
<td>27</td>
<td>-$16,401</td>
<td>-2%</td>
</tr>
<tr>
<td>T8 Fluorescent, As-Is vs. LED and ALCS</td>
<td>67</td>
<td>-$55,019</td>
<td>-8%</td>
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<tr>
<td>T8 Fluorescent, Re-Lamp vs. LED and ALCS</td>
<td>37</td>
<td>-$46,438</td>
<td>-5%</td>
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</table>

Scenarios in Table 16 returning a simple payback of NaN (not a number) are investments that will never result in a return on the initial cost. For this demonstration, the LED retrofit as compared to the as-Is system, used more electricity thus resulting in NaN. A negative incremental net present value at the end of the 15 year evaluation cycle further supports this determination by requiring a negative interest rate (IRR) for the investment to break even.

Using the calculated energy use of the LED and ALCS system compared to the re-lamped fluorescent system, varying system costs were modeled to identify the system cost required for the Watermelon Music installation to break even (Figure 38).

![Figure 38: Projected Payback and IRR for Varying System Costs](image)

The breakeven point is defined when the LCA results in an IRR of 0%. An IRR of 0% corresponds to a total system cost (including materials and installation) of $21,515 with a simple payback of 13.7 years. This is in comparison to the total system cost of the demonstration system which totaled $53,970 with a simple payback of 37 years.
RECOMMENDATIONS

To achieve increased demand among small- and medium-sized commercial retail applications for emerging LED and ALCS products, it is recommended that an incentive structure be developed to enable utility customers to implement these systems without incurring a net cost to their business. Design, installation and commissioning verification steps should be defined and enforced to ensure the ALCS system is performing as designed in order to optimize photometric performance and energy savings. To guarantee a successful installation it is recommended that the ALCS system be installed by a California Advanced Lighting Controls Training Program (CALCTP) certified installer.

ALCS technology limitations identified during this field demonstration support the recommendation for additional research, development and education in the design, installation and commissioning of occupancy and daylight harvesting control strategies.

Metric limitations identified during the photometric performance evaluation of this demonstration support the recommendation for the development of alternate design practices. End user feedback expressed satisfaction with the photometric performance of the as-is system, the re-lamp system and the LED light system. However, when anecdotally asked to pick their ‘favorite’ light system the store employees identified to the re-lamped system and LED light system with no controls. Table 1 provides average light levels for the re-lamped system as compared to IES recommended light levels for specialty retail applications. The average measured light level (footcandles) for vertical illuminance in general areas are 29%-53% ‘over lit’ as compared to the IES recommended light levels.
APPENDIX

APPENDIX 1: SPECIFICATION SHEETS

APPENDIX 2: INSTALLATION AND END USER SURVEY

APPENDIX 3: ALCS GUIDELINES

APPENDIX 4: MV EQUIPMENT SPECIFICATION SHEET

APPENDIX 5: ALCS START UP DOCUMENTATION

APPENDIX 6: PHOTOMETRIC MEASUREMENTS

APPENDIX 7: WATERMELON MUSIC COST INFORMATION
CR6™
Six-Inch LED Downlight

Product Description
The CR6™ LED downlight delivers up to 800 lumens of exceptional 90+ CRI light while achieving up to 67 lumens per watt. This breakthrough performance is achieved by combining the high efficacy and high-quality light of Cree TrueWhite® Technology. The CR6 is available in a warm color temperature and has a variety of trim options. It easily installs into most standard six-inch recessed IC or non-IC housings, making the CR6 perfect for use in both residential and light commercial, new construction or retrofit, applications.

Performance Summary
- Utilizes Cree TrueWhite® Technology
- Delivered Light Output: 625, 800 lumens
- Input Power: 9.5, 12 watts
- CRI: 90
- CCT: 2700K, 3000K, 3500K, 4000K
- Warranty: 5 years†
- Lifetime: Designed to last 50,000 hours
- Dimming: Dimmable to 5%*

Housings & Accessories
Reference Housing & Accessory documents for more details.

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<thead>
<tr>
<th>Trims &amp; Reflectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT6A</td>
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<td>CT6AW</td>
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<td>CT6AB</td>
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<tr>
<td>CT6BB</td>
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<table>
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<th>Housings (GU24 Only)</th>
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</thead>
<tbody>
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</tr>
<tr>
<td>RC6</td>
</tr>
<tr>
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<tr>
<td>SC6</td>
</tr>
<tr>
<td>SC6-CM</td>
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<td>SC6-WM</td>
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Ordering Information
Example: CR6-800L-27K-12-E26

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<th>Source Lumen Output</th>
<th>CCT</th>
<th>Voltage</th>
<th>Base Type</th>
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<td></td>
<td></td>
<td>6 inch</td>
<td>625L 625 Lumens</td>
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<td></td>
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<td>GU24 GU24 Base (Title 24 Compliant)</td>
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<td></td>
<td></td>
<td></td>
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<td>800L 800 Lumens</td>
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<td>E26 Edison Base</td>
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<tr>
<td>CR</td>
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<td>12</td>
<td>GU24 GU24 Base (Title 24 Compliant)</td>
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<td></td>
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<td></td>
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† See www.cree.com/lighting/products/warranty for warranty terms.

Click below to select Quick Ship products
CR6-800L-40K-12-GU24
CR6-800L-27K-12-E26
CR6-625L-27K-12-E26
CR6-625L-30K-12-GU24
CR6-625L-35K-12-GU24
CR6-625L-40K-12-GU24
CR6-800L-27K-12-E26
CR6-800L-30K-12-GU24
CR6-800L-35K-12-GU24

For full list of Cree Quick Ship products visit www.cree.com/lighting/quickship

Rev. Date 01/24/2014

CREE
TRUE WHITE TECHNOLOGY

US: www.cree.com/lighting
T (800) 236-6800 F (262) 504-5415

Canada: www.cree.com/canada
T (800) 473-1234 F (800) 890-7507
Product Specifications

CREE TRUEWHITE® TECHNOLOGY
A revolutionary way to generate high-quality white light, Cree TrueWhite® Technology mixes the light from the highest performing red and unsaturated yellow LEDs. This patented approach delivers an exclusive combination of 90+ CRI, beautiful light characteristics, and lifelong color consistency, all while maintaining high luminous efficacy—a true no compromise solution.

CONSTRUCTION & MATERIALS
• Durable upper housing protects LEDs, driver and power supply. Adjustable flip clips resist heat while providing retention for flush ceiling fit.
• Thermal management system uses both upper housing and lower reflector to conduct heat away from LEDs and transfer it to the plenum space for optimal performance. LED junction temperatures stay below specified maximum even when installed in insulated ceilings.
• Suitable for insulated and non-insulated ceilings.
• One-piece aluminum lower reflector redirects light while also conducting heat away from LEDs. It creates a comfortable visual transition from the lens to the ceiling plane and easily accommodates CT6 snap-in trims.

OPTICAL SYSTEM
• Unique combination of reflective and refractive optical components achieves a uniform, comfortable appearance while eliminating pixelation and color fringing. This ensures smooth light patterns are projected with no hot spots and minimal striations.
• Components work together to optimize distribution, balancing the delivery of high illumination levels on horizontal surfaces with an ideal amount of light on walls and vertical surfaces. This increases the perception of spaciousness.
• Diffusing lens shields direct view of LEDs while lower reflector balances brightness of lens with the ceiling to create a low-glare high angle appearance.

ELECTRICAL SYSTEM
• Integral, high-efficiency driver and power supply.
• Power Factor > 0.9
• Input Voltage: 120V, 60Hz
• Dimming: Dimmable to 5% with most incandescent dimmers. Reference www.cree.com/lighting for recommended dimmers.

REGULATORY & VOLUNTARY QUALIFICATIONS
• ENERGY STAR® qualified.
• cULus Listed
• Exceeds California Title-24 high efficacy luminaire requirements.
• Suitable for wet locations.

Photometry

CR6 BASED ON ONSPEX REPORT #: 30014047-3
CR6-625L: MULTIPLY BY 0.78

Intensity (Candlepower) Summary

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<td>432</td>
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Zonal Lumen Summary

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<td>0-90</td>
<td>800</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Reference www.cree.com/lighting for detailed photometric data.

Installation

• Designed to easily install in standard 6” downlight housings from Cree and other manufacturers.*
• Quick install system utilizes a unique retention feature. Simply attach socket to CR6. Move light to ready position and slide into housing.

*Reference www.cree.com/lighting for a list of compatible housings.

Application Reference

<table>
<thead>
<tr>
<th>Spacing</th>
<th>Lumens</th>
<th>Wattage</th>
<th>LPW</th>
<th>w/ft²</th>
<th>Average FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Space</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4 x 4</td>
<td>625</td>
<td>9.5</td>
<td>61</td>
<td>0.60</td>
<td>36</td>
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<tr>
<td>6 x 6</td>
<td>800</td>
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<td>0.19</td>
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<td>8 x 8</td>
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<td>0.13</td>
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<tr>
<td>10 x 10</td>
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<td>0.35</td>
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<td>47</td>
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<td>7</td>
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<td>8 x 8</td>
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<td></td>
<td></td>
<td>0.15</td>
<td>10</td>
</tr>
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<td></td>
<td></td>
<td>0.28</td>
<td>18</td>
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</tbody>
</table>

Corridor 10’ Ceiling, 80/50/20 Reflectances, Light levels on the ground. LLF: 1.0 Initial. Corridor: 6’ Wide x 100’ Long
<table>
<thead>
<tr>
<th>Spacing</th>
<th>Lumens</th>
<th>Wattage</th>
<th>LPW</th>
<th>w/ft²</th>
<th>Average FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>4’ on Center</td>
<td>625</td>
<td>9.5</td>
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<td>0.40</td>
<td>13</td>
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<tr>
<td>6’ on Center</td>
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<td></td>
<td></td>
<td>0.34</td>
<td>11</td>
</tr>
<tr>
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<td>0.25</td>
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</tr>
<tr>
<td>10’ on Center</td>
<td></td>
<td></td>
<td></td>
<td>0.21</td>
<td>7</td>
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</table>

10’ Ceiling, 80/50/20 Reflectances, 2.5 workspace. LLF: 1.0 Initial. Open Space: 50’ x 40’ x 10’
Product Description
The UR Series 4ft LED upgrade kit delivers 4500 lumens of enhanced spectrum 80 CRI light while achieving over 100 lumens per watt at the system level. This innovative kit is designed for retrofitting existing 1'x4' or 2'x4' fixtures to energy saving LED. The UR Series is available in neutral or cool color temperatures and step dimming comes standard. The UR Series upgrade retrofit kit is easy to install and fits into almost any existing linear fluorescent fixture making it a perfect upgrade option where energy savings and long life are critical.

Performance Summary

<table>
<thead>
<tr>
<th>Upgrade Existing 1'x4' &amp; 2'x4' fixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Definition Color Quality</td>
</tr>
<tr>
<td>Efficacy: 102 LPW at source level</td>
</tr>
<tr>
<td>System Delivered Light Output: 4500 lumens</td>
</tr>
<tr>
<td>Fixture Delivered Light Output: 4000 lumens*</td>
</tr>
<tr>
<td>Input Power: 44 watts</td>
</tr>
<tr>
<td>CRI: &gt;80</td>
</tr>
<tr>
<td>CCT: 3500K, 4000K</td>
</tr>
<tr>
<td>Input Voltage: 120-277 VAC</td>
</tr>
<tr>
<td>Warranty: 7 years</td>
</tr>
<tr>
<td>Lifetime: Designed to last 50,000 hours</td>
</tr>
<tr>
<td>Controls: Step Level to 50%</td>
</tr>
<tr>
<td>Mounting: Existing Recessed</td>
</tr>
</tbody>
</table>

* Varies by Fixture

UR2-48™ Includes
(6) Mounting Clips
(8) Self-Tapping Screws
(1) Driver Screw
(2) 4' LED Lightbars
(1) LED Driver
(1) Installation Instructions
(1) UL1598C Certification Label

UR3-48™ Includes
(9) Mounting Clips
(12) Self-Tapping Screws
(1) Driver Screw
(3) 4' LED Lightbars
(1) LED Driver
(1) Installation Instructions
(1) UL1598C Certification Label

Ordering Information

<table>
<thead>
<tr>
<th>Product</th>
<th>Lumen Output</th>
<th>Color Temp</th>
<th>Voltage</th>
<th>Control</th>
<th>Options</th>
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</thead>
<tbody>
<tr>
<td>UR2-48™</td>
<td>4SL</td>
<td>4500 lumens - 102 LPW</td>
<td>35K 3500 Kelvin</td>
<td>Blank 120-277 Volt (Standard)</td>
<td>S Step Dimming to 50%</td>
</tr>
<tr>
<td>UR3-48™</td>
<td>44W</td>
<td>4000 Kelvin</td>
<td>40K</td>
<td></td>
<td>FD Full Definition (&gt;80 CRI)</td>
</tr>
</tbody>
</table>

Example: UR2-48-45L-35K-S-FD
UR Series

Product Specifications

FULL DEFINITION COLOR
An enhanced spectrum color quality that delivers > 80 CRI.

LUMEN MAINTENANCE FACTORS
• Reference www.cree.com/lighting for detailed lumen maintenance factors.

CONSTRUCTION & MATERIALS
• Lightweight aluminum heat sink housing provides strength and durability.
• Durable plastic mounting clips with integrated magnets allow for simple snap on design to fixture.

OPTICAL SYSTEM
• Specialized lens design for optimal light distribution and smooth visual effect.
• Measured and designed to achieve optimal light performance in existing fluorescent troffers.

ELECTRICAL SYSTEM
• Integral, high-efficiency driver and power supply.
• Power Factor: 0.9 nominal
• Input Power: Stays constant over life.
• Input Voltage: 120V-277V, 50/60Hz
• Temperature Rating: Designed to operate in temperatures 0-35°C
• Total Harmonic Distortion: < 20%

CONTROLS
• Step dimming to 50% comes standard.*

REGULATORY & VOLUNTARY QUALIFICATIONS
• UL1598C (Retrofit Kit).
• This product is UL Classified for U.S. and Canada for use in existing linear fluorescent fixtures.
• Suitable for damp locations.
• Designed for indoor use.

*Reference www.cree.com/lighting for recommended dimming controls and wiring diagrams.

Photometry

UR2-48-4500L PHOTOMETRY BASED ON TEST REPORT#: CESTL-2013-0080

Coefficients Of Utilization

<table>
<thead>
<tr>
<th>RCC (%)</th>
<th>80</th>
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<tbody>
<tr>
<td>RW %:</td>
<td>70</td>
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<td>RCR:</td>
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<tr>
<td></td>
<td>1</td>
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<tr>
<td></td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>10</td>
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</table>

Effective Floor Cavity Reflectance: 20%

Average Luminance Table (cd/m2)

<table>
<thead>
<tr>
<th>Horizontal Angle</th>
<th>0˚</th>
<th>45˚</th>
<th>90˚</th>
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</thead>
<tbody>
<tr>
<td>0˚</td>
<td>1645</td>
<td>1645</td>
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<tr>
<td>45˚</td>
<td>941</td>
<td>1,020</td>
<td>1,138</td>
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<tr>
<td>55˚</td>
<td>595</td>
<td>685</td>
<td>746</td>
</tr>
<tr>
<td>65˚</td>
<td>349</td>
<td>349</td>
<td>380</td>
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<tr>
<td>75˚</td>
<td>191</td>
<td>155</td>
<td>226</td>
</tr>
<tr>
<td>85˚</td>
<td>68</td>
<td>68</td>
<td>85</td>
</tr>
</tbody>
</table>

Reference www.cree.com/lighting for detailed photometric data.
The Cree TW Series LED bulb produces beautiful light with a very high Color Rendering Index (CRI) that makes colors look like they really do. See the difference in the food you eat, the clothes you wear and the appearance of your skin.

Plus it looks like a traditional incandescent light bulb, uses at least 78% less energy and is designed to last 25 times longer.

Cree LED bulbs: easy on the eyes and your wallet.

### What makes them great?
- Spectral Notching with neodymium optics augments LED light quality to show colors true and natural.
- Save money now and save money later. Uses at least 78% less energy than an incandescent.
- Built to light and fast. Covered by Cree’s industry-leading 10-year limited warranty.
- Cree LED Filament Tower™ Technology. The genius idea inside that powers our omni-directional, all-around light.
- 25,000-hour lifetime compared to about 1,000 hours for typical incandescent.
- Dimmable with most standard dimmers.
- Instant-on light.
- Mercury free.

### Specifications:

<table>
<thead>
<tr>
<th>Cree TW Series LED bulb</th>
<th>60W A-Type Replacement</th>
<th>40W A-Type Replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Used (Watts)</td>
<td>13.5</td>
<td>8.5</td>
</tr>
<tr>
<td>Lumens</td>
<td>800</td>
<td>450</td>
</tr>
<tr>
<td>Color Rendering Index</td>
<td>93</td>
<td>93</td>
</tr>
<tr>
<td>Rated Life (Hours)</td>
<td>25,000</td>
<td>25,000</td>
</tr>
<tr>
<td>Color Temperature (K)</td>
<td>2700</td>
<td>2700</td>
</tr>
<tr>
<td>Beam Spread</td>
<td>Omni-directional</td>
<td>Omni-directional</td>
</tr>
</tbody>
</table>

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The Cree TW Series LED bulb produces beautiful light with a very high Color Rendering Index (CRI). The higher the CRI of a bulb, the more accurately you’ll see the true color of the objects it illuminates. Compared to a lower CRI light source like a CFL, the TW Series will display colors true and natural, the way they were intended.

**Why is it blue?**
The rare earth element neodymium is added to the glass of our Cree TW Series LED bulbs to augment the LED light. This creates a “spectral notch,” allowing the LED light passing through the glass to show colors that are true and natural.

**TW Series Soft White LED Bulb**
- **60 Watt Replacement**
  - 13.5 Watts (78% less energy)
  - 93 Color Rendering Index (CRI)
  - 800 Lumens brightness
  - 25,000 Hour rated lifetime
  - $1.63* Annual energy cost

- **40 Watt Replacement**
  - 8.5 Watts (79% less energy)
  - 93 Color Rendering Index (CRI)
  - 450 Lumens brightness
  - 25,000 Hour rated lifetime
  - $1.02* Annual energy cost

*At $0.11 per kWh when compared to a typical incandescent.

Available in soft white (2700K) color temperatures, The Cree TW Series LED Bulb is available now online at homedepot.com/cree and will be available this fall at The Home Depot® stores in California.
ULTRA HD Professional Series LED PAR Lamps
High Definition Lighting

Key Features & Benefits
- 95 typical CRI
- Excellent color quality – within a 3-step MacAdam ellipse
- R9 greater than 60
- Assembled in USA
- No warm up time, instant on with full light output and stable color
- Lasts up to 20 times longer than comparable PAR lamps
- Available in 2700K and 3000K color temperature
- Reduces energy consumption up to 80%
- UV and IR free
- RoHS compliant
- Dimmable to 10%*
- Mercury and lead free
- Long life: up to 50,000 hours (L70)
- Suitable for damp locations

* Performance may vary depending on dimmer use in application. Please refer to Dimmer Compatibility List (RETRO-DIM) for a list of compatible dimmers or visit www.sylvania.com/LEDretrofit

The SYLVANIA ULTRA HD Professional Series family of LED PAR lamps offers premium performance in every category. With exceptional color quality, efficiency, and electrical design standards, this top-tier family of lamps is designed to ensure the highest aesthetics while complying with the most stringent sustainability goals. Designed to be the most efficient replacements for halogen at 3000K, these SYLVANIA LED lamps last up to 20 times longer and are rated for use in damp locations. An optimized LED selection process is used to ensure that color within the ULTRA HD Professional family of LED lamps is extremely consistent, within a 3-step MacAdam ellipse. With outstanding color rendering capabilities (95 typical CRI) and exceptionally rich deep red content (R9≥60), ULTRA HD Professional Series LED lamps enhance warm color palettes and make whites more crisp, making them ideal for residential, hospitality, healthcare or retail applications. With lamp efficacies higher than 50 lumens per watt and smooth dimming performance, ULTRA HD Professional Series LED lamps are an ideal part of any energy-conservation strategy.

Product Offering

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Wattage</th>
<th>Color Temperature</th>
<th>Beam Angle</th>
<th>Lumens</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAR38</td>
<td>21</td>
<td>3000K</td>
<td>30°</td>
<td>1150</td>
</tr>
<tr>
<td>PAR38</td>
<td>20</td>
<td>2700K &amp; 3000K</td>
<td>12°</td>
<td>1000 &amp; 1050</td>
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<tr>
<td>PAR30LN</td>
<td>17</td>
<td>3000K</td>
<td>25° &amp; 40°</td>
<td>970</td>
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<tr>
<td>PAR30</td>
<td>15</td>
<td>3000K</td>
<td>40°</td>
<td>880</td>
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<td>PAR20</td>
<td>10</td>
<td>3000K</td>
<td>30°</td>
<td>550</td>
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<td>PAR16</td>
<td>8</td>
<td>3000K</td>
<td>36°</td>
<td>390</td>
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<td>MR16</td>
<td>7</td>
<td>3000K</td>
<td>36°</td>
<td>400</td>
</tr>
</tbody>
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Application Information

Market Segments
- Art galleries and museums
- Hospitality
- Offices
- Residential
- Restaurants
- Retail

Applications
- Accent/display lighting
- General lighting
- Recessed downlighting
- Track lighting

Application Notes
1. Operating Temperature: -40°F and +113°F (-40°C and +45°C)
   -4°F to +104°F (-20°C to +40°C)
2. Suitable for outdoor use when used in a UL rated fixture where protected from weather
3. Use in fixtures that support 2lb. lamp
4. Not for use with emergency light fixtures or exit lights
5. Not for use in enclosed fixture
6. All PAR lamps from OSRAM SYLVANIA use polymethyl methacrylate (PMMA) for their lenses. It is a transparent thermoplastic, often used as a lightweight, shatter-resistant alternative to glass.

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation. For FCC Part 15 user information, please see www.sylvania.com/fcc15b
## Lamp Dimensions

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Diameter (inches)</th>
<th>MOL (inches)</th>
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</thead>
<tbody>
<tr>
<td>PAR38 Med Base</td>
<td>4.99</td>
<td>4.76</td>
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<td>PAR38 GU24</td>
<td>5.03</td>
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<td>PAR30LN Med Base</td>
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<td>PAR20 GU24</td>
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## Ordering Information

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<th>Item Number</th>
<th>Ordering Abbreviation</th>
<th>Wattage (W)</th>
<th>Base Type</th>
<th>Replaces</th>
<th>Input Voltage (VAC)</th>
<th>Average Rated Life (hrs L70)</th>
<th>CCT</th>
<th>Typical Lumens (lm)</th>
<th>CBCP (cd)</th>
<th>CRI</th>
<th>Beam Angle</th>
<th>R9</th>
<th>Power Factor</th>
<th>ENERGY STAR®</th>
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<tr>
<td>78745</td>
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<td>21</td>
<td>Med</td>
<td>PAR38</td>
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<td>3700</td>
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<td>3000K</td>
<td>1150</td>
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<td>95</td>
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<td>95</td>
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<td>3000K</td>
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<td>1600</td>
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<td>78744</td>
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<td>GU24</td>
<td>PAR20</td>
<td>120</td>
<td>50,000</td>
<td>3000K</td>
<td>970</td>
<td>1600</td>
<td>95</td>
<td>30°</td>
<td>63</td>
<td>0.9</td>
<td>Yes</td>
</tr>
<tr>
<td>72547</td>
<td>LED8PAR16/GU10/DIM/FL36P</td>
<td>8</td>
<td>GU10</td>
<td>PAR16</td>
<td>120</td>
<td>25,000</td>
<td>3000K</td>
<td>390</td>
<td>950</td>
<td>90</td>
<td>36°</td>
<td>50</td>
<td>0.73</td>
<td>No</td>
</tr>
<tr>
<td>72546</td>
<td>LED8PAR16/DIM/930/FL36</td>
<td>8</td>
<td>Med</td>
<td>PAR16</td>
<td>120</td>
<td>25,000</td>
<td>3000K</td>
<td>390</td>
<td>950</td>
<td>90</td>
<td>36°</td>
<td>50</td>
<td>0.73</td>
<td>No</td>
</tr>
<tr>
<td>72544</td>
<td>LED7MR16/DIM/930/FL36</td>
<td>7</td>
<td>GU5.3</td>
<td>MR16</td>
<td>12</td>
<td>25,000</td>
<td>3000K</td>
<td>400</td>
<td>1000</td>
<td>95</td>
<td>36°</td>
<td>90</td>
<td>0.91</td>
<td>No</td>
</tr>
</tbody>
</table>

OSRAM SYLVANIA submits most lamps for ENERGY STAR testing. Early qualification for ENERGY STAR lamps begins at 25,000 hours (L70) regardless that the design of the lamp is manufactured for a greater life expectancy. As the lamps pass ENERGY STAR qualifications, manufacturers are able to increase rated life as dictated by ENERGY STAR guidelines becoming either provisionally qualified or fully qualified. Please visit ENERGYSTAR.gov for more information about testing requirements for ENERGY STAR qualified products.

1. Hours lifetime with 70% (L70) lumen maintenance  
2. Thermally stable typical lumens (±10%)  
3. Thermally stable typical CCT (±10%)  
4. CRI – Color Rendering Index

## Ordering Guide

<table>
<thead>
<tr>
<th>LED</th>
<th>Wattage</th>
<th>Lamp Type</th>
<th>DIM</th>
<th>P</th>
<th>930</th>
<th>FL</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED Lamps</td>
<td>7, 8, 10, 15, 17, 20, 21</td>
<td>PAR20, PAR30, PAR30LN, PAR38, PAR16, MR16</td>
<td>DIM = Dimmable</td>
<td>Professional Series</td>
<td>930: 90+ CRI, 3000K CCT</td>
<td>Beam Type: FL: Flood, NFL: Narrow Flood, WSP: Wide Spot</td>
</tr>
</tbody>
</table>

---

**Note:** ENERGY STAR testing requirements may vary, and products may be provisionally or fully qualified based on their performance. Always check the latest guidelines provided by ENERGYSTAR.gov for the most accurate information.
### Energy Savings

<table>
<thead>
<tr>
<th>Basic Product Description</th>
<th>LED Life (hrs.)</th>
<th>Similar Halogen</th>
<th>Halogen Life (hrs.)</th>
<th>Watts Saved</th>
<th>Energy Savings*</th>
<th>LED Life vs. Halogen Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED21PAR38</td>
<td>50,000</td>
<td>90PAR38</td>
<td>2,500</td>
<td>69</td>
<td>$379.50</td>
<td>20x</td>
</tr>
<tr>
<td>LED20PAR38</td>
<td>40,000</td>
<td>90PAR38</td>
<td>2,500</td>
<td>68</td>
<td>$299.20</td>
<td>16x</td>
</tr>
<tr>
<td>LED17PAR38LN</td>
<td>50,000</td>
<td>75PAR38LN</td>
<td>2,500</td>
<td>58</td>
<td>$310.00</td>
<td>20x</td>
</tr>
<tr>
<td>LED15PAR30</td>
<td>50,000</td>
<td>60PAR30</td>
<td>3,000</td>
<td>45</td>
<td>$247.50</td>
<td>16x</td>
</tr>
<tr>
<td>LED10PAR20</td>
<td>50,000</td>
<td>50PAR20</td>
<td>2,500</td>
<td>40</td>
<td>$220.00</td>
<td>20x</td>
</tr>
<tr>
<td>LED8PAR16</td>
<td>25,000</td>
<td>50PAR16</td>
<td>2,000</td>
<td>42</td>
<td>$115.00</td>
<td>12.5x</td>
</tr>
</tbody>
</table>

*Energy savings over life of lamp calculated at $0.11/kWh

### Technical Information

#### LED10PAR20/DIM/P/930/FL30
- **Wattage**: 10<br>**Lumens**: 1200<br>**Beam Angle**: 30°
- **Lumens**
  - Distance: 4 feet<br>  - Footcandles: 120<br>  - Diameter: 1.1 feet
  - Distance: 6 feet<br>  - Footcandles: 70<br>  - Diameter: 1.8 feet
  - Distance: 8 feet<br>  - Footcandles: 44<br>  - Diameter: 2.7 feet
  - Distance: 10 feet<br>  - Footcandles: 34<br>  - Diameter: 3.5 feet

#### LED17PAR30LN/DIM/P/930/FL30
- **Wattage**: 15<br>**Lumens**: 1400<br>**Beam Angle**: 25°
- **Lumens**
  - Distance: 4 feet<br>  - Footcandles: 120<br>  - Diameter: 1.1 feet
  - Distance: 6 feet<br>  - Footcandles: 70<br>  - Diameter: 1.8 feet
  - Distance: 8 feet<br>  - Footcandles: 44<br>  - Diameter: 2.7 feet
  - Distance: 10 feet<br>  - Footcandles: 34<br>  - Diameter: 3.5 feet

#### LED15PAR30/DIM/P/930/FL40
- **Wattage**: 15<br>**Lumens**: 1600<br>**Beam Angle**: 30°
- **Lumens**
  - Distance: 4 feet<br>  - Footcandles: 120<br>  - Diameter: 1.1 feet
  - Distance: 6 feet<br>  - Footcandles: 70<br>  - Diameter: 1.8 feet
  - Distance: 8 feet<br>  - Footcandles: 44<br>  - Diameter: 2.7 feet
  - Distance: 10 feet<br>  - Footcandles: 34<br>  - Diameter: 3.5 feet

#### LED12PAR38/DIM/P/930/FL50
- **Wattage**: 10<br>**Lumens**: 1100<br>**Beam Angle**: 40°
- **Lumens**
  - Distance: 4 feet<br>  - Footcandles: 120<br>  - Diameter: 1.1 feet
  - Distance: 6 feet<br>  - Footcandles: 70<br>  - Diameter: 1.8 feet
  - Distance: 8 feet<br>  - Footcandles: 44<br>  - Diameter: 2.7 feet
  - Distance: 10 feet<br>  - Footcandles: 34<br>  - Diameter: 3.5 feet

#### LED8PAR16/DIM/930/FL36
- **Wattage**: 8<br>**Lumens**: 950<br>**Beam Angle**: 35°
- **Lumens**
  - Distance: 4 feet<br>  - Footcandles: 120<br>  - Diameter: 1.1 feet
  - Distance: 6 feet<br>  - Footcandles: 70<br>  - Diameter: 1.8 feet
  - Distance: 8 feet<br>  - Footcandles: 44<br>  - Diameter: 2.7 feet
  - Distance: 10 feet<br>  - Footcandles: 34<br>  - Diameter: 3.5 feet

*Approximate footcandle values at center of beam.
<table>
<thead>
<tr>
<th>Light Source</th>
<th>Light Output (Lumen)</th>
<th>Watts</th>
<th>CRI (Color Rendering Index)</th>
<th>Color Temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21W PAR38</td>
<td>1150</td>
<td>21</td>
<td>95</td>
<td>3000</td>
</tr>
<tr>
<td>20W PAR38</td>
<td>1150</td>
<td>21</td>
<td>95</td>
<td>3000</td>
</tr>
<tr>
<td>17W PAR30LN</td>
<td>970</td>
<td>17</td>
<td>95</td>
<td>3000</td>
</tr>
<tr>
<td>15W PAR30</td>
<td>970</td>
<td>17</td>
<td>95</td>
<td>3000</td>
</tr>
<tr>
<td>10W PAR20</td>
<td>860</td>
<td>10</td>
<td>95</td>
<td>3000</td>
</tr>
</tbody>
</table>

Lamp(s) shall be ULTRA HD Professional Series lamps (21W PAR38, 20W PAR38, 17W PAR30LN, 15W PAR30, 10W PAR20) having either a medium base or GU24 base. Lamp(s) shall have an average rated life of up to 50,000 at L70. Lamps should have a typical CRI of 95 with a R9 > 60 and an excellent color quality at 3-step MacAdam ellipse.
**SORAA LED MR16 6W**

**OUTPUT RANGE: VIVID SERIES**
290 - 310 lumen; CRI-95, R9>90

**OUTPUT RANGE: BRILLIANT SERIES**
355 - 375 lumen; CRI-80

**BEAM ANGLE RANGE**
25°, 36°

**COLOR TEMPERATURE RANGE**
2700K, 3000K

**APPLICATION**
Halogen replacement for indoor & outdoor applications

---

**POINT SOURCE OPTICS**
Exceptional beam control with smooth uniform beams
Single light source, single crisp shadow

**VP3 VIVID COLOR AND VP3 NATURAL WHITE**
VIVID series provides accurate color rendering across the visible spectrum from 400nm to 700nm, CRI-95, R9>90
Accurate white rendering based on >70% excitation of Optical Brightening Agents with emission between 400nm & 440 nm

**ENERGY EFFICIENCY AND LONG LIFE**
85% more energy efficient than standard halogen lamps
Typical payback of one year or less
Rated lifetime of 35,000 hours. Three year warranty

**CERTIFICATIONS**
UL/CUL Class 2 and non-Class 2, FCC Title 47 Part 15B, RoHS, CE

---

**GENERAL SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Form Factor</th>
<th>Operating Temperature</th>
<th>Electrical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width: 50.1mm (1.97&quot;)</td>
<td>Minimum: -40°C (ambient)</td>
<td>Wattage: 6W</td>
</tr>
<tr>
<td>Height: 45.5mm (1.79&quot;)</td>
<td>Typical: 60°C - 70°C (base)</td>
<td>Power factor: 0.92</td>
</tr>
<tr>
<td>Weight: 47g</td>
<td>Maximum: 80°C (base)</td>
<td>Voltage: 12V +/- 1.2V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dimmable to &lt; 20%</td>
</tr>
</tbody>
</table>

**COLOR RENDERING**

Harmful UV
Visible Spectrum
Wasteful IR
Soraa VIVID
Soraa BRILLIANT
Halogen
80 CRI LED

**DIMENSIONS**
50.1mm (1.97")
45.5mm (1.79")
### SORAA LED MR16 6W

#### BEAM DIAGRAM

<table>
<thead>
<tr>
<th>Narrow Flood 25°</th>
<th>Distance to Floor (m)</th>
<th>Flood 36°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Dia at 50% Intensity (m)</td>
<td>Field Dia at 10% Intensity (m)</td>
<td>Lux (% of Intensity)</td>
</tr>
<tr>
<td>Beam Dia at 50% Intensity (m)</td>
<td>Field Dia at 10% Intensity (m)</td>
<td>Lux (% of Intensity)</td>
</tr>
</tbody>
</table>

**Note:** Lux may be calculated by multiplying the peak intensity of the desired model number by the percentage in the tables above.

#### SPECIFICATIONS BY MODEL NUMBER*

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Reference Number</th>
<th>Product Code</th>
<th>CCT (K)</th>
<th>Beam Angle (*)</th>
<th>CBCP (Cd)</th>
<th>Halogen Equivalent** (Watts)</th>
<th>Total Flux (Lm)</th>
<th>Efficacy (Lm/W)</th>
<th>CRI/R9</th>
<th>White Point (McA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM16-06-25D-927-03</td>
<td>MR16-36-B01-12-927-25</td>
<td>01161</td>
<td>2700</td>
<td>25</td>
<td>1600</td>
<td>35</td>
<td>290</td>
<td>48</td>
<td>95/95</td>
<td>3</td>
</tr>
<tr>
<td>SM16-06-36D-927-03</td>
<td>MR16-36-B01-12-927-36</td>
<td>01173</td>
<td>2700</td>
<td>36</td>
<td>750</td>
<td>35</td>
<td>290</td>
<td>48</td>
<td>95/95</td>
<td>3</td>
</tr>
<tr>
<td>SM16-06-25D-930-03</td>
<td>MR16-36-B01-12-930-25</td>
<td>01165</td>
<td>3000</td>
<td>25</td>
<td>1710</td>
<td>35</td>
<td>310</td>
<td>52</td>
<td>95/95</td>
<td>3</td>
</tr>
<tr>
<td>SM16-06-36D-930-03</td>
<td>MR16-36-B01-12-930-36</td>
<td>01177</td>
<td>3000</td>
<td>36</td>
<td>810</td>
<td>35</td>
<td>310</td>
<td>52</td>
<td>95/95</td>
<td>3</td>
</tr>
<tr>
<td>SM16-06-25D-827-03</td>
<td>MR16-50-B01-12-827-25</td>
<td>01235</td>
<td>2700</td>
<td>25</td>
<td>1960</td>
<td>40</td>
<td>355</td>
<td>59</td>
<td>80/&gt;0</td>
<td>3</td>
</tr>
<tr>
<td>SM16-06-36D-827-03</td>
<td>MR16-50-B01-12-827-36</td>
<td>01247</td>
<td>2700</td>
<td>36</td>
<td>930</td>
<td>40</td>
<td>355</td>
<td>59</td>
<td>80/&gt;0</td>
<td>3</td>
</tr>
<tr>
<td>SM16-06-25D-830-03</td>
<td>MR16-50-B01-12-830-25</td>
<td>01239</td>
<td>3000</td>
<td>25</td>
<td>2070</td>
<td>40</td>
<td>375</td>
<td>63</td>
<td>80/&gt;0</td>
<td>3</td>
</tr>
<tr>
<td>SM16-06-36D-830-03</td>
<td>MR16-50-B01-12-830-36</td>
<td>01251</td>
<td>3000</td>
<td>36</td>
<td>980</td>
<td>40</td>
<td>375</td>
<td>63</td>
<td>80/&gt;0</td>
<td>3</td>
</tr>
</tbody>
</table>

*Specifications are at stable warm operating conditions (25°C ambient)  **Energy Star Minimum

CCT = Correlated Color Temperature  
CRI = Color Rendering Index (Ra-8)  
White Point = White Point Accuracy in McA step

#### SAFETY NOTE ON HEAT

Although Soraa’s lamps operate at cooler temperatures than halogen lamps, it is recommended that gloves be worn when handling bare lamps that have been energized.
ENCELIUM® Energy Management System
Application and Design Guide
Office

Quality office lighting control may increase a company’s bottom line while improving employee morale. The ENCELUM Energy Management System easily adapts to the lighting requirements of any space to maximize lighting energy savings while still allowing employees control of the lighting in their personal workspace.

12 Private Office
13 Open Office
14 Conference Room
15 Lobby/Reception Area
16 Break Room
17 Storage/Warehouse
Healthcare

Bringing quality lighting into healthcare facilities positively impacts human health and the performance of patients, visitors and staff. The ENCELUM® Energy Management System easily adapts to the lighting requirements of any space to maximize lighting energy savings while ensuring the comfort and safety of patients and staff.

Education

Educational facilities typically consist of a large array of buildings and spaces, each with differing uses and lighting requirements. The ENCELUM Energy Management System easily adapts to the lighting requirements of any space to maximize lighting energy savings while providing the right amount of light when and where required.

Common Areas

The ENCELUM Energy Management System reduces lighting energy consumption in rooms that are used intermittently.

TABLE OF CONTENTS

18 Patient Room
19 Nurses Station
20 Waiting Room
21 Laboratory
22 Surgical Suite
23 Classroom
24 Laboratory
25 Auditorium
26 Dining Hall
27 Library
28 Gymnasium
29 Rest Room
30 Corridor
31 Storage Room
OSRAM, one of the leading light manufacturers in the world, offers intelligent lighting controls in the form of the ENCELUM Energy Management System (EMS). The ENCELUM EMS was designed from the ground up as a software-based, integrated lighting control and energy management system that dynamically responds to the changing characteristics of a building by providing the right amount of light when and where required. This first-of-its kind system allows for building owners and facility managers to provide comfortable lighting to all occupants despite varying needs, while conserving lighting energy consumption and optimizing lighting energy savings.

The ENCELUM Energy Management System is comprised of the ENCELUM GreenBus II™ communication network and the ENCELUM Polaris 3D® software.
ENCELIUM® GreenBus II™ is a networked communication system designed specifically for controlling lighting to achieve maximum energy savings and optimum lighting comfort. It enables cost effective, individual dimming control of all fixtures in a building by integrating peripheral devices, including luminaires, switches, and sensors, with front-end servers via dedicated ENCELIUM GreenBus II cabling, into a complete, programmable lighting solution.

Features & Benefits
- Individual dimming control of thousands of fixtures
- Agnostic control network that can integrate non-dimming ballasts/LED drivers or DALI-based systems from third party suppliers
- Detects and locates field bus communication faults via the ENCELIUM Polaris 3D software
- BACnet® compatible for easy integration with building automation systems, such as HVAC, fire and security
- Integrates occupancy sensors, photo sensors and relay-based controls

ENCELIUM Polaris 3D® is the central control software application used to commission, configure, and manage the ENCELIUM EMS. It enables configuration of every system parameter in a building for each individual user or space and establishes the baseline settings. The ENCELIUM Polaris 3D software offers enhanced ability to analyze and update lighting layouts from an intuitive and easy-to-use computer interface. This brings lighting control to a whole new level, by giving facility managers the ability to easily control individual fixtures, groups of fixtures, entire floors, or even entire buildings right from their desktop or laptop.

Through the Advanced Energy Reporting Module (AERM), the ENCELIUM Polaris 3D software has the ability to display and communicate energy savings in a variety of formats for any specified period of time. Reports generated can focus on an entire building all the way down to an individual fixture, show overall savings or be broken down by energy management strategy. This type of granular control can help identify lighting-related inefficiencies or operational anomalies anywhere in a facility.

Features & Benefits
- Intuitive, user-friendly software that shows an interactive, 360° 3D building view
- Generates real-time energy savings data in formats ranging from kWh to dollars
- Provides users with the ability to easily adjust lighting layouts without physical rewiring of your multi-facility campus
- Change set points and time schedules for multiple zones as desired right from your web browser
- Easy detection of lighting status, consumption and energy trends from colorized lighting system data representation
## ENCELUM® Hardware and Software

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ENCELIUM GreenBus II™ Communication Network</strong></td>
<td>Provides low voltage power to all devices on the network eliminating the need for external power supplies.</td>
<td>• Enables cost effective, individual dimming control of thousands of fixtures in a building.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Integrates peripheral devices such as occupancy sensors, photo sensors, wall stations...etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Originates at an Energy Control Unit and typically propagates in a daisy-chain fashion from device to device.</td>
</tr>
<tr>
<td><strong>Energy Control Unit (ECU)</strong></td>
<td>Collects information from photo sensors, occupancy sensors, and wall mounted lighting controllers.</td>
<td>• Adjusts appropriate brightness levels and ON/OFF status for each fixture and zone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Determines what action to take based on status signals from sensors.</td>
</tr>
<tr>
<td><strong>System Support Unit (SSU)</strong></td>
<td>Acts as the database server for all data related to an ENCELUM system.</td>
<td>• Stores all system settings and parameters and logs historical data regarding operational and energy savings results.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Provides the ability to remotely access the ENCELUM system in order to change system settings or configurations, analyze system performance and energy data, and troubleshoot any problems.</td>
</tr>
<tr>
<td><strong>Luminaire Control Module (LCM)</strong></td>
<td>Provides an interface between ballasts, LED drivers and the ENCELUM Greenbus II communication network.</td>
<td>• Enables each ballast or LED driver to be independently controlled and configured to best meet the needs of the facility.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Switches or dims fixture based on two-way communication with ECU.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Can switch or dim any conventional 0-10V dimming ballast, non-dimming ballast, LED driver, or 0-10V LED driver.</td>
</tr>
<tr>
<td>Function</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
<td></td>
</tr>
</tbody>
</table>
| **Sensor Interface Module (SIM)** | Provides an interface between occupancy or photo sensors and the ENCELUM® Greenbus II™ communication network.  
- Enables each sensor to be independently controlled and configured to best meet the needs of the facility.  
- Automatically detects and adjusts itself to the type of sensor to which it is wired.  
- Establishes a two-way communication between the Energy Control Unit (ECU) and itself. |
| **Area Lighting Controller (ALC)** | Provides a high power switching and dimming interface between a group of luminaires and the ENCELUM GreenBus II communication network.  
- Switches a single wired zone of multiple luminaires ON or OFF while setting the zone’s overall light level with a 0-10V dimming output wired to the dimming ballasts or LED drivers of the fixtures.  
- Can switch an entire circuit of electrical loads and is suitable for general purpose plug load control  
- Replaces the need for standard power relays or switch packs. |
| **Dual Relay Luminaire Control Module** | Provides the switching capability of two LCM modules in a single package as an interface between luminaires and the ENCELUM EMS.  
- Enables inboard/outboard switching, step dimming or two fixture switching by controlling two AC loads independently.  
- Can be connected to power relays or switch packs in order to switch larger electrical loads. |
| **Three-Scene Dimming Controller Wall Station** | Provides customized light level control for a single lighting zone.  
- Allows the user to select three pre-programmed light levels or “scenes” for a single zone by the push of a button.  
- Scene configuration is programmed and changed through the ENCELUM Polaris 3D® software. |
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Three-Zone Controller Wall Station** | Provides ON/OFF switching for up to three lighting zones configured through the ENCELUM® Polaris 3D® software.  
  • "Activates" or "de-activates" a lighting zone indicated by an LED display with white indicating ON and blue indicating OFF.  
  • Where lighting zones are controlled by a time schedule, this wall station can override the time schedule by simply "re-activating" the zone about to be shut down. |
| **Rocker Switch Wall Station** | Provides local ON/OFF and dimming control for a single zone configured through the ENCELUM Polaris 3D software.  
  • A short press of the upper/lower buttons turns lighting ON/OFF while a "press and hold" dims lighting up or down.  
  • Where lighting zones are controlled by a time schedule, this wall station can override the time schedule by pressing the upper button which "re-activates" the zone about to be shut down. |
| **Industrial Push Button** | Provides local ON/OFF control over a single lighting zone configured through the ENCELUM Polaris 3D software.  
  • "Activates" or "de-activates" a lighting zone indicated by an LED display with white indicating ON and blue indicating OFF.  
  • Where lighting zones are controlled by a time schedule, this wall station can override the time schedule by simply "reactivating" the zone about to be shut down. During shut down mode, the wall station will alternately flash blue and white LEDs to indicate to occupants that an override is necessary. |
| **Touch Screen Panel** | Allows the ENCELUM EMS to be controlled with an interactive 7" flush-mount LCD touch screen display.  
  • Provides the ability to recall multiple scenes for a given zone.  
  • Ideal for large multi-purpose spaces where lighting requirements vary throughout the day. |
<table>
<thead>
<tr>
<th><strong>FUNCTION</strong></th>
<th><strong>DESCRIPTION</strong></th>
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| **ENCELIUM® Polaris 3D®** | Web-based application, featuring an interactive three-dimensional view of a building or complex in real-time.  
- Facility managers are now able to see an entire facility or complex in a convenient 3D snapshot allowing for faster and easier navigation to desired control zones.  
- Uses Microsoft’s Silverlight technology providing for an enhanced user experience and allowing access to the system from a web browser. |
| **Personal Control Software (PCS)** | Application which enables individuals in a building to control lighting levels in their workspace from their own desktop PC.  
- User can control and preset the light levels of each fixture or group of fixtures in their workspace.  
- PCS is installed on a user’s local computer and can be accessed by clicking on a light bulb icon appearing in the system tray found on the lower right hand side of the PC screen. |
| **CarbonWatch Software** | Displays the energy and carbon reduction performance of a building controlled by the ENCELUM EMS.  
- CarbonWatch is a slide show that can be customized to show sustainability data, highlight corporate initiatives and foster awareness for lighting conservation.  
- The CarbonWatch software runs off a network connection to the ENCELUM EMS. |
| **BACnet Interface Module** | Enables the integration of the ENCELUM EMS with any BACnet compatible building automation system.  
- The ENCELUM EMS operates autonomously while lighting status, light levels and energy usage are all shared and can be controlled via BACnet.  
- Connects to HVAC, fire, and security systems. |
| **AV Interface** | Resides on SSU, allowing the integration of audio-visual systems to the ENCELUM EMS.  
- Allows various scenarios for a given space by changing lighting, audio and visual to achieve a desired atmosphere.  
- In many cases, these scenarios can be recalled through an interactive touch screen. |
System Architecture

The software-based ENCELUM® EMS networks stand-alone lighting components through intelligent hardware creating an integrated lighting control and energy management system for optimal savings.

- Each light fixture, sensor and wall controller is daisy-chained back to the Energy Control Unit (ECU) using pre-terminated "click & go" ENCELUM GreenBus II™ communication cabling.
- All components are individually addressable and networked back to an Energy Control Unit (ECU). There is one ECU per floor.
- The System Support Unit (SSU) stores system settings and logs historical data, enabling the ENCELUM EMS to analyze system performance and energy information.
- Internet or LAN connection allows floor plan based control software to be operated anywhere on the network.
- Changes to lighting layouts are made through the ENCELUM Polaris 3D® software.
- Through the Advanced Energy Reporting Module, the ENCELUM Polaris 3D software generates energy savings in a variety of graphical formats for any specified period of time or building area.
Sensor Integration & Comfort Zones

The ENCELUM® EMS uses occupancy/vacancy sensors, photo sensors, and comfort zones to integrate entire floors and achieve a massive reduction in lighting energy consumption.

**Occupancy Sensors**
- Occupancy sensor settings are configurable through the ENCELUM Polaris 3D® software.
- Set time delay to the minimum on occupancy sensors connected to the ENCELUM EMS. Time delays are set through the ENCELUM Polaris 3D software. With the ENCELUM EMS, occupancy sensors employ aggressive time-outs by using a two-stage occupancy sensing feature. Fixtures in a zone are in “dim” status in response to lengths of time where no occupancy is detected and turn bright in response to occupancy detection.
- The ENCELUM EMS also provides Personal Control Software which acts as a virtual occupancy sensing feature at individual work stations.
- Occupancy sensors should be placed out of the line-of-sight of doorways, office furniture and decoration.

**Comfort Zones**
- The ENCELUM system allows for the creation of “comfort” or “support” zones in areas adjacent to occupied rooms to ensure that occupants are not isolated for both comfort and safety.
- Examples of “comfort zones” would be the areas immediately outside of a private office, corridors leading to exits, and elevators.
- With the ENCELUM Energy Management System, all of these comfort zones can be grouped with the same master zone. When lights in a master zone are ON, lights in a comfort zone remain ON at a reduced level. Comfort zones are created through the ENCELUM Polaris 3D software.

**Photo Sensors**
- Utilizing networked photo sensors, the Energy Control Unit reduces artificial light levels when natural daylight is available and maintains a steady light level when subjected to fluctuating daylight conditions where 0-10V dimming ballasts and/or drivers exist. Areas with fixed output ballasts and/or drivers energize when natural daylight falls below the foot-candle levels specified.
- The ENCELUM system utilizes light level inputs from common and/or remote sensor locations to minimize the number of photo sensors required. If the office is part of a multi-floor building, then the weighted value of photo sensor readings (the floors just above and just below the office location) is considered to control lighting in order to economize the sensor usage.
- Light level sensor parameters are configurable through the ENCELUM Polaris 3D software. Photo sensors should be placed in areas where their line-of-sight is not blocked by furniture or decoration.
Private Office

The ENCELUM® Energy Management System helps reduce lighting energy consumption while providing the flexibility to adjust light levels for a wide range of tasks and personal preferences.

Features
- Occupants can recall customizable preset lighting scenes in their workspace from their personal computers using the ENCELUM Personal Control Software
- Networked photo sensors enable the ENCELUM EMS to adjust artificial light based on the availability of natural daylight
- Private offices have “comfort zones” assigned to them that remain ON when offices are occupied after regular business hours

ENCELUM Hardware Components Shown:
- ENCELUM GreenBus II™ Cable
- Luminaire Control Module (LCM)
- Sensor Interface Module (SIM)
- Occupancy Sensor
- Photo Sensor
- Rocker Switch

Recommended ENCELUM Software:
- ENCELUM Polaris 3D®
- Personal Control Software

The Luminaire Control Module (LCM) enables each fixture to be independently controlled and configured through the ENCELUM Polaris 3D software.
Open Office

The ENCELUM® Energy Management System reduces lighting energy consumption in areas where multiple employees work, each with differing lighting preferences.

Features

- Group fixtures into zones through the ENCELUM Polaris 3D® software and control zones with the Three-Zone Controller wall station
- Send occupancy information from the ENCELUM EMS to Building Management Systems (HVAC, fire, security) with the BACnet Interface Module
- With the ENCELUM EMS, lighting is scalable to accommodate future changes or upgrades as your office space changes

ENCELIUM Hardware Components Shown:

ENCELIUM® GreenBus II™ Cable  |  Luminaire Control Module (LCM)  |  Sensor Interface Module (SIM)  |  Occupancy Sensor  |  Three-Zone Controller

Recommended ENCELUM Software:

ENCELIUM Polaris 3D®  |  BACnet Interface Module  |  Personal Control Software
Conference Rooms

The ENCELUM® Energy Management System reduces lighting energy consumption while providing a wide customizable array of lighting configurations and levels to suit a variety of tasks.

Features

• Tailor light levels and configurations to best suit the use of the space:
  – Presentation
  – Meeting
  – Video Conferencing
  – Projected Presentation

• Recall customizable preset lighting scenes with the Three-Scene Dimming Controller wall station

• Send occupancy information from the ENCELUM EMS to Building Management Systems (HVAC, fire, security) with the BACnet Interface Module

ENCELIUM Hardware Components Shown:

- ENCELUM GreenBus II™ Cable
- Luminaire Control Module (LCM)
- Sensor Interface Module (SIM)
- Occupancy Sensor
- Three-Scene Dimming Controller

Recommended ENCELUM Software:

- ENCELUM Polaris 3D®
- BACnet Interface Module

The Luminaire Control Module (LCM) enables each fixture to be independently controlled and configured through the ENCELUM Polaris 3D software.
Lobby/Reception Area

The ENCELUM® Energy Management System reduces lighting energy consumption while ensuring the comfort of all office visitors.

**Features**
- Switch light levels ON/OFF with the Rocker Switch wall station or “press and hold” to dim light levels up or down
- Set time schedules for light levels through the ENCELUM Polaris 3D® software
- Showcase your energy savings and carbon footprint reduction with ENCELUM CarbonWatch

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**ENCELUM Hardware Components Shown:**
- ENCELUM GreenBus II™ Cable
- Luminaire Control Module (LCM)
- Rocker Switch
- Power Pack

**Recommended ENCELUM Software:**
- ENCELUM Polaris 3D®
- CarbonWatch
Break Room

The ENCELUM® Energy Management System reduces lighting energy consumption in areas that are used intermittently.

Features

• Networked occupancy sensors enable the ENCELUM EMS to ensure lights remain ON/OFF or dimmed based on occupancy
• Set maximum level of brightness for luminaires in the space with ENCELUM Polaris 3D® software
• Switch light levels ON/OFF with the Rocker Switch wall station or “press and hold” to dim light levels up or down

The Area Lighting Controller (ALC) enables group control of fixtures where individual control is not necessary

ENCELUM Hardware Components Shown:

ENCELUM GreenBus II™ Cable
Area Lighting Controller (ALC)
Sensor Interface Module (SIM)
Occupancy Sensor
Rocker Switch

Recommended ENCELUM Software:

ENCELUM Polaris 3D®
Storage/Warehouse

The ENCELUM® Energy Management System reduces lighting energy consumption while still providing the right amount of light required to work safely.

Features

• Networked occupancy sensors enable the ENCELUM EMS to switch between two light levels based on occupancy
• Manually turn lights ON/OFF with the rugged stainless steel housing of the Industrial Push Button wall station
• Designate areas for load shedding to shave electrical demand during peak hours with the ENCELUM Polaris 3D® software

ENCELIUM Hardware Components Shown:

ENCELIUM GreenBus II™ Cable, Dual Relay Luminaire Control Module, Occupancy Sensor, Sensor Interface Module (SIM), Industrial Push Button

Recommended ENCELUM Software:

ENCELIUM Polaris 3D®
Patient Room

The ENCELUM® Energy Management System reduces lighting energy consumption in areas that are operational 24 hours a day while individual patients recover on unique schedules.

Features

• Give patients the option to adjust light levels to suit their needs by linking patient call button systems with lighting
• Networked photo sensors enable the ENCELUM EMS to adjust artificial light based on the availability of natural daylight
• Set time schedules for light levels based on natural circadian rhythms with ENCELUM Polaris 3D® software

ENCELIUM Hardware Components Shown:

ENCELIUM GreenBus II™ Cable
Luminaire Control Module (LCM)
Sensor Interface Module (SIM)
Occupancy Sensor
Photo Sensor
Three-Scene Dimming Controller

Recommended ENCELUM Software:

ENCELIUM Polaris 3D®
Nurses Station

The ENCELUM® Energy Management System gives nurses localized control of hospital lighting from their personal workspaces.

Features

- Maintain local manual control of lighting in hospital wing for patient management and handling of medicine with the Three-Zone Controller wall station
- Tailor light levels based on personal preference from work station computer with ENCELUM Personal Control Software
- Set time schedules for light levels based on visiting hours and quiet times with the ENCELUM Polaris 3D® software

ENCeLIum Hardware Components Shown:

ENCeLIum GreenBus II™ Cable
Luminaire Control Module (LCM)
Three-Zone Controller

Recommended ENCELUM Software:

ENCeLIum Polaris 3D®
Personal Control Software (PCS)
Waiting Room

The ENCELUM® Energy Management System reduces lighting energy consumption while ensuring the comfort of all hospital visitors.

Features

- Create lighting scenes by lowering light to reduce stress levels with the ENCELUM Polaris 3D® software
- Load shed to shave electrical demand during peak hours
- Showcase your energy savings and carbon footprint reduction with ENCELUM CarbonWatch

ENCELUM Hardware Components Shown:

- ENCELUM GreenBus II™ Cable
- Luminaire Control Module (LCM)
- Touch Screen Panel

Recommended ENCELUM Software:

- ENCELUM Polaris 3D®
- CarbonWatch
- AV Interface
Laboratory

The ENCELUM® Energy Management System reduces lighting energy consumption while providing a wide array of lighting configurations and light levels to suit a variety of tasks.

**Features**

- Recall customizable preset lighting scenes with the Three-Scene Dimming Controller wall station
- Networked occupancy sensors enable the ENCELUM EMS to ensure lights remain ON/OFF or dimmed based on occupancy
- Different zones are easily established and updated through the ENCELUM Polaris 3D® software to reduce light levels in favor of energy savings where luminance requirements are variable

**Recommended ENCELUM Software:**

ENCELIUM Polaris 3D®
The ENCELUM® Energy Management System reduces lighting energy consumption while providing control of ambient lighting for optimal viewing of the surgical field.

**Features**
- Using the ENCELUM Touch Screen Panel, focus attention to certain areas by recalling customizable preset lighting scenes:
  - Prep/Set-Up
  - Procedures
  - Post-Op Cleaning
- Integrate audio-visual systems into the ENCELUM EMS for access to music or video conferencing
- With the ENCELUM EMS, lighting is scalable to accommodate future changes or upgrades

**ENC LiUM Hardware Components Shown:**
- ENCELUM GreenBus II™ Cable
- Luminaire Control Module (LCM)
- Area Lighting Controller (ALC)
- Touch Screen Panel

**Recommended ENCELUM Software:**
- ENCELUM Polaris 3D®
The ENCELUM® Energy Management System enables the easy selection of lighting scenes to direct student attention and create a stimulating learning environment.

Features

- Teachers can easily recall customizable preset lighting scenes for common activities to create an engaging learning environment from their classroom computer using ENCELUM Personal Control Software
- Networked photo sensors enable the ENCELUM EMS to adjust artificial light based on the availability of natural daylight
- Networked occupancy sensors enable the ENCELUM EMS to ensure lights remain ON/OFF or dimmed based on occupancy

Recommended ENCELUM Software:

- ENCELUM Polaris 3D®
- Personal Control Software (PCS)
Laboratory

The ENCELUM® Energy Management System reduces lighting energy consumption while providing a wide array of lighting schemes and light levels to suit a variety of tasks.

Features

- Recall customizable preset lighting scenes with the Three-Scene Dimming Controller wall station
- Lighting zones can be established through the ENCELUM Polaris 3D® software to illuminate areas differently to suit the needs of students and staff
- Adjust light levels as needed for testing and examinations with the ENCELUM Three-Scene Dimming Controller wall station

Recommended ENCELUM Software:

ENCELUM Polaris 3D®

ENCIELUM Hardware Components Shown:

- ENCELUM GreenBus II™ Cable
- Luminaire Control Module (LCM)
- Sensor Interface Module (SIM)
- Occupancy Sensor
- Three-Scene Dimming Controller

The Luminaire Control Module (LCM) enables each fixture to be independently controlled and configured through the ENCELUM Polaris 3D software.
Auditorium

The ENCELUM® Energy Management System enables the easy selection of lighting scenes to direct focus and attention while simultaneously reducing lighting energy consumption.

Features
- Recall customizable preset lighting scenes to best focus student attention for the current activity using the ENCELUM Touch Screen Panel
- Networked occupancy sensors enable the ENCELUM EMS to ensure lights remain ON/OFF or dimmed based on occupancy
- Send occupancy information from the ENCELUM EMS to Building Management Systems (HVAC, fire, security) with the BACnet Interface Module

ENCELUM Hardware Components Shown:

Recommended ENCELUM Software:

The Luminaire Control Module (LCM) enables each fixture to be independently controlled and configured through the ENCELUM Polaris 3D software
Dining Hall

The ENCELUM® Energy Management System allows you to set an array of lighting scenes to suit the time of day while still ensuring the comfort of student and staff diners.

Features

- Set time schedules for light levels through the ENCELUM Polaris 3D® software
- Networked photo sensors enable the ENCELUM EMS to adjust artificial light based on the availability of natural daylight
- Group fixtures into zones through the ENCELUM Polaris 3D software to set desired light levels

ENCELUM Hardware Components Shown:

- ENCELUM GreenBus II™ Cable
- Luminaire Control Module (LCM)
- Sensor Interface Module (SIM)
- Photo Sensor
- Area Lighting Controller (ALC)
- Rocker Switch

Recommended ENCELUM Software:

- ENCELUM Polaris 3D®
The ENCELUM® Energy Management System maximizes energy savings in a building or space with extended hours and sporadic occupancy while maintaining a safe and secure environment for students and faculty.

**Features**
- Networked photo sensors enable the ENCELUM EMS to adjust artificial light based on the availability of natural daylight.
- Appeal to different personal preferences and study habits by creating areas with different illumination levels through the ENCELUM Polaris 3D® software.
- Create “secure zones” for spaces such as restrooms, lounge areas and exits to ensure student and faculty safety at night.

**ENCELUM Hardware Components Shown:**

<table>
<thead>
<tr>
<th>ENCELUM GreenBus II™ Cable</th>
<th>Luminaire Control Module (LCM)</th>
<th>Sensor Interface Module (SIM)</th>
<th>Photo Sensor</th>
<th>Three-Zone Controller</th>
</tr>
</thead>
</table>

**Recommended ENCELUM Software:**

<table>
<thead>
<tr>
<th>ENCELUM Polaris 3D®</th>
<th>BACnet Interface Module</th>
</tr>
</thead>
</table>
Gymnasium

The ENCELUM® Energy Management System reduces lighting energy consumption while setting light configurations as needed for specific activities.

Features

• Networked occupancy sensors enable the ENCELUM EMS to ensure lights remain ON/OFF or dimmed based on occupancy
• Eliminate glare and uneven illumination by setting maximum light levels through the ENCELUM Polaris 3D® software
• Group fixtures into zones through the ENCELUM Polaris 3D software and control zones with the Three-Zone Controller wall station

Recommended ENCELUM Software:

ENCIELUM Polaris 3D®

BACnet Interface Module

ENCIELUM Hardware Components Shown:

ENCIELUM GreenBus II™ Cable
Luminaire Control Module (LCM)
Sensor Interface Module (SIM)
Occupancy Sensor
Three-Zone Controller

The Luminaire Control Module (LCM) enables each fixture to be independently controlled and configured through the ENCELUM Polaris 3D software.
COMMON AREAS

Rest Room

The ENCELUM® Energy Management System ensures that lights are only ON when occupancy is detected.

Features
- Networked occupancy sensors enable the ENCELUM EMS to ensure lights remain ON/OFF or dimmed based on occupancy
- Send occupancy information from the ENCELUM EMS to Building Management Systems (HVAC, fire, security) with the BACnet Interface Module to operate bathroom fan
- Load shed in pre-determined areas to shave electrical demand during peak hours with the ENCELUM Polaris 3D® software

ENCIELUM Hardware Components Shown:

ENCIELUM GreenBus II™ Cable  Sensor Interface Module (SIM)  Occupancy Sensor  Area Lighting Controller (ALC)

Recommended ENCELUM Software:

ENCIELUM Polaris 3D®  BACnet Interface Module
Corridor

The ENCELUM® Energy Management System will reduce lighting energy consumption while ensuring the safety and security of all building occupants.

Features
• With the ENCELUM Polaris 3D® software, designate hallways as “comfort zones” in relation to offices and main areas so lighting remains ON as long as occupancy is detected in master zones for both comfort and safety.
• Set time schedules for light levels through the ENCELUM Polaris 3D software.
• Load shed in pre-determined areas to shave electrical demand during peak hours with ENCELUM Polaris 3D software.

ENCIELUM Hardware Components Shown:

Recommended ENCELUM Software:

ENCIELUM Polaris 3D®
Storage Room

The ENCELUM® Energy Management System ensures that lights are only ON when occupancy is detected.

Features
- Networked occupancy sensors enable the ENCELUM EMS to ensure lights remain ON/OFF or dimmed based on occupancy
- Manually turn lights ON/OFF with the rugged stainless steel housing of the Industrial Push Button wall station
- Load shed in pre-determined areas to shave electrical demand during peak hours with the ENCELUM Polaris 3D® software

ENCELUM Hardware Components Shown:
- ENCELUM GreenBus II™ Cable
- Sensor Interface Module (SIM)
- Occupancy Sensor
- Area Lighting Controller (ALC)
- Industrial Push Button

Recommended ENCELUM Software:
- ENCELUM Polaris 3D®
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Specifications subject to change without notice.

LMS095 10-13

SEE THE WORLD IN A NEW LIGHT
APPENDIX 2: INSTALLATION AND END USER SURVEY
PG&E Tubular LED Lamps and Advanced Lighting Control System Demonstration: Post-Retrofit Survey

Installation Team Survey: Watermelon Music, Davis, CA

General

What is the name of your organization? ______________________________________________________

What is your position/title at the organization? __________________________________________________

What is your age bracket: <25  25-34  35-44  45-54  55+

How important is the lighting in your home to you?
SCALE: -3 = Not Important at All / 0 = Indifferent / 3 = Incredibly Important

-3  -2  -1  0  1  2  3

Important is the lighting at your place of work to you?
SCALE: -3 = Not Important at All / 0 = Indifferent / 3 = Incredibly Important

-3  -2  -1  0  1  2  3

What type of lighting do you typically install in retail applications?

Sources: __________________________________________________________
(Source Examples: Linear fluorescent, LED, Halogen)

Controls: __________________________________________________________
(Control Examples: A/B Switching, Advanced Controls)

Have you installed tubular LED products in previous projects? Yes / No
If yes, how many projects? ____

Have you installed advanced lighting control products in previous projects? Yes / No
If yes, how many projects? ____

Based on your experience with tubular LED products, would you recommend them to future customers? Yes / No

Please describe reason: ________________________________________________

Based on your experience with advanced lighting control products, would you recommend them to future customers? Yes / No
Watermelon Music Demonstration

How long did the installation of the tubular LED product take in each luminaire? ______ (man minutes)

Were specialized tools required for the installation of the tubular LEDs or advanced controls? Yes / No
If yes, please list tools: ____________________________________________________________

Were wiring diagrams provided by the manufacturer for the installation of the tubular LED product?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
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<tr>
<td>If yes, were they accurate?</td>
<td>Yes / No</td>
</tr>
<tr>
<td>If yes, were they helpful?</td>
<td>Yes / No</td>
</tr>
</tbody>
</table>

If no, please describe your experience: __________________________________________________

____________________________________________________

____________________________________________________

____________________________________________________

Have you received specialized training on Advanced Lighting Control Systems? Yes / No
If yes, what program or manufacturer provided the training?

____________________________________________________

____________________________________________________

____________________________________________________

If yes, was it helpful for this installation?

____________________________________________________

____________________________________________________

____________________________________________________

Is the installation team performing the acceptance testing? Yes / No
If no, who is performing the acceptance testing? __________________________________________
If no, has the installation team coordinated with the acceptance tester per Title 24 requirements? Yes / No
If no, please describe reason: _________________________________________________________

____________________________________________________

____________________________________________________

What would you change about the installation process?

____________________________________________________

____________________________________________________

____________________________________________________
### General

What type of end user are you?  
Store Owner/Store Employee/Customer/Lighting Designer

What is your age bracket?  
<25  25-34  35-44  45-54  55+

How important is the lighting in your home to you?  

How important is the lighting at your place of work to you?  

### Watermelon Music Demonstration

What time are you typically in the store?  
(Circle all ranges that apply)

Before 8 AM  8 AM to 10 AM  10 AM to Noon  Noon to 2 PM  2 PM to 4 PM  4 PM to 6 PM  6 PM – 8 PM  After 8 PM

How important is the lighting at your place of work/shopping to you?  

SCALE:  
-3 = Not Important at All  0 = Indifferent  3 = Incredibly Important

<table>
<thead>
<tr>
<th></th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color of Light</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Light Level at Task Planes</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Object Appearance</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Light Flickering</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Glare</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Light Level Uniformity</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

**Store Owner Only**

Light Controllability  

<table>
<thead>
<tr>
<th></th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
</table>

Please rate your satisfaction with the lighting in each space type:  

SCALE:  
-3 = Worse than before  0 = Indifferent  3 = Major improvement

<table>
<thead>
<tr>
<th>Space Type</th>
<th>-3</th>
<th>-2</th>
<th>-1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales floor</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Cash Register</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Restroom</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Instrument Repair Room</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Storage</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
Rate your familiarity with the following concepts:
SCALE: A= I can describe the use and function / B= heard of it / C= No knowledge

LED lighting  A  B  C
Institutional/Task Tuning A  B  C
Scheduling A  B  C
Occupancy Sensing A  B  C
Daylight Harvesting A  B  C
Demand Response A  B  C

Do you have any additional feedback regarding the new lighting system? If so, what?
________________________________________________________________________
________________________________________________________________________

If answered yes to Store Owner:

How important is it to you that you maintain your business’ lighting system yourself?
________________________________________________________________________
________________________________________________________________________

What is your typical monthly electric utility bill?
<$100   $100-$150  $151-$200  $201-$250  $251-$300  $301-$350  $351-$400  <$400

What role do utilities play when making lighting design choices? _____________________________
________________________________________________________________________

Are you aware of incentives programs of your energy provider? Yes/No

Do you participate in utility incentive programs outside of this demonstration? Yes/No
APPENDIX 3: ALCS GUIDELINES
Advanced Lighting Control System (ALCS) Measurement and Verification Guidelines

Pacific Gas and Electric Company
San Diego Gas and Electric Company
Southern California Edison

Issued: April 2013
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Appendix A: General Best Practices for Lighting M&V

Appendix B: Sample ALCS M&V Plan
Executive Summary

Implementation of Advanced Lighting Control Systems (ALCS) in California buildings promises to deliver significant energy savings to the State. The California Investor Owned Utilities (IOUs) are investigating this emerging technology for possible future inclusion in their portfolio of energy efficiency offerings to customers.

In order to support development of incentive programs for ALCSs, the IOUs are conducting field demonstrations of the technology to fully understand the energy savings potential of this technology. Energy consumption data collected from these field demonstrations can be used to support energy savings estimates that may be incorporated into future IOU incentive programs. These field demonstrations can also provide valuable information about qualitative aspects of new technologies, such as user acceptance, installation and commissioning issues, and installation and material costs.

In an effort to ensure that monitored energy data collected from the various demonstration projects conducted by the IOUs is aligned statewide, the IOUs have developed these ALCS Measurement and Verification Guidelines. These M&V Guidelines are intended to provide the following:
1. A consistent methodology for capturing energy and demand savings for ALCS demonstration projects.
2. The robust data collection necessary to support energy savings estimates.
This document does not provide guidance on assessment of the qualitative aspects of new technologies.

The M&V Guidelines provide guidance in three general areas.
- General Considerations for California IOU ALCS Demonstration Projects
- ALCS Data Collection (Metrics)
- Energy and Demand Savings Calculation Methodologies
In addition, the M&V Guidelines provide guidance in general best practices for lighting M&V through reference to a Lighting M&V guide developed by Pacific Northwest National Laboratories.

This document was developed to meet specific needs of California utilities and support the regulatory process of energy efficiency program development in collaboration with the California Public Utility Commission. These M&V Guidelines are a living document. They will be revised and updated as California IOU demonstration projects are completed and related national efforts are developed more fully.
Background and Introduction

The California IOU’s are evaluating the potential for energy savings delivered by Advanced Lighting Control Systems (ALCS). An Advanced Lighting Control System is an automatic control system that provides multiple integrated lighting control strategies that are implemented simultaneously. Typical control strategies offered through ALCS include the following.

- Tuning: Set the maximum output level of electric lighting to meet the requirement for each space at a lower level than full lighting power.
- Lumen Maintenance: Adjust light output to provide a constant level of lighting from a lighting system regardless of the age of the lamps or the maintenance of the luminaires.
- Occupancy Sensing: Turn lights on and off based on occupancy detection.
- Daylight Harvesting: Automatically adjust the output level of electric lighting based on available daylight.
- Scheduling: Turn off and/or dim electric lighting according to a pre-determined schedule.
- Personal Control: Enable individuals to adjust the light output from electric lighting to meet personal preferences.
- Demand Response: Reduce light output from electric lighting in response to automated signals from electric utilities.

This document provides guidelines for measurement and verification of energy savings delivered by Advanced Lighting Control Systems. These guidelines are intended for use by the California IOUs when conducting demonstration and scaled-field placement projects to evaluate an ALCS. It provides specific requirements and recommendations for robust data collection necessary to support energy savings estimates that may be incorporated into future IOU incentive programs. These ALCS M&V Guidelines should be used to guide development of an individual M&V plan that incorporates the specific features of a particular installation.

General Best Practices for Lighting Measurement and Verification

This ALCS M&V Guidelines provides guidance specific to M&V of energy savings delivered by ALCS. However, M&V of all lighting energy efficiency projects should follow basic best practices in the areas of site selection and setup, instrumentation requirements, power measurement and light level measurement protocols.

Pacific Northwest National Laboratories has developed a “Standard Measurement and Verification Plan for Lighting Retrofit Projects for Building and Building Sites”. This document provides detailed guidance for general best practices for measurement and verification of lighting projects. This document is included in Appendix A for reference.
General Considerations for California IOU ALCS Demonstration Projects

Projects with Both Light Source Change and ALCS Installation
It is not uncommon for an ALCS demonstration project to also include installation of new, more efficient lighting sources. In this case, energy savings will result from both the light source change and from implementation of advanced lighting control strategies.

For projects that include both a light source change and installation of an ALCS, the energy savings provided by the replacement of traditional lighting sources with efficient sources should be monitored and reported separately from the energy savings delivered by the ALCS.

Details and best practices for monitoring of the light source energy savings are not discussed within the body of this document, but are included in the Best Practices provided in Appendix A.

Baseline Monitoring
The first step in M&V for an ALCS is monitoring the energy consumption and lighting performance of the baseline condition. There are two possible baseline situations depending on whether or not the demonstration project includes a light source change in addition to installation of an ALCS.

Situation 1: Light Source Change and ALCS Installation
In this situation, the existing lighting system will be replaced or lamps and ballasts will be upgraded at the same time that the ALCS is installed. The baseline for evaluation of the energy savings provided by the ALCS shall be the new lighting system operating at full light output. Any existing controls, such as occupancy sensors, should be operational.

In most cases, it will be practical to install the ALCS at the same time that new lighting sources are installed, or the ALCS may be integral to the new lighting sources. In this instance, the baseline will be the new lighting system with the ALCS operating with control features enabled to duplicate the existing controls. For instance, if occupancy sensor control was part of the existing lighting system, new occupancy sensors installed as part the ALCS should be commissioned to operate in the same manner as the existing occupancy controls (same time delay, etc.). No additional ALCS control features shall be enabled. In particular, tuning control should not be implemented. This will provide a baseline that incorporates the new lighting sources, but does not include any of the advanced control features provided by the ALCS.

Situation 2: ALCS Installation Only
In a situation where the existing lighting system is “controls-ready” and no change in the light source or ballast/driver is included, the baseline for evaluation of the energy savings provided by the ALCS shall be the existing lighting system in an “as-restored” condition. The “as restored” condition should represent the lighting system fully functioning in the same manner as a lighting system that has recently been installed. This would include replacing burnt out lamps and non-functioning fixtures if they would typically be replaced under normal maintenance of the existing lighting system. The following tasks should be completed to bring the lighting system to the “as-restored” condition.

- Install new lamps and operate for 100 hours
- Clean fixtures
- Commission existing controls

**Post-Installation Monitoring**

After baseline monitoring is complete, monitoring of energy use and lighting performance should be performed to characterize the operation and energy consumption of the ALCS. As described in the section Energy and Demand Savings Calculation Methodologies, a simulation tool is being developed for estimation of energy savings provided by an ALCS. Data collected from these field demonstrations will be used to refine the simulation tool. Since any monitoring project is specific to the site being monitored, it is important that sufficient data be collected in a consistent manner to allow it to be useful in refining the tool.

The simulation tool will allow layering of multiple control types in a space. The tool will allow a user to choose a number of advanced lighting controls and provide aggregated savings for each space accounting for interactive effects between controls. Given this tool structure, it is important to collect data for scenarios where control strategies are implemented incrementally.

It is recommended to monitor lighting and energy performance for the following scenarios:

1. Scheduled, Full Output: Lighting system operating per the customer’s operating schedule at full light output.
2. Scheduled + Tuned: Lighting system operating per the customer’s operating schedule at the desired task-tuned light level.
3. Scheduled + Tuned + Occupancy Control: Lighting system operating per the customer’s operating schedule at the desired task-tuned light level with occupancy sensor control enabled.
4. Scheduled + Tuned + Occupancy Control + Daylight Control: Lighting system operating per the customer’s operating schedule at the desired task-tuned light level with occupancy sensor and daylight control enabled.
5. Scheduled + Tuned + Occupancy Control + Daylight Control + Personal Control (if applicable): Lighting system operating per the customer’s operating schedule at the desired task-tuned light level with occupancy sensor and daylight control enabled and with personal controls available to occupants. If personal controls
are not installed with the ALCS, then this scenario will not be part of the assessment.

**Energy Monitoring Duration**

In general, the energy monitoring duration must be sufficient to ensure an accurate representation of the energy consumption of the lighting system both before and after installation of the ALCS. To the extent possible, the dates chosen for monitoring should provide a time period that is representative of typical operation and use of the space.

A minimum of 14 days of data collection is required for the baseline and each of the post-installation scenarios. Longer data collection periods are preferred, if possible. In particular, a minimum of 30 days is strongly recommended for scenarios that include operation of daylighting controls. The M&V plan should include appropriate steps to ensure the validity of the data collected. For instance, time should be included for periodic review of the raw data and for additional data collection, should some of the data be unusable. If the weather during the initial required 14 day monitoring period is not typical, it is recommended to continue the energy use monitoring for another 7 days.

**Demand Response Monitoring**

In situations where a customer will be implementing demand response (DR) as part of the ALCS, monitoring of the DR capabilities of the ALCS shall be conducted to determine the on-site response of the lighting system to a DR signal sent by the utility. It is strongly recommended that staff from the appropriate IOU DR Emerging Technologies team is consulted to coordinate any specific monitoring or testing that may be useful to DR ET efforts.

Monitoring of the demand response (DR) capabilities of the ALCS shall be conducted to determine the demand reduction achieved in response to a DR signal sent by the utility. Typically, an advanced lighting control system provides a manual scheduling feature for initiation of a DR event. This feature can be used to schedule a simulated dispatchable DR event for monitoring purposes. DR testing and monitoring shall take place after completion of all other ALCS post-installation monitoring.

DR events are typically initiated at various levels, corresponding to the significance of the DR event and the associated pricing signal. For example, DR events may be triggered at very high, high and moderate levels and the ALCS may be programed to initiate a different response in lighting reduction at each level.

DR monitoring should include measurement of power and energy data before, during, and after each DR test. First, establish the DR baseline condition with power and energy measurements. The baseline should represent operation of the ALCS with all of the energy efficiency control strategies fully functional. Then initiate a DR signal through the control system front-end. During the DR event, again record power and
energy data. Remove the DR signal, and record measurements again to ensure a return to baseline conditions.

The measurements should be repeated at each of the various dispatchable DR levels that are programmed into the ALCS front end. It is important that the lighting response triggered at the various DR levels represent the actual reductions in light levels that the customer will use on an ongoing basis. The duration of the simulated DR event should be sufficient to allow for recording of power and energy data that is representative of the programmed lighting response. A minimum duration of 30 minutes is recommended.

**ALCS Data Collection (Metrics)**

In order to build a robust dataset to inform and refine development of an ALCS energy savings simulation tool, the following minimum data collection is required.

**Building, Space and Environmental Information**

To allow use of the results from a specific demonstration project to inform refinement of the simulation tool, detailed information about the building and environment should be provided.

At a minimum, the following information should be included in the Emerging Technologies Assessment Report:

- Building type: reference a building type as listed in the DEER database
- Specific dates of data collection
- Building address
- Building square footage and number of floors
- Building occupancy during test period (percent occupied)
- Number of full time workers
- Normal business hours
- Presence of any exterior shading attached to building
- Presence of any exterior obstructions (trees, nearby buildings) and approximate height
- For each floor (or space) studied:
  - Ceiling height
  - Window height
  - Window visible light transmission (VLT)
  - Window to wall ratio (Note interior=net or exterior=gross)
  - Number, size, and type of any skylights
  - Partition height
  - Surface colors or reflectance (floor, wall, partitions, ceiling)
  - Space type (for instance, open office, private office, conference room)
  - Percent of each space type in the building
  - Control strategies being implemented
**Lighting and Control System Description**

Both the existing and new systems should be described. Pertinent information should be provided to enable readers to fully understand the features and capabilities of the lighting and control systems. Information should be provided that provides a clear alignment of measurements with luminaires and lighting circuits.

At a minimum, the following information should be included in the Emerging Technologies Assessment Report for both the existing and new systems.

- Luminaire description (make, model, mounting, light source, ballast/driver)
- Control system description (make, model, features, including Open ADR compliance, if applicable)
- Number of luminaires per power monitoring circuit
- Note any non-functioning luminaires, if applicable
- Description/drawings of electrical circuits and reflected ceiling plans that align with power monitoring and indicate which luminaires are included in specific control zones
- Location of occupancy and daylight sensors

Additional information should be recorded as appropriate to fully describe the lighting and control systems.

**Energy Consumption**

Power and energy consumption for both the baseline and the post-installation scenarios should be monitored. Due to the complex nature of the impact of advanced lighting control strategies on the operation of the lighting system, continuous monitoring of the lighting electrical circuits is required. This will provide a direct measurement of actual energy and power as the lighting system is dynamically operated through the control system.

A continuous power logger that provides true RMS metering should be connected to lighting circuits. The logger should record data at an interval of 5 minutes, or shorter. It is important to ensure that the monitored circuits provide power to only the lighting loads that are part of the project. If other loads constitute less than 10% of the total load, the circuit measurements can still be used: If possible, isolate the non-lighting loads and sub-meter those to permit the non-lighting loads to be subtracted from the full circuit lighting loads.

Do not forget to ensure that the lighting control system power is metered, as it may not be connected to the same panel or circuit as the lighting equipment, especially if there is integration into a larger building energy monitoring system.

The number of circuits and/or control zones monitored will be determined by a number of variables, including the budget for the field demonstration, the existing electrical wiring configuration, the control zoning configuration and others. In general, monitor the maximum number of circuits/control zones feasible for the field demonstration. If a
limited number of circuits/zones are monitored, ensure that a variety of zones are monitored that include typical space types in the building.

The following data should be collected for each monitored circuit.

- Volts
- Amps
- Power (watts)
- Power factor
- Total Harmonic Distortion, current (THD-I)
- Energy (kWh)
- Date, time and duration of measurements

**Lighting Performance**

Illuminance measurements for both the baseline and each post-installation scenario should be monitored. Measurements should be taken in representative areas such that power monitoring can be aligned with illuminance measurements. At a minimum, illuminance measurements should be made in a representative location for each of these areas.

- Primary daylit zone
- Secondary daylit zone
- Interior space

For each of these areas, establish representative locations for horizontal illuminance measurements and document the measurement locations to ensure that subsequent readings will be recorded in precisely the same locations and orientations. Include a space plan that documents the location of the measurement locations in the assessment report. To capture variability in light levels during the day, take illuminance readings in the primary and secondary daylit zones 3 times during the day: morning, noon, and late afternoon. Document the time of illuminance measurements. Alternatively, an illuminance logger can be used to capture illuminance readings throughout the data collection period. A data collection interval of 5 minutes is recommended.

Refer to Appendix A for best practices for illuminance measurements.

To verify proper operation of the daylighting controls, select representative illuminance measurement points in the secondary daylit areas and measure illuminance at these points to verify light levels meet customer design criteria when lights are dimmed by the daylighting controls. If the space does not include secondary daylit zones, use representative illuminance measurement points in the primary daylit zone.

Representative measurement points should be selected that will adequately assess daylight control operation based on space geometry and time of day of measurements. Confirm proper operation of daylight controls before initiating energy monitoring.
**Demand Response**

Power and energy consumption and illuminance measurements should be recorded for three conditions: before, during, and after the demand response test. The measurements should be repeated at each of the various DR levels.

The following data should be collected.
- Volts
- Amps
- Power (watts)
- Power factor
- Energy (kWh)
- Total Harmonic Distortion, current (THD-I)
- DR signal level
- Date, time and duration of DR signal

**Energy and Demand Savings Calculation Methodologies**

The annual energy savings resulting from implementation of the ALCS is the difference between baseline and post-installation measured energy use. Energy savings can be calculated using a number of different methodologies.

Additional information about the tool, including a web link where the tool can be downloaded, will be provided when available.

**Demand Response Savings**

During a demand response event, the critical functionality to be delivered through the ALCS is a reduction in lighting power (kW) for the duration of the event. The demand response savings will be the actual measured reduction in lighting power during the DR tests at each of the various DR levels.

\[ DRS \ (kW) = [DEM_{\text{Base}} - DEM_{DR}] \]

Where:
- \( DRS \) = DR lighting electric demand savings (kW)
- \( DEM_{\text{Base}} \) = baseline measured lighting demand (kW)
- \( DEM_{DR} \) = measured lighting demand (kW) during DR event

**Compare to Control System Reported Energy Use**

Many ALCS’s now incorporate energy use reporting as an integral feature of the system. Energy use reporting can be accomplished in a variety of ways, and the
method(s) employed and available will differ between manufacturers. Some possible methods of energy use reporting include

- **Calculated:** Lighting energy use is calculated by software based on measured state of the lights (on, off, dim level) and information provided for the luminaires (ballast/driver power consumption data, dimming to power consumption data).
- **Wireless controllers with integrated power meters:** Power meters are integrated into ballasts and measured data is wirelessly communicated to the ALCS to provide luminaire level metering.
- **Modbus power meters with current transformers:** Power meters are installed on lighting circuits and measured data is integrated into the ALCS front end.

If the ALCS under investigation in the demonstration project includes an energy use reporting function, it is recommended to compare the measured lighting energy use from the IOU demonstration project to the ALCS reported energy use. It is important to carefully coordinate the data collection periods such that the energy use reported by the ALCS is for the same time period as the measured energy use. It is equally important to ensure that the energy use data reported by the ALCS includes the same lighting fixtures, and no additional loads, as the measured data. A complete description of the ALCS energy use reporting method should be provided. This information can be used to inform possible IOU efforts to use ALCS monitoring systems for reporting of energy use to use for incentive payment calculations.
Appendix A

General Best Practices for Lighting M&V

Excerpted from “Standard Measurement and Verification Plan for Lighting Retrofit Projects for Building and Building Sites”

E Richman, PNNL, May 2011
Appendix B

Sample ALCS M&V Plan

To be developed at a later date.
APPENDIX 4: MV EQUIPMENT SPECIFICATION SHEET
Revenue-grade Energy and Power Meters

The WattNode Revenue meters are designed for use in applications where revenue-grade or utility-grade accuracy is required. The WattNode Revenue meters meet the accuracy requirements of ANSI C12.1 and support Modbus®, BACnet® or LonTalk® communications protocols or a pulse output.

The WattNode Revenue marks a new level of performance for the WattNode brand of electric power meters. The WattNode Revenue electric power meters are optimized for tenant submetering in residential and commercial spaces, PV energy generation metering, UMCS metering on military bases and more.

The WattNode Revenue meters are designed for 120/208 and 277/480 Vac applications. For ANSI C12.1 accuracy, current transformers compliant with IEEE C57.13 Class 0.6 are required. Each meter is calibrated using NIST traceable equipment following the procedures specified by ANSI C12.1 metering standards and is supplied with a certificate of calibration.

<table>
<thead>
<tr>
<th>WattNode Revenue for BACnet</th>
<th>WattNode Revenue for Modbus</th>
<th>WattNode Revenue for LonWorks</th>
<th>WattNode Revenue Pulse</th>
<th>Current Transformers</th>
</tr>
</thead>
<tbody>
<tr>
<td>· Native BACnet MS/TP (RS-485)</td>
<td>· Modbus RTU protocol (RS-485)</td>
<td>· LonWorks network variables (SNIVs)</td>
<td>· Low cost, high accuracy kWh pulse output</td>
<td>· Split-core, solid-core, bus bar and mini</td>
</tr>
<tr>
<td>· Selectable serial baud rates to 76,800</td>
<td>· Supports 127 DP switch selectable addresses</td>
<td>· Logger option</td>
<td>· Bidirectional metering, (consumption and production)</td>
<td>· High accuracy model meets IEEE C57.13 Class 0.6</td>
</tr>
<tr>
<td>· Field upgradable firmware</td>
<td>· 50+ measurements (kW, kWh, volts, amps, PF, demand and more)</td>
<td>· 30+ measurements (kW, kWh, volts, amps, PF, demand and more)</td>
<td>· Single and three phase metering, (energy and power)</td>
<td>· Ranges from 15 to 400 amps</td>
</tr>
<tr>
<td>· 50+ measurements (kW, kWh, volts, amps, PF, demand and more)</td>
<td>· Pulse meter input or 5 volt control output (optional)</td>
<td>· LNS plug-in (free)</td>
<td>· 3-Single phase meters in one (optional)</td>
<td>· Safe 333 mVac output</td>
</tr>
</tbody>
</table>

• Meets ANSI C12.1 accuracy standards
• Supplied with NIST traceable certificate of calibration
• Offers bidirectional, true net metering
• 120/208-240 Vac or 277/480 Vac services
• Line powered, compact, easy to install
• Use with safe, low voltage (333 mVac) current transformers
• Available interfaces: BACnet®, LonWorks®, Modbus® or pulse output
1 Precautions

1.1 Only qualified personnel or licensed electricians should install the WattNode meter. The mains voltages of 120 to 600 Vac can be lethal!

1.2 Follow all applicable local and national electrical and safety codes.

1.3 The terminal block screws are not insulated. Do not contact metal tools to the screw terminals if the circuit is live!

1.4 Verify that circuit voltages and currents are within the proper range for the meter model.

1.5 Use only UL listed or UL recognized current transformers (CTs) with built-in burden resistors, that generate 0.333 Vac (333 millivolts AC) at rated current. Do not use current output (ratio) CTs such as 1 amp or 5 amp output CTs: they will destroy the meter and may create a shock hazard.

1.6 Protect the line voltage inputs to the meter with fuses or circuit breakers (not needed for the neutral or ground wires). See 3.3.1 below.

1.7 Equipment must be disconnected from the HAZARDOUS LIVE voltages before access.

1.8 If the meter is not installed correctly, the safety protections may be impaired.

1.9 Symbols

Read, understand, and follow all instructions including warnings and precautions before installing and using the product.

Potential Shock Hazard from Dangerous High Voltage.

Functional ground; should be connected to earth ground if possible, but is not required for safety grounding.

UL Listing mark. This shows the UL and cUL (Canadian) listing mark.

FCC Mark. This logo indicates compliance with part 15 of the FCC rules.

Complies with the regulations of the European Union for Product Safety and Electro-Magnetic Compatibility.


This indicates an AC voltage.

2 Overview

Congratulations on your purchase of the WattNode® Pulse watt/hour transducer. The WattNode meter enables you to make power and energy measurements within electric service panels avoiding the costly installation of subpanels and associated wiring. It is designed for use in demand side management (DSM), submetering, and energy monitoring applications.

2.1 Additional Literature

See the Continental Control Systems, LLC website (www.ccontrolsys.com) for product pages, datasheets, and support pages for all WattNode meter models and current transformers. Each WattNode model has an Operating and Reference Guide with detailed information on the available measurements and interface.

2.2 Electrical Service Types

Table 1 above lists the WattNode models and common circuit types. In the “Electrical Service Types” column, when two voltages are listed with a slash between them, they indicate the line-to-neutral / line-to-line voltages. The “Line-to-Neutral” and “Line-to-Line” columns show the operating ranges for the WattNode meters.

Connect the line voltages to the meter inputs as shown in the following figures for each service type. See Figure 1 above for an overview.
2.2.1 Single-Phase Two-Wire with Neutral
This is a common residential and branch circuit connection. Up to three such circuits may be monitored with one meter by also using the φB and φC inputs.

2.2.2 Single-Phase Two-Wire No Neutral
This circuit occurs in residential (commonly 120/240 Vac) and some commercial applications. The meter is powered from the φA and φB terminals. We recommend connecting the N terminal to ground to provide a clean voltage reference for the measurement circuitry (no current will flow through this terminal).

2.2.3 Single-Phase Three-Wire with Neutral
This is a common residential service at 120/240 Vac.

2.2.4 Three-Phase Three-Wire Delta No Neutral
This is common in commercial and industrial settings. In some cases, the service may be four-wire, wye but the load may only be three wire (no neutral). Occasionally, a load will only be connected to two of the three lines (say L1 and L2). For this case, connect the two active lines to the φA and φB terminals and connect two CTs for the two lines.

2.2.5 Three-Phase Four-Wire Wye with Neutral
This is a common commercial and industrial service.

2.2.6 Three-Phase Four-Wire Delta with Neutral (Wild Leg)
The uncommon four-wire delta electrical service is a three-phase delta service with a center-tap on one of the transformer windings to create a neutral for single-phase loads.

The high-leg or phase with the higher voltage as measured to neutral has traditionally been designated “Phase B”. A change to the 2008 NEC now allows the high leg of a four-wire three-phase delta service to be labeled as the “C” phase instead of the “B” phase. The WattNode meter will work correctly with the high-leg connected to φA, φB, or φC.

See the web article Four Wire Delta Circuits for more information.

2.2.7 Grounded Leg Service
In rare cases with delta services or single-phase two-wire services without neutral, one of the phases may be grounded.

The WattNode meter will correctly measure services with a grounded leg, but the measured voltage and power for the grounded phase will be zero and the status LEDs (if present) will not light for the grounded phase, because the voltage is near zero. Also, this type of service may result in unusual power factors.

See the web article Grounded Leg Services for more information.

3 Installation

3.1 Installation Checklist
See the sections referenced below for installation details.
- Mount the WattNode meter (see 3.2).
- Turn off power before making line voltage connections.
- Connect circuit breakers or fuses and disconnects (see 3.3.1).
- Connect the line voltage wires to the meter’s green terminal block (see 3.3.2).
- Mount the CTs around the line conductors. Make sure the CTs face the source (see 3.4).
- Connect the twisted white and black wires from the CTs to the black terminal block on the meter, matching the wire colors to the white and black dots on the meter label (see 3.4.1).
- Check that the CT phases match the line voltage phases (see 3.4).
- Record the CT rated current for each meter, because it will be required during commissioning.
- Connect the output terminals of the WattNode meter to the monitoring equipment (see 3.5).
- Check that all the wires are securely installed in the terminal blocks by tugging on each wire.
- Apply power to the meter.
- Verify that the LEDs indicate correct operation (see 4.2).

3.2 Mounting
- Protect the meter from temperatures below –30°C (-22°F) or above 55°C (131°F), excessive moisture, dust, salt spray, or other contamination, using a NEMA rated enclosure if necessary. The meter requires an environment no worse than pollution degree 2 (normally only non-conductive pollution; occasionally, a temporary conductivity caused by condensation).
- The meter must be installed in an electrical service panel, an enclosure, or a limited access electrical room.
- Do not use the meter as a drilling guide; the drill chuck can damage the screw terminals and metal shavings may fall into the connectors.

The meter has two mounting holes spaced 136.6 mm (5.375 in) apart (center-to-center). These mounting holes are normally obscured by the detachable screw terminals. Remove the screw terminals to mark the hole positions and mount the meter.

Self-tapping #8 sheet metal screws are included. Don’t over-tighten the screws, as long-term stress on the case can cause cracking.

3.3 Connect Voltage Terminals

3.3.1 Circuit Protection
The WattNode meter is considered “permanently connected equipment” and requires a disconnect means (circuit breaker, switch, or disconnect) and over-current protection (fuse or circuit breaker).

The meter only draws 10-30 milliamps, so the rating of any switches, disconnects, fuses, and/or circuit breakers is determined by the wire gauge, the mains voltage, and the current interrupting rating required.
• The switch, disconnect, or circuit breaker must be as close as practicable to the meter and must be easy to operate.
• Use circuit breakers or fuses rated for 20 amps or less.
• Use ganged circuit breakers when monitoring more than one line voltage.
• The circuit breakers or fuses must protect the mains terminals labeled \( \Phi_A \), \( \Phi_B \), and \( \Phi_C \). If neutral is also protected, then the overcurrent protection device must interrupt both neutral and the ungrounded conductors simultaneously.
• The circuit protection / disconnect system must meet IEC 60947-1 and IEC 60947-3, as well as all national and local electrical codes.

3.3.2 Line Wiring
• Always disconnect power before connecting the line voltage inputs to the meter.
• For the line voltage wires, CCS recommends 16 to 12 AWG stranded wire, type THHN, MTW, or THWN, 600 V.
• Do not place more than one voltage wire in a screw terminal; use separate wire nuts or terminal blocks if needed.
• Verify that the line voltages match the line-to-line \( \Phi - \Phi \) and line-to-neutral \( \Phi - N \) values printed in the white box on the front label.

Connect each line voltage to the appropriate phase; also connect ground and neutral (if applicable). The neutral connection “N” is not required on delta models (3D-240, 3D-400, and 3D-480), but we recommend connecting it to ground if neutral is not present.

The screw terminals handle wire up to 12 AWG. Connect each voltage line to the green terminal block as shown in Figure 1 above. After the voltage lines have been connected, make sure both terminal blocks are fully seated in the meter.

When power is first applied, check that the LEDs behave normally: on models with status LEDs, if you see them flashing red-green-red-green (see Figure 7), the line voltage is too high for this model, so disconnect the power immediately!

3.3.3 Grounding
The WattNode uses a plastic enclosure, insulation, and internal isolation barriers instead of protective earthing. The ground terminal on the green screw terminal block must interrupt both neutral and the ungrounded conductors simultaneously.

3.4 Connect Current Transformers
To meet the UL listing requirements, the WattNode meter may only be used with the following UL listed or UL recognized voltage output current transformer models. These all generate 333.33 millivolts AC at rated current. See the current transformer datasheets for CT ratings.

| ACT-0750-xxx | CTT-0750-xxx | CTTM-0360-xxx |
| CTM-0360-xxx | CTTS-1250-xxx | CTM-2000-xxx |
| CTT-0750-xxx | CTTS-2000-xxx | CTT-0300-xxx |
| CTT-0500-xxx | CTT-0750-xxx | CTT-1000-xxx |
| CTT-1250-xxx |

• “xxx” indicates the full scale current rating.
• “www” and “hhh” indicate the width and height in inches.
• “dddd” indicates the opening diameter of the loop for flexible Rogowski CTs.

See the web article Selecting Current Transformers for information on selecting appropriate current transformers (CTs).

• Do not use ratio or current output CTs such as 1 amp or 5 amp output models!
• See the CT datasheets for the maximum input current ratings.
• Be careful to match the CTs with the voltage phases. Make sure the \( \Phi_A \) CT is measuring the current on the same phase being monitored by \( \Phi_A \), and the same for phases B and C. Use the supplied colored labels or colored tape to identify the CT leads.
• To minimize current measurement noise, avoid extending the CT wires, especially in noisy environments. If it is necessary to extend the wires, use twisted pair wire 22 to 14 AWG, rated for 300 V or 600 V (not less than the service voltage) and shielded if possible.
• Find the source arrow or label “THIS SIDE TOWARD SOURCE” on the CT and face/point toward the source of current.
• OPTIONAL: if you see spurious readings on unused phases, jumper the unused CT inputs: for each unused CT, connect a short wire from the terminal marked with a white dot to the terminal marked with a black dot.

To install the CTs, pass the conductor to be measured through the CT and connect the CT leads to the meter. Always remove power before disconnecting any live conductors. Put the line conductors through the CTs as shown in Figure 1 above.

CTs are directional. If they are mounted backwards or with their white and black wires swapped the measured power will be negative. The status LEDs indicate negative measured power by flashing red.

Split-core CTs can be opened for installation around a conductor. A nylon cable tie may be secured around the CT to prevent inadvertent opening.

3.4.1 CT Wiring
Connect the white and black CT wires to the meter terminals marked \( \Phi_A \) CT, \( \Phi_B \) CT, and \( \Phi_C \) CT (see Figure 1 above). Excess length may be trimmed from the wires if desired. The current transformers connect to the six position black screw terminal block. Connect each CT with the white wire aligned with the white dot on the label, and the black wire aligned with the black dot. Note the order in which the phases are connected, as the line voltage phases must match the current phases for accurate power measurement.

3.5 Connect the Output Signals
• The meter outputs are isolated from dangerous voltages, so you can connect them at any time.
• If the output wiring is near line voltage wiring, use wires or cables with a 300 V or 600 V rating (not less than the service voltage).
• If the output wiring is near bare conductors, it should be double insulated or jacketed.
• You may install two wires into each screw terminal by twisting the wires together, inserting them into terminal, and securely tightening. Note: a loose wire can disable an entire network section.
• Use twisted-pair cable (unshielded or shielded) to prevent interference.

3.5.1 WattNode Pulse Outputs
Use the following directions when connecting the pulse outputs of a WattNode Pulse meter.

• The outputs P1, P2, and P3 should not be connected to negative voltages, or to voltages greater than +60 Vdc.
• For long distances, use shielded twisted-pair cable to prevent interference. With shielded cable, connect the shield to earth ground at one end.
• If you need to add pull-up resistors, see the Operating and Reference Guide.

The WattNode pulse outputs may be connected to most devices that expect a contact closure or relay input. See the Operating and Reference Guide for more complex connection information.

The following table shows the pulse output channel assignments for the standard bidirectional outputs and for the optional per-phase outputs (Option P3).

<table>
<thead>
<tr>
<th>Pulse Output</th>
<th>P1 Output</th>
<th>P2 Output</th>
<th>P3 Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Outputs - Bidirectional</td>
<td>Positive energy - all phases</td>
<td>Negative energy - all phases</td>
<td>Not used</td>
</tr>
<tr>
<td>Option P3 Per-Phase Outputs</td>
<td>Phase A positive energy</td>
<td>Phase B positive energy</td>
<td>Phase C positive energy</td>
</tr>
<tr>
<td>Option PV Photovoltaic</td>
<td>Phase A+B pos. energy</td>
<td>Phase A+B neg. energy</td>
<td>Phase C positive energy</td>
</tr>
<tr>
<td>Option DPO Dual Positive Outputs</td>
<td>Positive energy - all phases</td>
<td>Negative energy - all phases</td>
<td>Positive energy - all phases</td>
</tr>
</tbody>
</table>

Table 2: Pulse Output Assignments
4 Operation

4.1 Initial Configuration

For WattNode Pulse meters, the only required configuration will be in the data logger or pulse counting device, which must be configured with the correct scale factors to convert from pulses to energy (kWh).

For details on configuring the WattNode meter, see the appropriate Operating and Reference Guide for your model.

The meter does not include a display or buttons, so it is not possible to configure or monitor the meter directly, other than the basic LED diagnostics described below.

4.2 Power Status LEDs

The three status LEDs on the front of the meter can help indicate correct operation. The “A”, “B”, and “C” on the diagrams indicate the three phases.

4.2.1 Normal Startup

The meter displays the following startup sequence whenever power is first applied.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Red</td>
<td>Yellow</td>
</tr>
<tr>
<td>B</td>
<td>Red</td>
<td>Yellow</td>
</tr>
<tr>
<td>C</td>
<td>Red</td>
<td>Yellow</td>
</tr>
<tr>
<td></td>
<td>1.0sec</td>
<td>1.0sec</td>
</tr>
</tbody>
</table>

4.2.2 Positive Power

Any phase with the LEDs flashing green is indicating normal positive power.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Green</td>
<td>Off</td>
</tr>
</tbody>
</table>

4.2.3 No Power

Any phase with a solid green LED indicates no power, but line voltage is present.

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
</tr>
</tbody>
</table>

4.2.4 No Voltage

Any phase LED that is off indicates no voltage on that phase.

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Off</td>
</tr>
</tbody>
</table>

4.2.5 Negative Power

Red flashing indicates negative power for that phase. Reversed CTs, swapped CT wires, or CTs not matched with line voltage phases can cause this.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Red</td>
<td>Off</td>
</tr>
</tbody>
</table>

4.2.6 Overvoltage Warning

The following indicates that the line voltage is too high for this model. Disconnect power immediately! Check the line voltages and the meter ratings (in the white box on the label).

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>R</td>
<td>G</td>
</tr>
<tr>
<td>B</td>
<td>R</td>
<td>G</td>
</tr>
<tr>
<td>C</td>
<td>R</td>
<td>G</td>
</tr>
<tr>
<td></td>
<td>1.0sec</td>
<td></td>
</tr>
</tbody>
</table>

4.2.7 Meter Not Operating

If none of the LEDs light, then check that the correct line voltages are applied to the meter. If the voltages are correct, call customer service for assistance.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Off</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Off</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Off</td>
<td></td>
</tr>
</tbody>
</table>

4.2.8 WattNode Error

If the meter experiences an internal error, it will light all LEDs red for three or more seconds. If you see this happen repeatedly, return the meter for service.

For other LED patterns, see the Operating and Reference Guide or contact support for assistance.

4.3 Monitoring

The meter does not include a display or buttons, so it is not possible to operate the meter directly. The following is a brief overview of the possible remote monitoring.

The WattNode Pulse models uses optoisolator outputs that simulate contact closures. These are generally connected to a datalogger or similar monitoring device which can count pulses to measure energy. See the Operating and Reference Guide for equations to scale pulse counts and frequencies to energy and power.

4.4 Maintenance and Repair

The WattNode meter requires no maintenance. It is not user serviceable and there are no replaceable parts except the pluggable screw terminals. There are no diagnostic tests that can be performed by the user, other than checking for errors via the status LEDs.

In the event of any failure, the meter must be returned for service (contact CCS for an RMA). For a new installation, follow the diagnostic and troubleshooting instructions in the Operating and Reference Guide before returning the meter for service, to ensure that the problem is not connection related.

The WattNode meter should not normally need to be cleaned, but if cleaning is desired, power must be disconnected first and a dry or damp cloth or brush should be used.

5 Specifications

The following is a list of basic specifications. For extended specifications, see the Operating and Reference Guide.

5.1 Accuracy

The following accuracy specifications do not include errors caused by the current transformer accuracy or phase angle errors. “Rated current” is the current that generates a CT output voltage of 0.33333 Vac.

5.1.1 Normal Operation

- Line voltage: -20% to +15% of nominal
- Power factor: 1.0
- Frequency: 48 - 62 Hz
- Ambient Temperature: 23°C ± 5°C
- CT Current: 5% - 100% of rated current

Accuracy: ±0.5% of reading

For accuracy at other conditions, see the reference guide.

5.2 Measurement

Update Rate: Internally, all measurements are performed at this rate.
- ~200 milliseconds

Start-Up Time: the meter starts measuring power/energy and reporting measurements or generating pulses this long after AC voltage is applied
- ~500 milliseconds

Default CT Phase Angle Correction: 0.0 degrees.
5.3 Models and Electrical Specifications

The service “3Y-208” applies to the model WNB-3Y-208-P, RWNB-3Y-208-P, and so on for the other service types.

<table>
<thead>
<tr>
<th>Service</th>
<th>Nominal Vac Line-to-Neutral</th>
<th>Nominal Vac Line-to-Line</th>
<th>Phases</th>
<th>Wires</th>
</tr>
</thead>
<tbody>
<tr>
<td>3Y-208</td>
<td>120</td>
<td>208–240</td>
<td>1-3</td>
<td>2-4</td>
</tr>
<tr>
<td>3Y-400</td>
<td>230</td>
<td>400</td>
<td>1-3</td>
<td>2-4</td>
</tr>
<tr>
<td>3Y-480</td>
<td>277</td>
<td>480</td>
<td>1-3</td>
<td>2-4</td>
</tr>
<tr>
<td>3Y-600</td>
<td>347</td>
<td>600</td>
<td>1-3</td>
<td>2-4</td>
</tr>
<tr>
<td>3D-240</td>
<td>120*</td>
<td>208–240</td>
<td>1-3</td>
<td>2-4</td>
</tr>
<tr>
<td>3D-400</td>
<td>230*</td>
<td>400</td>
<td>3</td>
<td>2-4</td>
</tr>
<tr>
<td>3D-480</td>
<td>277*</td>
<td>480</td>
<td>3</td>
<td>2-4</td>
</tr>
</tbody>
</table>

Table 3: WattNode Model Service Typess

*Note: the delta models have an optional neutral connection that may be used for measuring wye circuits. In the absence of neutral, voltages are measured with respect to ground. Delta WattNode models use the phase A and phase B connections for power.

Over-Voltage Limit: 125% of nominal Vac. Extended over-voltage operation can damage the WattNode and void the warranty.

Over-Current Limit: 120% of rated current. Exceeding 120% of rated current will not harm the WattNode meter but the current and power will not be measured accurately.

Maximum Surge: 4kV according to EN 61000-4-5

Power Consumption: The following tables show maximum volt-amperes, the power supply ranges, typical power consumption, and typical power factor values with all three phases powered at nominal line voltages. The power supply draws most of the total power consumed, while the measurement circuitry draws 1-10% of the total (6-96 milliwatts per phase, depending on the model). Due to the design of the power supply, WattNode meters draw slightly more power at 50 Hz.

<table>
<thead>
<tr>
<th>Service</th>
<th>Rated VA ( \text{VA} )</th>
<th>Power Supply Range (Vac)</th>
<th>Power Supply Terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>3Y-208</td>
<td>4 VA</td>
<td>96 – 138</td>
<td>N and ( \Phi A )</td>
</tr>
<tr>
<td>3Y-400</td>
<td>4 VA</td>
<td>184 – 264</td>
<td>N and ( \Phi A )</td>
</tr>
<tr>
<td>3Y-480</td>
<td>4 VA</td>
<td>222 – 318</td>
<td>N and ( \Phi A )</td>
</tr>
<tr>
<td>3Y-600</td>
<td>4 VA</td>
<td>278 – 399</td>
<td>N and ( \Phi A )</td>
</tr>
<tr>
<td>3D-240</td>
<td>3 VA</td>
<td>166 – 276</td>
<td>( \Phi A ) and ( \Phi B )</td>
</tr>
<tr>
<td>3D-400</td>
<td>3 VA</td>
<td>320 – 460</td>
<td>( \Phi A ) and ( \Phi B )</td>
</tr>
<tr>
<td>3D-480</td>
<td>3 VA</td>
<td>384 – 552</td>
<td>( \Phi A ) and ( \Phi B )</td>
</tr>
</tbody>
</table>

Table 4: Service Volt-Amperes and Power Supply Range

\( ^{\text{Note:}} \) The Rated VA is the maximum at 115% of nominal Vac at 50 Hz. This is the same as the value that appears on the front label of the meter.

<table>
<thead>
<tr>
<th>Service</th>
<th>Real Power (60 Hz)</th>
<th>Real Power (50 Hz)</th>
<th>Power Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>3Y-208</td>
<td>1.6 W</td>
<td>1.8 W</td>
<td>0.75</td>
</tr>
<tr>
<td>3Y-400</td>
<td>1.6 W</td>
<td>1.8 W</td>
<td>0.64</td>
</tr>
<tr>
<td>3Y-480</td>
<td>2.1 W</td>
<td>2.4 W</td>
<td>0.63</td>
</tr>
<tr>
<td>3Y-600</td>
<td>1.2 W</td>
<td>1.2 W</td>
<td>0.47</td>
</tr>
<tr>
<td>3D-240</td>
<td>1.7 W</td>
<td>1.9 W</td>
<td>0.63</td>
</tr>
<tr>
<td>3D-400</td>
<td>1.4 W</td>
<td>1.5 W</td>
<td>0.47</td>
</tr>
<tr>
<td>3D-480</td>
<td>1.8 W</td>
<td>2.2 W</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Table 5: Power Consumption

Maximum Power Supply Voltage Range: -20% to +15% of nominal (see table above). For the 3D-240 service, this is -20% of 208 Vac (166 Vac) to +15% of 240 Vac (276 Vac).

Operating Frequencies: 50/60 Hz

Measurement Category: CAT III

Measurement category III is for measurements performed in the building installation. Examples are measurements on distribution boards, circuit-breakers, wiring, including cables, bus-bars, junction boxes, switches, socket-outlets in the fixed installation, and equipment for industrial use and some other equipment, for example, stationary motors with permanent connection to the fixed installation.

The line voltage measurement terminals on the meter are rated for the following CAT III voltages (these ratings appear on the front label):

<table>
<thead>
<tr>
<th>Service</th>
<th>CAT III Voltage Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>3Y-208</td>
<td>240 Vac</td>
</tr>
<tr>
<td>3D-240</td>
<td>400 Vac</td>
</tr>
<tr>
<td>3Y-400</td>
<td>480 Vac</td>
</tr>
<tr>
<td>3D-400</td>
<td>600 Vac</td>
</tr>
</tbody>
</table>

Table 6: WattNode CAT III Ratings

Current Transformer Inputs:
Nominal Input Voltage (At CT Rated Current): 0.3333 Vac RMS
Absolute Maximum Input Voltage: 5.0 Vac RMS
Input Impedance at 50/60 Hz: 23 kΩ

5.4 Pulse Outputs

Full-Scale Pulse Frequencies:
Standard (All Models): 4.00 Hz
Custom (Bidirectional): 0.01 Hz to 600 Hz
Custom (Option P3, Option PV, Option DPO): 0.01 Hz to 150 Hz

Absolute Maximum Pulse Output Frequencies:
Standard Models (Bidirectional): 900 Hz
Option P3, Option PV, Option DPO: 200 Hz

Output Waveform: square-wave, ~50% duty cycle
Option PW: programmable pulse ON (closed or conducting period, 1 to 65535 milliseconds)

Optoisolator Outputs:
Isolation: 5000 Vac RMS
Breakdown Voltage (collector–emitter): 60 V (exceeding this may destroy the outputs)
Maximum Reverse Voltage (emitter-collector): 5 Vdc (exceeding may destroy the outputs)
Maximum Leakage (OFF) Current (collector–emitter): 100 nA
Recommended Load Current (collector–emitter): 1 μA (microamp) to 5 mA (milliamp)
Maximum Load Current: ~8 mA

5.5 Certifications

Safety:
- UL 61010-1
- CAN/CSA-C22.2 No. 61010-1-04
- IEC 61010-1

Immunity:
- EN 61326: 2002 (Industrial Locations)
- EN 61000-4-2
- EN 61000-4-3
- EN 61000-4-4
- EN 61000-4-5
- EN 61000-4-6

Voltage Dips, Interrupts:
- EN 61000-4-11

Emissions:
- FCC Part 15, Class B
- EN 55022: 1994, Class B

5.6 Environmental

Operating Temperature: -30°C to +55°C (-22°F to 131°F)
Altitude: Up to 2000 m (6560 ft)
Operating Humidity: non-condensing, 5 to 90% relative humidity (RH) up to 40°C, decreasing linearly to 50% RH at 55°C

Pollution: POLLUTION DEGREE 2 - Normally only non-conductive pollution; occasionally, a temporary conductivity caused by condensation must be expected.

Indoor Use: Suitable for indoor use.
Outdoor Use: Suitable for outdoor use if mounted inside an electrical enclosure (Hammond Mfg., Type EJ Series) rated NEMA 3R or 4 (IP 66).

5.7 Mechanical

Enclosure: High impact, ABS/PC plastic

Flame Resistance Rating: UL 94V-0, IEC FV-0

Size: 153 mm × 85 mm × 38 mm (6.02 in × 3.35 in × 1.50 in)

Connectors: Euroblock pluggable terminal blocks

Green: up to 12 AWG (2.5 mm²), 600 V

Black: up to 12 AWG (2.5 mm²), 300 V

5.8 FCC Information

This equipment has been tested and complies with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

The FCC limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

5.9 Warranty

All products sold by Continental Control Systems, LLC (CCS) are guaranteed against defects in material and workmanship for a period of five years from the original date of shipment. CCS’s responsibility is limited to repair, replacement, or refund, any of which may be selected by CCS at its sole discretion. CCS reserves the right to substitute functionally equivalent new or serviceable used parts.

WattNode Logger models include a lithium battery to preserve the date and time during power failures. CCS will replace or provide a replacement battery at no charge if the battery fails within five years from the original date of shipment.

This warranty covers only defects arising under normal use and does not include malfunctions or failures resulting from: misuse, neglect, improper application, improper installation, water damage, acts of nature, lightning, product modifications, alterations or repairs by anyone other than CCS.

Except as set forth herein, CCS makes no warranties, expressed or implied, and CCS disclaims and negates all other warranties, including without limitation, implied warranties of merchantability and fitness for a particular purpose.

5.10 Limitation of Liability

In no event shall CCS be liable for any indirect, special, incidental, punitive or consequential damages of any kind or nature arising out of the sale or use of its products whether such liability is asserted on the basis of contract, tort or otherwise, including without limitation, lost profits, even if CCS has been advised of the possibility of such damages.

Customer acknowledges that CCS’s aggregate liability to Customer relating to or arising out of the sale or use of CCS’s products, whether such liability is asserted on the basis of contract, tort or otherwise, shall not exceed the purchase price paid by Customer for the products in respect of which damages are claimed. Customer specifically acknowledges that CCS’s price for the products is based upon the limitations of CCS’s liability set forth herein.

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Document Number: WN-Inst-P-1.01
Revision Date: April 18, 2013

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(303) 444-7422, http://www.ccontrolsys.com

• WattNode is a registered trademark of Continental Control Systems, LLC.
WattNode® Pulse
Installation and Operation Manual

- WNB-3Y-208-P
- WNB-3Y-400-P
- WNB-3Y-480-P
- WNB-3Y-600-P
- WNB-3D-240-P
- WNB-3D-400-P
- WNB-3D-480-P
FCC Information

This equipment has been tested and complies with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

The FCC limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician to help.
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Overview

Congratulations on your purchase of the WattNode® Pulse watt/watt-hour transducer/meter. It accurately measures energy and power in a compact package. The WattNode meter can fit in existing electric service panels avoiding the costly installation of sub-panels and associated wiring. It is designed for use in demand side management (DSM), sub-metering, and energy monitoring applications. The WattNode meter generates pulses proportional to total watt-hours. The pulse rate or frequency is proportional to the instantaneous power. Models are available for single-phase and three-phase, wye and delta configurations for voltages from 120 Vac to 600 Vac at 50 and 60 Hz.

Pulse Outputs

The WattNode meter generates pulse outputs using one or more optoisolators (also called photocouplers). These provide 5000 Vac of electrical isolation. The pulse outputs can interface to monitoring or data logging hardware without concerns about interference, ground loops, shock hazard, etc.

The standard Pulse WattNode meter makes bidirectional power measurements (energy consumption and energy production). It can be used for conventional power and energy measurement as well as for net metering and photovoltaic (PV) applications.

- **Option P3** - The per-phase measurement option measures one, two, or three separate branch circuits with a single meter, saving money and space.
- **Option PV** - The photovoltaic option measures residential PV systems. One WattNode meter measures the bidirectional total house energy, and the PV (or wind) generated energy. See Manual Supplement MS-10: Option PV (Photovoltaic) for details.
- **Options DPO** - The dual positive outputs option behaves exactly like the standard bidirectional model, but with the addition of a second positive pulse output channel (on the P3 output terminal). This allows you to connect to two devices, such as a display and a data logger. See Manual Supplement MS-11: Option DPO (Dual Positive Outputs) for details.

See Model Options (p. 30) in the Specifications section below for details and more options.

Diagnostic LEDs

The Pulse WattNode meter includes three diagnostic LEDs—one per phase. During normal operation, these LEDs flash on and off, with the speed of flashing roughly proportional to the power on each phase. The LEDs flash green for positive power and red for negative power. Other conditions are signaled with different LED patterns. See the Installation LED Diagnostics (p. 20) section for full details.

Current Transformers

The WattNode meter uses solid-core (toroidal), split-core (opening), and bus-bar style current transformers (CTs) with a full-scale voltage output of 0.33333 Vac. Split-core and bus-bar CTs are easier to install without disconnecting the circuit being measured. Solid-core CTs are more compact, generally more accurate, and less expensive, but installation requires that you disconnect the circuit to install the CTs.

Additional Literature

- WattNode Advanced Pulse - Quick Install Guide
- Manual Supplement MS-10: Option PV (Photovoltaic)
- Manual Supplement MS-11: Option DPO (Dual Positive Outputs)
- Manual Supplement MS-17: Option PW (Pulse Width)
- Manual Supplement MS-19: Option SSR (Solid-State Relay)
Front Label

This section describes all the connections, information, and symbols that appear on the front label.

Figure 1: Front Label Diagram

A: WattNode model number. The “WNB” indicates a second generation WattNode meter with diagnostic LEDs and up to three pulse output channels. The “3” indicates a three-phase model. The “Y” or “D” indicates wye or delta models, although delta models can measure wye circuits (the difference is in the power supply). The “208” (or other value) indicates the nominal line-to-line voltage. Finally, the “P” indicates pulse output.

B: Functional ground. This terminal should be connected to earth ground if possible. It is not required for safety grounding, but ensures maximum meter accuracy.

C: Neutral. This terminal “N” should be connected to neutral when available.

D, E, F: Line voltage inputs. These terminals connect to the $\phi A$ (phase A), $\phi B$ (phase B), and $\phi C$ (phase C) electric mains. On wye models the meter is powered from $\phi A$ and $N$ terminals. On delta models, the meter is powered from the $\phi A$ and $\phi B$ terminals.

G: Line voltage measurement ratings. This block lists the nominal line-to-neutral “$\phi-N$ 120V~” voltage, line-to-line “$\phi-\phi$ 240V~” voltage, and the rated measurement voltage and category “240V CAT III” for this WattNode model. See the Specifications (p. 30) for more information about the measurement voltage and category.

H: UL Listing mark. This shows the UL and cUL (Canadian) listing mark and number “3KNN”.

I: FCC Mark. This logo indicates that the meter complied with part 15 of the FCC rules.

J: Status LEDs. These are status LEDs used to verify and diagnose meter operation. See Installation LED Diagnostics (p. 20) for details.

K: Current transformer (CT) voltage rating. These markings “0.333V~” indicate that the meter must be used with CTs that generate a full-scale output of 0.333 Vac (333 millivolts).
M, N, O: Current transformer (CT) inputs. These indicate CT screw terminals. Note the white and black circles at the left edge of the label: these indicate the color of the CT wire that should be inserted into the corresponding screw terminal. The terminals marked with black circles are connected together internally.

P: Pulse output common (COM). This is the common terminal for all three pulse output channels. This terminal should be more negative than the P1, P2, and P3 terminals (unless the meter was ordered with Option SSR).

Q, R, S: Pulse outputs (P1, P2, P3). These are the pulse output channels. Different models use one, two, or three channels. They should always be positive relative to the common terminal.

T: Serial number. This shows the meter serial number and options if any are selected. The barcode contains the serial number in Code 128C format.

U: Mains supply rated voltage. This is the rated supply voltage for this model. The V~ indicates AC voltage. For wye models, this voltage should appear between the N and ØA terminals. For delta models, this voltage should appear between the ØA and ØB terminals.

V: Mains frequencies. This indicates the rated mains frequencies for the meter.

W: Maximum rated power. This is the maximum power consumption (watts) for this model.

X: Manufacture date. This is the date of manufacture for the WattNode meter.

Y: Caution, risk of electrical shock. This symbol indicates that there is a risk of electric shock when installing and operating the meter if the installation instructions are not followed correctly.

Z: Attention - consult Manual. This symbol indicates that there can be danger when installing and operating the meter if the installation instructions are not followed correctly.

Symbols

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>!</td>
<td>Attention - Consult Installation and Operation Manual</td>
</tr>
<tr>
<td></td>
<td>Read, understand, and follow all instructions in this Installation and Operation Manual including all warnings, cautions, and precautions before installing and using the product.</td>
</tr>
<tr>
<td>⚠</td>
<td>Caution – Risk of Electrical Shock</td>
</tr>
<tr>
<td></td>
<td>Potential Shock Hazard from Dangerous High Voltage.</td>
</tr>
<tr>
<td>CE</td>
<td>CE Marking</td>
</tr>
<tr>
<td></td>
<td>Complies with the regulations of the European Union for Product Safety and Electro-Magnetic Compatibility.</td>
</tr>
<tr>
<td></td>
<td>• Low Voltage Directive – EN 61010-1: 2001</td>
</tr>
</tbody>
</table>
Precautions

Always adhere to the following checklist:

1) Only qualified personnel or licensed electricians should install the WattNode meter. The mains voltages of 120 Vac to 600 Vac can be lethal!
2) Follow all applicable local and national electrical and safety codes.
3) Install the meter in an electrical enclosure (panel or junction box) or in a limited access electrical room.
4) Verify that circuit voltages and currents are within the proper range for the meter model.
5) Use only UL recognized current transformers (CTs) with built-in burden resistors, that generate 0.333 Vac (333 millivolts AC) at rated current. Do not use current output (ratio) CTs such as 1 amp or 5 amp output CTs: they will destroy the meter and may create a shock hazard. See Current Transformers (p. 35) for CT maximum input current ratings.
6) Ensure that the line voltage inputs to the meter are protected by fuses or circuit breakers (not needed for the neutral wire). See Circuit Protection (p. 16) for details.
7) Equipment must be disconnected from the HAZARDOUS LIVE voltages before access.
8) The terminal block screws are not insulated. Do not contact metal tools to the screw terminals if the circuit is live!
9) Do not place more than one line voltage wire in a screw terminal; use wire nuts instead. You may use more than one CT wire per screw terminal.
10) Before applying power, check that all the wires are securely installed by tugging on each wire.
11) Do not install the meter where it may be exposed to temperatures below –30°C or above 55°C, excessive moisture, dust, salt spray, or other contamination. The meter requires an environment no worse than pollution degree 2 (normally only non-conductive pollution; occasionally, a temporary conductivity caused by condensation must be expected).
12) Do not drill mounting holes using the meter as a guide; the drill chuck can damage the screw terminals and metal shavings can fall into the connectors, causing an arc risk.
13) If the meter is installed incorrectly, the safety protections may be impaired.
Electrical Service Types

Below is a list of service types, with connections and recommended models. Note: the ground connection improves measurement accuracy, but is not required for safety.

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>Line-to-Neutral</th>
<th>Line-to-Line</th>
<th>Electrical Service Types</th>
</tr>
</thead>
</table>
| WNB-3Y-208-P| Wye          | 120 Vac         | 208–240 Vac  | 1 Phase 2 Wire 120V with neutral  
1 Phase 3 Wire 120V/240V with neutral  
3 Phase 4 Wire Wye 120V/208V with neutral |
| WNB-3Y-400-P| Wye          | 230 Vac         | 400 Vac      | 1 Phase 2 Wire 230V with neutral  
3 Phase 4 Wire Wye 230V/400V with neutral |
| WNB-3Y-480-P| Wye          | 277 Vac         | 480 Vac      | 3 Phase 4 Wire Wye 277V/480V with neutral  
1 Phase 2 Wire 277V with neutral |
| WNB-3Y-600-P| Wye          | 347 Vac         | 600 Vac      | 3 Phase 4 Wire Wye 347V/600V with neutral |
| WNB-3D-240-P| Delta or Wye | 120–140 Vac     | 208–240 Vac  | 1 Phase 2 Wire 208V (no neutral)  
1 Phase 2 Wire 240V (no neutral)  
1 Phase 3 Wire 120V/240V with neutral  
3 Phase 3 Wire Delta 208V (no neutral)  
3 Phase 4 Wire Wye 120V/208V with neutral  
3 Phase 4 Wire Delta 120/208/240V with neutral |
| WNB-3D-400-P| Delta or Wye | 230 Vac         | 400 Vac      | 3 Phase 3 Wire Delta 400V (no neutral)  
3 Phase 4 Wire Wye 230V/400V with neutral |
| WNB-3D-480-P| Delta or Wye | 277 Vac         | 480 Vac      | 3 Phase 3 Wire Delta 480V (no neutral)  
3 Phase 4 Wire Wye 277V/480V with neutral  
3 Phase 4 Wire Delta 240/415/480V with neutral |

*The wire count does NOT include ground. It only includes neutral (if present) and phase wires.

**Table 1: WattNode Models**

**Single-Phase Two-Wire with Neutral**

This configuration is most often seen in homes and offices. The two conductors are neutral and line. For these models, the meter is powered from the N and φA terminals.
**Recommended WattNode Models**

The following table shows the WattNode models that should be used, depending on the line to neutral voltage.

<table>
<thead>
<tr>
<th>Line to Neutral Voltage</th>
<th>WattNode Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 Vac</td>
<td>WNB-3Y-208-P</td>
</tr>
<tr>
<td>230 Vac</td>
<td>WNB-3Y-400-P</td>
</tr>
<tr>
<td>277 Vac</td>
<td>WNB-3Y-480-P</td>
</tr>
</tbody>
</table>

**Single-Phase Three-Wire (Mid-Point Neutral)**

This configuration is seen in North American residential and commercial service with 240 Vac for large appliances. The three conductors are a mid-point neutral and two line voltage wires with AC waveforms 180° out of phase; this results in 120 Vac between either line conductors (phase) and neutral, and 240 Vac (or sometimes 208 Vac) between the two line conductors (phases).

![Figure 3: Single-Phase Three-Wire Connection](image)

**Recommended WattNode Models**

The following table shows the WattNode models that can be used. If neutral may or may not be present, you should use the WNB-3D-240-P (see **Single-Phase Two-Wire without Neutral** below). If neutral is present, it must be connected for accurate measurements. If phase B may not be present, you should use the WNB-3Y-208-P (see **Single-Phase Two-Wire with Neutral** above).

<table>
<thead>
<tr>
<th>Meter Power Source</th>
<th>WattNode Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>N and φA (Neutral and Phase A)</td>
<td>WNB-3Y-208-P</td>
</tr>
<tr>
<td>φA and φB (Phase A and Phase B)</td>
<td>WNB-3D-240-P</td>
</tr>
</tbody>
</table>
Single-Phase Two-Wire without Neutral

This is seen in residential and commercial service with 208 to 240 Vac for large appliances. The two conductors have AC waveforms 120° or 180° out of phase. Neutral is not used. For this configuration, the meter is powered from the ΦA and ΦB (phase A and phase B) terminals.

For best accuracy, we recommend connecting the N (neutral) terminal to the ground terminal. This will not cause ground current to flow because the neutral terminal does not power the meter.

Figure 4: Single-Phase Two-Wire without Neutral Connection

Recommended WattNode Model

This configuration is normally measured with the following WattNode model.

<table>
<thead>
<tr>
<th>Line-to-Line Voltage</th>
<th>WattNode Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>208 - 240 Vac</td>
<td>WNB-3D-240-P</td>
</tr>
</tbody>
</table>

If neutral is available, you may also use the WNB-3Y-208-P model. If you use the WNB-3Y-208-P, you will need to hook up the meter as shown in section Single-Phase Three-Wire (Mid-Point Neutral) and connect neutral. You will need two CTs.

If one of the conductors (phase A or phase B) is grounded, see Grounded Leg Service below for recommendations.
Three-Phase Four-Wire Wye

This is typically seen in commercial and industrial environments. The conductors are neutral and three power lines with AC waveforms shifted 120° between phases. The line voltage conductors may be connected to the $\phi_A$, $\phi_B$, and $\phi_C$ terminals in any order, so long as the CTs are connected to matching phases. It is important that you connect N (neutral) for accurate measurements. For wye “-3Y” models, the meter is powered from the N and $\phi_A$ terminals.

Figure 5: Three-Phase Four-Wire Wye Connection

Recommended WattNode Models

The following table shows the WattNode models that should be used, depending on the line-to-neutral voltage and line-to-line voltage (also called phase-to-phase voltage).

<table>
<thead>
<tr>
<th>Line-to-Neutral Voltage</th>
<th>Line-to-Line Voltage</th>
<th>WattNode Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 Vac</td>
<td>208 Vac</td>
<td>WNB-3Y-208-P</td>
</tr>
<tr>
<td>230 Vac</td>
<td>400 Vac</td>
<td>WNB-3Y-400-P</td>
</tr>
<tr>
<td>277 Vac</td>
<td>480 Vac</td>
<td>WNB-3Y-480-P</td>
</tr>
<tr>
<td>347 Vac</td>
<td>600 Vac</td>
<td>WNB-3Y-600-P</td>
</tr>
</tbody>
</table>

Note: you may also use the following delta WattNode models to measure three-phase four-wire wye circuits. The only difference is that delta WattNode models are powered from $\phi_A$ and $\phi_B$, rather than N and $\phi_A$. If neutral is present, it must be connected for accurate measurements.

<table>
<thead>
<tr>
<th>Line-to-Neutral Voltage</th>
<th>Line-to-Line Voltage</th>
<th>WattNode Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 - 140 Vac</td>
<td>208 - 240 Vac</td>
<td>WNB-3D-240-P</td>
</tr>
<tr>
<td>230 Vac</td>
<td>400 Vac</td>
<td>WNB-3D-400-P</td>
</tr>
<tr>
<td>277 Vac</td>
<td>480 Vac</td>
<td>WNB-3D-480-P</td>
</tr>
</tbody>
</table>
Three-Phase Three-Wire Delta Without Neutral

This is typically seen in manufacturing and industrial environments. There is no neutral wire, just three power lines with AC waveforms shifted 120° between the successive phases. With this configuration, the line voltage wires may be connected to the $\phi_A$, $\phi_B$, and $\phi_C$ terminals in any order, so long as the CTs are connected to matching phases. For these models, the meter is powered from the $\phi_A$ and $\phi_B$ (phase A and phase B) terminals. Note: all delta WattNode models provide a neutral connection $N$, which allows delta WattNode models to measure both wye and delta configurations.

For best accuracy, we recommend connecting the $N$ (neutral) terminal to earth ground. This will not cause ground current to flow because the neutral terminal is not used to power the meter.

![Figure 6: Three-Phase Three-Wire Delta Connection](image)

Recommended WattNode Models

The following table shows the WattNode models that should be used, depending on the line-to-line voltage (also called phase-to-phase voltage).

<table>
<thead>
<tr>
<th>Line-to-Line Voltage</th>
<th>WattNode Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>208 - 240 Vac</td>
<td>WNB-3D-240-P</td>
</tr>
<tr>
<td>400 Vac</td>
<td>WNB-3D-400-P</td>
</tr>
<tr>
<td>480 Vac</td>
<td>WNB-3D-480-P</td>
</tr>
</tbody>
</table>

Three-Phase Four-Wire Delta (Wild Leg)

The uncommon four-wire delta electrical service is a three-phase delta service with a center-tap on one of the transformer windings to create a neutral for single-phase loads.

See [http://www.ccontrolsys.com/w/Four_Wire_Delta_Circuits](http://www.ccontrolsys.com/w/Four_Wire_Delta_Circuits) for details.

Grounded Leg Service

In rare cases with delta services or single-phase two-wire services without neutral, one of the phases may be grounded. You can check for this by using a multimeter (DMM) to measure the voltage between each phase and ground. If you see a reading between 0 and 5 Vac, that leg is probably grounded (sometimes called a “grounded delta”).
The WattNode meter will correctly measure services with a grounded leg, but the measured power for the grounded phase will be zero and the status LED will not light for whichever phase is grounded, because the voltage is near zero.

For optimum accuracy with a grounded leg, you should also connect the N (neutral) terminal on the meter to the ground terminal; this will not cause any ground current to flow because the neutral terminal is not used to power the meter. If you have a grounded leg configuration, you can save money by removing the CT for the grounded phase, since all the power will be measured on the non-grounded phases. We recommend putting the grounded leg on the ØB or ØC inputs and attaching a note to the meter indicating this configuration for future reference.

**Mounting**

Protect the WattNode meter from moisture, direct sunlight, high temperatures, and conductive pollution (salt spray, metal dust, etc.) If moisture or conductive pollution may be present, use an IP 66 or NEMA 4 rated enclosure to protect the meter. Due to its exposed screw terminals, the meter must be installed in an electrical service panel, an enclosure, or an electrical room. The meter may be installed in any orientation, directly to a wall of an electrical panel or junction box.

The WattNode meter has two mounting holes spaced 5.375 inches (137 mm) apart (center to center). These mounting holes are normally obscured by the detachable screw terminals. Remove the screw terminals by pulling outward while rocking from end to end. The meter or Figure 7 may be used as a template to mark mounting hole positions, but do not drill the holes with the meter in the mounting position because the drill may damage the connectors and leave drill shavings in the connectors.

You may mount the meter with the supplied #8 self-tapping sheet metal screws using 1/8 inch pilot hole (3.2 mm). Or you may use hook-and-loop fasteners. If you use screws, avoid over-tightening which can crack the case. If you don’t use the supplied screws, the following sizes should work (bold are preferred); use washers if the screws could pull through the mounting holes.
Selecting Current Transformers

The rated full-scale current of the CTs should normally be chosen somewhat above the maximum current of the circuit being measured (see Current Crest Factor below for more details). In some cases, you might select CTs with a lower rated current to optimize accuracy at lower current readings. Take care that the maximum allowable current for the CT can not be exceeded without tripping a circuit breaker or fuse; see Current Transformers (p. 35).

We only offer CTs that measure AC current, not DC current. Significant DC current can saturate the CT magnetic core, reducing the AC accuracy. Most loads only have AC current, but some rare loads draw DC current, which can cause measurement errors. See our website for more information: http://www.ccontrolsys.com/w/DC_Current_and_Half-Wave_Rectified_Loads.

CTs can measure lower currents than they were designed for by passing the wire through the CT more than once. For example, to measure currents up to 1 amp with a 5 amp CT, loop the wire through the CT five times. The CT is now effectively a 1 amp CT instead of a 5 amp CT. The effective current rating of the CT is the labeled rating divided by the number of times that the wire passes through the CT.

If you are using the measurement phases of the WattNode (\(\Phi_A\), \(\Phi_B\), and \(\Phi_C\)) to measure different circuits (as with Option P3), you can use CTs with different rated current on the different phases.

Current Crest Factor

The term “current crest factor” is used to describe the ratio of the peak current to the RMS current (the RMS current is the value reported by multimeters and the WattNode meter). Resistive loads like heaters and incandescent lights have nearly sinusoidal current waveforms with a crest factor near 1.4. Power factor corrected loads such as electronic lighting ballasts and computer power supplies typically have a crest factor of 1.4 to 1.5. Battery chargers, VFD motor controls, and other nonlinear loads can have current crest factors ranging from 2.0 to 3.0, and even higher.

High current crest factors are usually not an issue when metering whole building loads, but can be a concern when metering individual loads with high current crest factors. If the peak current is too high, the meter’s CT inputs can clip, causing inaccurate readings.

This means that when measuring loads with high current crest factors, you may want to be conservative in selecting the CT rated current. For example, if your load draws 10 amps RMS, but has a crest factor of 3.0, then the peak current is 30 amps. If you use a 15 amp CT, the meter will not be able to accurately measure the 30 amp peak current. Note: this is a limitation of the meter measurement circuitry, not the CT.

The following graph shows the maximum RMS current for accurate measurements as a function of the current waveform crest factor. The current is shown as a percentage of CT rated current. For example, if you have a 10 amp load with a crest factor of 2.0, the maximum CT current is approximately 85%. Eighty-five percent of 15 amps is 12.75, which is higher than 10 amps, so your measurements should be accurate. On the other hand, if you have a 40 amp load with a crest factor of 4.0, the maximum CT current is 42%. Forty-two percent of a 100 amp CT is 42 amps, so you would need a 100 amp CT to accurately measure this 40 amp load.
You frequently won’t know the crest factor for your load. In this case, it’s generally safe to assume the crest factor will fall in the 1.4 to 2.5 range and select CTs with a rated current roughly 150% of the expected RMS current. So if you expect to be measuring currents up to 30 amps, select a 50 amp CT.

### Connecting Current Transformers

- Use only UL recognized current transformers (CTs) with built-in burden resistors that generate 0.33333 Vac (333.33 millivolts AC) at rated current. See **Current Transformers (p. 35)** for the maximum input current ratings.

- **Do not** use ratio (current output) CTs such as 1 amp or 5 amp output CTs: they will destroy the meter and present a shock hazard! These are commonly labelled with a ratio like 100:5.

- Find the arrow or label “THIS SIDE TOWARD SOURCE” on the CT and face toward the current source: generally the utility meter or the circuit breaker for branch circuits. If CTs are mounted backwards or with their white and black wires reversed the measured power will be negative. The diagnostic LEDs indicates negative power with flashing red LEDs.

- Be careful to match up the current transformers to the voltage phases being measured. Make sure the $\Phi A$ CT is measuring the line voltage connected to $\Phi A$, and the same for phases B and C. Use the supplied colored labels or tape to identify the wires.

- To prevent magnetic interference, the CTs on different phases should be separated by 1 inch (25 mm). The line voltage conductors for each phase should be separated by at least 1 inch (25 mm) from each other and from neutral.

- For best accuracy, the CT opening should not be much larger than the conductor. If the CT opening is much larger, position the conductor in the center of the CT opening.

- Because CT signals are susceptible to interference, we recommend keeping the CT wires short and cutting off any excess length. It is generally better to install the meter near the line voltage conductors instead of extending the CT wires. However, you may extend the CT wires by 300 feet (100 m) or more by using shielded twisted-pair cable and by running the CT wires away from high current and line voltage conductors.

- **OPTIONAL:** if you see spurious readings on unused phases, jumper the unused CT inputs.

To connect CTs, pass the wire to be measured through the CT and connect the CT to the meter. **Always remove power before disconnecting any live wires.** Put the line conductors through the CTs as shown in the section **Electrical Service Types (p. 8).** You may measure generated power by treating the generator as the source.
For solid-core CTs, disconnect the line voltage conductor to install it through the CT opening. Split-core and bus-bar CTs can be opened for installation around a wire by pulling the removable section straight away from the rest of the CT or unhooking the latch; it may require a strong pull. Some CT models include thumb-screws to secure the opening. The removable section may fit only one way, so match up the steel core pieces when closing the CT. If the CT seems to jam and will not close, the steel core pieces are probably not aligned correctly; DO NOT FORCE together. Instead, reposition or rock the removable portion until the CT closes without excessive force. A nylon cable tie can be secured around the CT to prevent inadvertent opening.

Some split-core CT models have flat mating surfaces. When installing this type of CT, make sure that mating surfaces are clean. Any debris between the mating surfaces will increase the gap, decreasing accuracy.

Next, connect the CT lead wires to the meter terminals labeled \( \Phi_A \) CT, \( \Phi_B \) CT, and \( \Phi_C \) CT. Route the twisted black and white wires from the CT to the meter. We recommend cutting off any excess length to reduce the risk of interference. Strip 1/4 inch (6 mm) of insulation off the ends of the CT leads and connect to the six position black screw terminal block. Connect each CT lead with the white wire aligned with the white dot on the label, and the black wire aligned with the black dot. Note the order in which the phases are connected, as the voltage phases must match the current phases for accurate power measurement.

Finally record the CT rated current as part of the installation record for each meter. If the conductors being measured are passed through the CTs more than once, then the recorded rated CT current is divided by the number of times that the conductor passes through the CT.

**Circuit Protection**

The WattNode meter is considered “permanently connected equipment”, because it does not use a conventional power cord that can be easily unplugged. Permanently connected equipment must have overcurrent protection and be installed with a means to disconnect the equipment.

- A switch, disconnect, or circuit breaker may be used to disconnect the meter and must be as close as practical to the meter. If a switch or disconnect is used, then there must also be a fuse or circuit breaker of appropriate rating protecting the meter.
- WattNode meters only draw 10-30 milliamps; CCS recommends using circuit breakers or fuses rated for between 0.5 amps and 20 amps and rated for the line voltages and the current interrupting rating required.
- The circuit breakers or fuses must protect the ungrounded supply conductors (the terminals labeled \( \Phi_A \), \( \Phi_B \), and \( \Phi_C \)). If neutral is also protected (this is rare), then the overcurrent protection device must interrupt neutral and the supply conductors simultaneously.
- Any switches or disconnects should have at least a 1 amp rating and must be rated for the line voltages.
- The circuit protection / disconnect system must meet IEC 60947-1 and IEC 60947-3, as well as all national and local electrical codes.
- The line voltage connections should be made with wire rated for use in a service panel or junction box with a voltage rating sufficient for the highest voltage present. CCS recommends 14 or 12 AWG (1.5 mm\(^2\) or 2.5 mm\(^2\)) stranded wire, rated for 300 or 600 volts. Solid wire may be used, but must be routed carefully to avoid putting excessive stress on the screw terminal.
- The WattNode meter has an earth connection, which should be connected for maximum accuracy. However, this earth connection is not used for safety (protective) earthing.
Connecting Voltage Terminals

Always turn off or disconnect power before connecting the voltage inputs to the meter. Connect each phase voltage to the appropriate input on the green terminal block; also connect ground and neutral (if required).

The voltage inputs to the meter do not need to be powered from to the same branch circuit as the load being monitored. In other words, if you have a three-phase panel with a 100 A three-pole breaker powering a motor that you wish to monitor, you can power the meter (or several meters) from a separate 20 A three-pole breaker installed in the same, or even adjacent panel, so long as the load and voltage connections are supplied from the same electric service.

The green screw terminals handle wire up to 12 AWG (2.5 mm²). Strip the wires to expose 1/4” (6 mm) of bare copper. When wiring the meter, do not put more than one wire under a screw. If you need to distribute power to other meters, use wire nuts or a power distribution block. The section Electrical Service Types (p. 8) shows the proper connections for the different meter models and electrical services. Verify that the voltage line phases match the CT phases.

If there is any doubt that the meter voltage rating is correct for the circuit being measured, unplug the green terminal block (to protect the meter), turn on the power, and use a voltmeter to compare the voltages (probe the terminal block screws) to the values in the white box on the meter front label. After testing, plug in the terminal block, making sure that is pushed in all the way.

The WattNode meter is powered from the voltage inputs: \( \Phi A \) (phase A) to \( N \) (neutral) for wye “-3Y” models, or \( \Phi A \) to \( \Phi B \) for delta “-3D” models. If the meter is not receiving at least 80% of the nominal line voltage, it may stop operating. Since the meter consumes a small amount of power itself (typically 1-3 watts), you may wish to power the meter from a separate circuit or place the current transformers downstream of the meter, so its power consumption is not measured.

For best accuracy, always connect the \( N \) (neutral) terminal on the meter. If you are using a delta meter and the circuit has no neutral, then jumper the earth ground to the \( N \) (neutral) terminal.

When power is first applied to the meter, check that the LEDs behave normally (see Installation LED Diagnostics (p. 20) below): if you see the LEDs flashing red-green-red-green, then disconnect the power immediately! This indicates the line voltage is too high for this model.

![Figure 9: WattNode LED Overvoltage Warning](image)

Connecting Pulse Outputs

- The outputs P1, P2, and P3 should not be connected to negative voltages (except with Option SSR), or to voltages greater than +60 Vdc.
- The recommended maximum current through the pulse output optoisolators is 5 mA, although they will generally switch 8-10 mA. If you need to switch higher currents, contact us about Option SSR (solid-state relay); see Specifications - Option SSR Outputs (p. 33).
- The outputs are isolated (5000 Vac RMS) from dangerous voltages, so you can connect them with the meter powered. The outputs are also isolated from the meter’s earth ground and neutral connections.
- If the output wiring is located near line voltage wiring, use wires or cables rated for the highest voltage present, generally 300V or 600V rated wire.
- If this cable will be in the presence of bare conductors, such as bus-bars, it should be double insulated or jacketed.
- When wiring over long distances, use shielded twisted-pair cable to prevent interference.
The pulse output channels are the collector and emitter of an optoisolator transistor (also called a photocoupler) controlled by the meter’s pulse stream (see Option SSR Outputs (p. 33) for solid-state relay outputs). These outputs may be connected to most data monitoring devices that expect a contact closure or relay input: data loggers, energy management systems, etc. Most of these devices provide excitation voltage with internal pull-up resistors. If your device does not, the following schematic illustrates connecting pull-up resistors on all three optoisolator outputs with a pull-up voltage of 5 Vdc.

![Figure 10: Optoisolator Outputs](image)

The meter can have from one to three pulse output channels. All three output channels share the common COM or ground connection. Each output channel has its own positive output connection, labeled P1, P2, and P3 (tied to the transistor collectors).

**Output Assignments**

The following table shows the pulse output channel assignments for the standard bidirectional output model and different options. See Manual Supplement MS-10 for details about Option PV, and Manual Supplement MS-11 for details about Option DPO.

<table>
<thead>
<tr>
<th>WattNode Outputs</th>
<th>P1 Output</th>
<th>P2 Output</th>
<th>P3 Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard: Bidirectional Outputs</td>
<td>Positive real energy</td>
<td>Negative real energy</td>
<td>Not used</td>
</tr>
<tr>
<td></td>
<td>(all phases)</td>
<td>(all phases)</td>
<td></td>
</tr>
<tr>
<td>Option P3: Per-Phase Outputs</td>
<td>Phase A positive real energy</td>
<td>Phase B positive real energy</td>
<td>Phase C positive real energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option PV: Photovoltaic</td>
<td>Phases A+B positive real energy</td>
<td>Phases A+B negative real energy</td>
<td>Phase C positive real energy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option DPO: Dual Positive Outputs</td>
<td>Positive real energy (all phases)</td>
<td>Negative real energy (all phases)</td>
<td>Positive real energy (all phases)</td>
</tr>
</tbody>
</table>

**Table 3: Pulse Output Assignments**

Note: we use the terms “positive” and “negative”, but other common terms are “production” and “consumption”. You can wire the meter so that positive energy corresponds to either production or consumption, depending on your application.
Pull-Up Resistor Selection

For standard WattNode meters with the normal 4.00 Hz full-scale frequency, pull-up resistor values between 10kΩ and 100kΩ work well. You may use values of 1.0MΩ or higher to reduce power consumption for battery powered equipment. Note: pull-up resistor values of 1.0MΩ or higher will make the pulse output signal more susceptible to interference, so you may want to keep the wiring short, use shielded cable, and avoid running the pulse signal near AC wiring.

The following table lists pull-up resistor values (in ohms, kilo-ohms, and mega-ohms) to use with the pulse output channels, particularly if you have ordered a model with a pulse frequency different than 4.00 Hz. For each configuration, the table lists a recommended value, followed by minimum and maximum resistor values. These values typically result in a pulse waveform rise time (from 20% to 80% of the pull-up voltage) of less than 10% of the total pulse period. The fall time is roughly constant in the 2 to 10 microsecond range. Lower resistance will result in faster switching and increase the current flow. If your frequency isn’t in the table, use the next higher frequency or interpolate between two values.

<table>
<thead>
<tr>
<th>Full-Scale Pulse Frequency</th>
<th>Pull-up to 3.0 Vdc Recommended (Min-Max)</th>
<th>Pull-up to 5.0 Vdc Recommended (Min-Max)</th>
<th>Pull-up to 12 Vdc Recommended (Min-Max)</th>
<th>Pull-up to 24 Vdc Recommended (Min-Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Hz</td>
<td>470kΩ (600Ω-4.7M)</td>
<td>470kΩ (1.0k-5.6M)</td>
<td>470kΩ (2.4k-7.5M)</td>
<td>1.0MΩ (4.7k-9.1M)</td>
</tr>
<tr>
<td>4 Hz</td>
<td>100kΩ (600Ω-1.2M)</td>
<td>100kΩ (1.0k-1.6M)</td>
<td>100kΩ (2.4k-2.2M)</td>
<td>200kΩ (4.7k-3.0M)</td>
</tr>
<tr>
<td>10 Hz</td>
<td>47kΩ (600Ω-470k)</td>
<td>47kΩ (1.0k-620k)</td>
<td>47kΩ (2.4k-910k)</td>
<td>100kΩ (4.7k-1.3M)</td>
</tr>
<tr>
<td>50 Hz</td>
<td>10kΩ (600Ω-91k)</td>
<td>10kΩ (1.0k-130k)</td>
<td>20kΩ (2.4k-200k)</td>
<td>47kΩ (4.7k-270k)</td>
</tr>
<tr>
<td>100 Hz</td>
<td>4.7kΩ (600Ω-47k)</td>
<td>4.7kΩ (1.0k-62k)</td>
<td>10kΩ (2.4k-100k)</td>
<td>20kΩ (4.7k-130k)</td>
</tr>
<tr>
<td>200 Hz</td>
<td>2.0kΩ (600Ω-24k)</td>
<td>2.0kΩ (1.0k-33k)</td>
<td>4.7kΩ (2.4k-47k)</td>
<td>10kΩ (4.7k-68k)</td>
</tr>
<tr>
<td>600 Hz</td>
<td>2.0kΩ (600Ω-8.2k)</td>
<td>2.0kΩ (1.0k-12k)</td>
<td>4.7kΩ (2.4k-16k)</td>
<td>10kΩ (4.7k-22k)</td>
</tr>
</tbody>
</table>

Table 4: Recommended Pulse Output Pull-up Resistors

When the optoisolator is on (conducting), there is a small voltage drop between the common and output terminals, typically 0.1 - 0.4 volts, called the saturation voltage. This voltage depends on the current flow through the optoisolator (see Specifications - Optoisolator Outputs (p. 32) below for details). To compute the current flow through the optoisolator, use the following approximate equation:

- $V_{pullup}$ - The supply voltage for the pull-up resistor (DC volts).
- $R_{pullup}$ - The pull-up resistor resistance (ohms).
- $I_{opto}$ - The approximate current (amps) through the optoisolator when it is on (conducting).

$$I_{opto} = \frac{V_{pullup}}{R_{pullup}}$$

Installation Summary

1) Mount the WattNode meter.
2) Turn off power before installing solid-core (non-opening) CTs or making voltage connections.
3) Mount the CTs around the line voltage conductors being measured. Take care to orient the CTs facing the source of power.
4) Connect the twisted white and black wires from the CT to the six position black terminal block on the meter, matching the wire colors to the white and black dots on the front label.
5) Connect the voltage wires including ground and neutral (if present) to the green terminal block, and check that the current (CT) phases match the voltage measurement phases.
6) Connect the pulse output terminals of the meter to the monitoring equipment.
7) Apply power to the meter.
8) Verify that the LEDs light correctly and don’t indicate an error condition.
Installation LED Diagnostics

The WattNode meter includes multi-color power diagnostic LEDs for each phase to help verify correct operation and diagnose incorrect wiring. The LEDs are marked “Status” on the label. The following diagrams and descriptions explain the various LED patterns and their meanings. The A, B, and C on the left side indicate the phase of the LEDs. Values like “1.0sec” and “3.0sec” indicate the time the LEDs are lit in seconds. In the diagrams, sometimes the colors are abbreviated: R = red, G or Grn = green, Y = yellow.

Normal Startup

On initial power-up, the LEDs will all light up in a red, yellow, green sequence. After this startup sequence, the LEDs will show the status, such as Normal Operation below.

Normal Operation

During normal operation, when positive power is measured on a phase, the LED for that phase will flash green. Typical flash rates are shown below.

<table>
<thead>
<tr>
<th>Percent of Full-Scale Power</th>
<th>LED Flash Rate</th>
<th>Flashes in 10 Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
<td>5.0 Hz</td>
<td>50</td>
</tr>
<tr>
<td>50%</td>
<td>3.6 Hz</td>
<td>36</td>
</tr>
<tr>
<td>25%</td>
<td>2.5 Hz</td>
<td>25</td>
</tr>
<tr>
<td>10%</td>
<td>1.6 Hz</td>
<td>16</td>
</tr>
<tr>
<td>5%</td>
<td>1.1 Hz</td>
<td>11</td>
</tr>
<tr>
<td>1% (and lower)</td>
<td>0.5 Hz</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 5: LED Flash Rates vs. Power

Zero Power

For each phase, if line Vac is present, but the measured power is below the minimum that the meter will measure (see Specifications - Measurement - Creep Limit), the meter will display solid green for that phase.

Inactive Phase

If the meter detects no power and line voltage below 20% of nominal, it will turn off the LED for the phase.

Negative Power

If one or more of the phase LEDs are flashing red, it indicates negative power (power flowing into the grid) on those phases. The rate of flashing indicates magnitude of negative power (see Table 5 above). This can happen for the following reasons:

- This is a bidirectional power measurement application, such as a photovoltaic system, where negative power occurs whenever you generate more power than you consume.
- The current transformer (CT) for this phase was installed backwards on the current carrying wire or the white and black wires for the CT were reversed at the meter. This can be solved by flipping the CT on the wire or swapping the white and black wires at the meter.
- In some cases, this can also occur if the CT wires are connected to the wrong inputs, such as if the CT wires for phases B and C are swapped.
Note: if all three LEDs are flashing red and they always turn on and off together, like the diagram for **Low Line Voltage** below, then the meter is experiencing an error or low line voltage, not negative power.

### Erratic Flashing

If the LEDs are flashing slowly and erratically, sometimes green, sometimes red, this generally indicates one of the following:

- Earth ground is not connected to the meter (the top connection on the green screw terminal).
- Voltage is connected for a phase, but the current transformer is not connected, or the CT has a loose connection.
- In some cases, particularly for a circuit with no load, this may be due to electrical noise. This is not harmful and can generally be disregarded, provided that you are not seeing substantial measured power when there shouldn’t be any. Try turning on the load to see if the erratic flashing stops.

To fix this, try the following:

- Make sure earth ground is connected.
- If there are unused current transformer inputs, install a shorting jumper for each unused CT (a short length of wire connected between the white and black dots marked on the label).
- If there are unused voltage inputs (on the green screw terminal), connect them to neutral (if present) or earth ground (if neutral isn’t available).
- If you suspect noise may be the problem, try moving the meter away from the source of noise. Also try to keep the CT wires as short as possible and cut off excess wire.

### Meter Not Operating

It should not be possible for all three LEDs to stay off when the meter is powered, because the phase powering the meter will have line voltage present. Therefore, if all LEDs are off, the meter is either not receiving sufficient line voltage to operate, or is malfunctioning and needs to be returned for service. Verify that the voltage on the Vac screw terminals is within ±20% of the nominal operating voltages printed in the white rectangle on the front label.

### Meter Error

If the meter experiences an internal error, it will light all LEDs red for three seconds (or longer). If you see this happen repeatedly, return the meter for service.

### Bad Calibration

This indicates that the meter has detected bad calibration data and must be returned for service.

### Line Voltage Too High

Whenever the meter detects line voltages over 125% of normal for one or more phases, it will display a fast red/green flashing for the affected phases. This is harmless if it occurs due a momentary surge, but if the line voltage is high continuously, **the power supply may fail. If you see continuous over-voltage flashing, disconnect the meter immediately!** Check that the model and voltage rating is correct for the electrical service.
Bad Line Frequency
If the meter detects a power line frequency below 45 Hz or above 70 Hz, it will light all the LEDs yellow for at least three seconds. The LEDs will stay yellow until the line frequency returns to normal. During this time, the meter should continue to accurately measure power. This can occur in the presence of extremely high noise, such as if the meter is too close to an unfiltered variable frequency drive.

Low Line Voltage
These LED patterns occur if the line voltage is too low for the meter to operate correctly and the meter reboots repeatedly. The pattern will be synchronized on all three LEDs. Verify that the voltage on the Vac screw terminals is not more than 20% lower than the nominal operating voltages printed in the white rectangle on the front label. If the voltages are in the normal range and the meter continues to display one of these patterns, return it for service.

Measurement Troubleshooting
If the WattNode meter does not appear to be operating correctly or generating expected pulses, start by checking the diagnostic LEDs as described in the previous section Installation LED Diagnostics (p. 20). Then double check the installation instructions. If there are still problems, check the following.

No Pulses
- Make sure the load is turned on.
- If the LEDs are flashing green, then the meter is measuring positive power and should output pulses on P1, so there may be something wrong with the pulse output connection or you may need a pull-up resistor; see Connecting Pulse Outputs (p. 17).
- If the LEDs on one or more phases are flashing red, then the total power may be negative, in which case the meter won’t generate positive energy pulses. If you have a bidirectional model, you can check for negative energy pulses on the P2 output. If this is the case, check that the line phases match the CT phases, that all the CTs face the source of power, and that the CT white and black wires are connected correctly.
- If all the LEDs are solid green (or off), then the measured power is below the creep limit (1/1500th of full-scale) and the meter will not generate any pulses. See Specifications - Creep Limit (p. 32).
- If the LEDs are flashing green slowly, the power may be very low. A WattNode meter with a nominal output frequency of 4.00 Hz can have a pulse period of several minutes at very low power levels.
- If all the LEDs are off, then the meter does not have sufficient line voltage to operate, or has malfunctioned. Use a DMM (multimeter) to verify that the voltage on the Vac screw terminals is within -20%, +15% of the nominal operating voltage.

Incorrect Power or Energy Readings.
This can be caused by any of the following:
- An incorrect estimate of expected power or energy readings. If possible, try to verify the actual energy, power, or current with a handheld power meter or current clamp.
• Incorrect scale factors to convert from pulses to energy and power. This is commonly caused by using the normal scale factors with an Option P3 meter or selecting the wrong row of column from the tables.

• Some pulse counting equipment (data loggers, etc.) counts both rising and falling edges as pulses, resulting in a count that is double the intended value. This can normally be corrected by reconfiguring the device or dividing the scale factor by 2.0.

• Some pulse monitoring devices cannot handle fast pulse rates. If the pulses occur too close together, some may be missed by the monitoring device. Check the specifications of your monitoring device or contact CCS support for assistance.

• The CTs are not installed on the correct line phases. Verify that the CT phasing matches the line Vac inputs.

• The measured current exceeds the CT rating. This can saturate CT or the WattNode meter input circuitry, resulting in lower than expected readings. If possible, use a current clamp to measure the current and make sure it is below the CT rated amps.

• The measured current is too small. Most current transformers are only specified to meet their accuracy from 10% to 100% of rated current. In practice, most CTs work reasonably well down to 1% of rated current. Very low currents may not register properly, resulting in low power or no power reported.

• Interference from a variable frequency or variable speed drive: VFD, VSD, inverter, or the like. Generally, these drives should not interfere with the meter, but if they are in very close proximity, or if the CT leads are long, interference can occur. Try moving the meter at least three feet (one meter) away from any VFDs. Use short CT leads if possible. NEVER connect the meter downstream of a VFD: the varying line frequency and extreme noise will cause problems!

• The CTs may be malfunctioning. If possible, use a current clamp to verify the current, then use a DMM (multimeter) to measure the AC voltage between the white and black wires from the CT (leave them connected to the meter during this test). At rated current, the CT output voltage should equal 0.333 Vac (333 millivolts AC). At lower currents, the voltage should scale linearly, so at 20% of rated current, the output voltage should be 0.20 * 0.333 = 0.0666 Vac (66.6 millivolts AC).

• The meter is not functioning correctly: if possible, swap the meter for another unit of the same model.
Operating Instructions

Pulse Outputs

The WattNode meter generates pulse outputs using one or more optoisolators (also called photocouplers). These provide 5000 Vac of isolation using an LED and a photo-transistor. This allows the meter to be interfaced to monitoring or data logging hardware without concerns about interference, ground loops, shock hazard, etc.

Depending on the options selected, the Pulse WattNode meter can generate full-scale pulses at output frequencies ranging from less than 1 Hz to 600 Hz. The standard full-scale pulse output frequency is 4.00 Hz. The standard model provides two pulse streams for measuring bidirectional power. With Option P3, there are three pulse channels for independently measuring each phase or three single-phase circuits.

The pulse outputs are approximately square-waves, with equal on and off periods. The frequency of pulses is proportional to the measured power. When the measured power is constant, the pulse frequency is constant and the output is an exact square-wave. If the power is increasing or decreasing, the output waveform will not be a perfect square-wave as the on and off periods are getting longer or shorter. If you need a fixed or minimum pulse duration (closed period), see Manual Supplement MS-17: Option PW (Pulse Width).

We define a “pulse” as a full cycle including both an Open → Closed and an Closed → Open transition. You can choose either a rising or falling edge to start a pulse; the end of the pulse will be the next matching edge. Some monitoring equipment or data loggers can be configured to count both rising and falling edges: if your equipment is configured this way, you will count twice as many pulses as expected. This can normally be corrected by reconfiguring the equipment or adjusting the scale factors by a factor of 2.

See Connecting Pulse Outputs (p. 17) and Specifications - Pulse Outputs (p. 32) for more information.
Power and Energy Computation

Every pulse from the meter corresponds to a fixed amount of energy. Power (watts) is energy divided by time, which can be measured as pulses per second (or pulses per hour). The following scale factor tables and equations convert from pulses to energy (watt-hours or kilowatt-hours) for different models.

If you have ordered a custom full-scale pulse output frequency, then see the Power and Energy Equations section below. For Option PV (Photovoltaic), see Manual Supplement MS-10: Option PV for scale factors.

Scale Factors - Standard Bidirectional Outputs (and Option DPO)

The following table provides scale factors for standard bidirectional output models with a full-scale pulse output frequency of 4.00 Hz. This table also works for 4.00 Hz models with Option DPO. Equations to compute power and energy follow the scale factor tables.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.125</td>
<td>0.2396</td>
<td>0.2885</td>
<td>0.3615</td>
<td>8000.00</td>
<td>4173.91</td>
<td>3465.70</td>
<td>2766.57</td>
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<td>15</td>
<td>0.375</td>
<td>0.7188</td>
<td>0.8656</td>
<td>1.0844</td>
<td>2666.67</td>
<td>1391.30</td>
<td>1155.24</td>
<td>922.190</td>
</tr>
<tr>
<td>20</td>
<td>0.500</td>
<td>0.9583</td>
<td>1.1542</td>
<td>1.4458</td>
<td>2000.00</td>
<td>1043.48</td>
<td>866.426</td>
<td>691.643</td>
</tr>
<tr>
<td>30</td>
<td>0.750</td>
<td>1.4375</td>
<td>1.7313</td>
<td>2.1688</td>
<td>1333.33</td>
<td>695.652</td>
<td>577.617</td>
<td>461.095</td>
</tr>
<tr>
<td>50</td>
<td>1.250</td>
<td>2.3958</td>
<td>2.8854</td>
<td>3.6146</td>
<td>800.000</td>
<td>417.391</td>
<td>346.570</td>
<td>276.657</td>
</tr>
<tr>
<td>60</td>
<td>1.500</td>
<td>2.8750</td>
<td>3.4625</td>
<td>4.3375</td>
<td>666.667</td>
<td>347.826</td>
<td>288.809</td>
<td>230.548</td>
</tr>
<tr>
<td>70</td>
<td>1.750</td>
<td>3.3542</td>
<td>4.0396</td>
<td>5.0604</td>
<td>571.429</td>
<td>298.137</td>
<td>247.550</td>
<td>197.612</td>
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<tr>
<td>100</td>
<td>2.500</td>
<td>4.7917</td>
<td>5.7708</td>
<td>7.2292</td>
<td>400.000</td>
<td>208.696</td>
<td>173.285</td>
<td>138.329</td>
</tr>
<tr>
<td>150</td>
<td>3.750</td>
<td>7.1875</td>
<td>8.6563</td>
<td>10.844</td>
<td>266.667</td>
<td>139.130</td>
<td>115.523</td>
<td>92.219</td>
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<tr>
<td>200</td>
<td>5.000</td>
<td>9.5833</td>
<td>11.542</td>
<td>14.458</td>
<td>200.000</td>
<td>104.348</td>
<td>86.643</td>
<td>69.164</td>
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<td>250</td>
<td>6.250</td>
<td>11.979</td>
<td>14.427</td>
<td>18.073</td>
<td>160.000</td>
<td>83.478</td>
<td>69.314</td>
<td>55.331</td>
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<tr>
<td>300</td>
<td>7.500</td>
<td>14.375</td>
<td>17.313</td>
<td>21.688</td>
<td>133.333</td>
<td>69.565</td>
<td>57.762</td>
<td>46.110</td>
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<tr>
<td>400</td>
<td>10.000</td>
<td>19.167</td>
<td>23.083</td>
<td>28.917</td>
<td>100.000</td>
<td>52.174</td>
<td>43.321</td>
<td>34.582</td>
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<tr>
<td>600</td>
<td>15.000</td>
<td>28.750</td>
<td>34.625</td>
<td>43.375</td>
<td>66.667</td>
<td>34.783</td>
<td>28.881</td>
<td>23.055</td>
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<td>800</td>
<td>20.000</td>
<td>38.333</td>
<td>46.167</td>
<td>57.833</td>
<td>50.000</td>
<td>26.087</td>
<td>21.661</td>
<td>17.291</td>
</tr>
<tr>
<td>1000</td>
<td>25.000</td>
<td>47.917</td>
<td>57.708</td>
<td>72.292</td>
<td>40.000</td>
<td>20.870</td>
<td>17.329</td>
<td>13.833</td>
</tr>
<tr>
<td>1200</td>
<td>30.000</td>
<td>57.500</td>
<td>69.250</td>
<td>86.750</td>
<td>33.333</td>
<td>17.391</td>
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<td>11.527</td>
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<tr>
<td>2000</td>
<td>50.000</td>
<td>95.833</td>
<td>115.42</td>
<td>144.58</td>
<td>20.000</td>
<td>10.435</td>
<td>8.6643</td>
<td>6.9164</td>
</tr>
<tr>
<td>3000</td>
<td>75.000</td>
<td>143.75</td>
<td>173.13</td>
<td>216.88</td>
<td>13.333</td>
<td>6.9565</td>
<td>5.7762</td>
<td>4.6110</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>any CtAmps 40</th>
<th>CtAmps 20.87</th>
<th>CtAmps 17.329</th>
<th>CtAmps 13.833</th>
<th>40.000 CtAmps 20.870 CtAmps 17.329 CtAmps 13.833</th>
</tr>
</thead>
</table>

Table 6: Scale Factors - Bidirectional Outputs

Contact CCS for scale factors for models with full-scale pulse output frequencies other than 4.00 Hz.
Scale Factors - Option P3: Per-Phase Outputs

The following table provides scale factors for Option P3 models with a full-scale pulse output frequencies of 4.00 Hz for each phase. Note: with Option P3, different phases can use different CTs with different rated currents.

WARNING: Only use this table if you have Option P3 (Per-Phase Outputs)!

<table>
<thead>
<tr>
<th>CT Size (amps)</th>
<th>Watt-hours per pulse (WHpP)</th>
<th>Pulses Per kilowatt-hour (PpKWH)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3Y-208 3D-240</td>
<td>3Y-400 3D-400</td>
</tr>
<tr>
<td>5</td>
<td>0.04167 0.07986</td>
<td>0.09618 0.12049</td>
</tr>
<tr>
<td>15</td>
<td>0.1250 0.2396</td>
<td>0.2885 0.3615</td>
</tr>
<tr>
<td>20</td>
<td>0.1667 0.3194</td>
<td>0.3847 0.4819</td>
</tr>
<tr>
<td>30</td>
<td>0.2500 0.4792</td>
<td>0.5771 0.7229</td>
</tr>
<tr>
<td>50</td>
<td>0.4167 0.7986</td>
<td>0.9618 1.2049</td>
</tr>
<tr>
<td>60</td>
<td>0.5000 0.9583</td>
<td>1.1542 1.4458</td>
</tr>
<tr>
<td>70</td>
<td>0.5833 1.1811</td>
<td>1.3465 1.6868</td>
</tr>
<tr>
<td>100</td>
<td>0.8333 1.5972</td>
<td>1.9236 2.4097</td>
</tr>
<tr>
<td>150</td>
<td>1.2500 2.3958</td>
<td>2.8854 3.6146</td>
</tr>
<tr>
<td>200</td>
<td>1.6667 3.1944</td>
<td>3.8472 4.8194</td>
</tr>
<tr>
<td>250</td>
<td>2.0833 3.9931</td>
<td>4.8090 6.0243</td>
</tr>
<tr>
<td>300</td>
<td>2.5000 4.7917</td>
<td>5.7708 7.2292</td>
</tr>
<tr>
<td>400</td>
<td>3.3333 6.3892</td>
<td>7.6944 9.6389</td>
</tr>
<tr>
<td>600</td>
<td>5.0000 9.5833</td>
<td>11.542 14.458</td>
</tr>
<tr>
<td>800</td>
<td>6.6667 12.778</td>
<td>15.389 19.278</td>
</tr>
<tr>
<td>1000</td>
<td>8.3333 15.972</td>
<td>19.236 24.097</td>
</tr>
<tr>
<td>1200</td>
<td>10.000 19.167</td>
<td>23.083 28.917</td>
</tr>
<tr>
<td>1500</td>
<td>12.500 23.958</td>
<td>28.854 36.146</td>
</tr>
<tr>
<td>3000</td>
<td>25.000 47.917</td>
<td>57.708 72.292</td>
</tr>
<tr>
<td>any CtAmps</td>
<td>120.00 CtAmps</td>
<td>62.609 CtAmps 51.986 CtAmps 41.499</td>
</tr>
</tbody>
</table>

Table 7: Scale Factors - Per-Phase Outputs (Option P3)

Scale Factor Equations

Using the “Watt-hours per pulse” WHpP value from the table above for your model and current transformer, you can compute energy and power as follows:

- **PulseCount** - This is the count of pulses, used to compute energy. You can use the count of pulses over specified periods of time (like a month) to measure the energy for that period of time.

- **PulseFreq** - This is the measured pulse frequency (Hertz) out of the meter. This can also be computed by counting the number of pulses in a fixed period of time and then dividing by the number of seconds in that time period. For example, if you count 720 pulses in five minutes (300 seconds), then PulseFreq = 720 / 300 = 2.40 Hz.

\[
\text{Energy (watt-hours)} = WHpP \cdot \text{PulseCount}
\]
\[
\text{Power (watts)} = WHpP \cdot 3600 \cdot \text{PulseFreq}
\]

To convert these values to kilowatt-hours and kilowatts, divide by 1000.
Using the “Pulses Per kilowatt-hour” \( PpKWH \) value from the table above for your model and current transformer, you can compute energy and power as follows (multiply by 1000 to convert kilowatts to watts):

\[
\text{Energy (kilowatt-hours)} = \frac{\text{PulseCount}}{PpKWH}
\]

\[
\text{Power (kilowatts)} = 3600 \cdot \frac{\text{PulseFreq}}{PpKWH}
\]

**Power and Energy Equations**

This section shows how to compute power and energy from pulses for any full-scale pulse output frequency. The power is proportional to the pulse frequency, while the energy is proportional to the count of pulses.

For these calculations, we use the following variables:

- \( NVac \) - This is the **nominal** line voltage (phase to neutral) of the WattNode model. For delta model, this is a virtual voltage, since there may not be a neutral connection. Note: this is not the actual measured voltage.
- \( PpPO \) - “Phases per Pulse Output”. This is the number of meter voltage phases associated with a pulse output channel. This may be different than the number of phases you are monitoring.
  - **Standard** and **Option DPO** (Dual Positive Outputs): \( PpPO = 3 \)
  - **Option P3** (Per-Phase Outputs): \( PpPO = 1 \)
  - **Option PV** (Photovoltaic): \( PpPO = 2 \) for outputs \( P1 \) and \( P2 \), \( PpPO = 1 \) for output \( P3 \)
- \( CtAmps \) - This is the current transformer (CT) rated amps. Note: If the conductors being measured are passed through the CTs more than once, then \( CtAmps \) is the rated CT current divided by the number of times that the conductor passes through the CT.
- \( FSHz \) - This is the full-scale pulse frequency of the meter. It is 4.00 Hz, unless the meter was ordered with **Option Hz=xxx** (where \( xxx \) specifies the full-scale pulse frequency) or **Option Kh**.
- \( PulseCount \) - This is the measured pulse count, used to compute energy. You can use the count of pulses over specified periods of time (such as a month) to measure the energy for that period of time.
- \( PulseFreq \) - This is the measured pulse frequency from one of the pulse channels (\( P1 \), \( P2 \), or \( P3 \)). This can be computed by counting the number of pulses in a fixed period of time and then dividing by the number of seconds in that time period. For example, if you count 720 pulses in five minutes (300 seconds), then \( PulseFreq = \frac{720}{300} = 2.40 \text{ Hz} \).

The values of the constant parameters are in the following table.

<table>
<thead>
<tr>
<th>WattNode Models</th>
<th>NVac</th>
<th>Standard FSHz Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>WNB-3Y-208-P</td>
<td>120</td>
<td>4.00 Hz</td>
</tr>
<tr>
<td>WNB-3Y-400-P</td>
<td>230</td>
<td>4.00 Hz</td>
</tr>
<tr>
<td>WNB-3Y-480-P</td>
<td>277</td>
<td>4.00 Hz</td>
</tr>
<tr>
<td>WNB-3Y-600-P</td>
<td>347</td>
<td>4.00 Hz</td>
</tr>
<tr>
<td>WNB-3D-240-P</td>
<td>120*</td>
<td>4.00 Hz</td>
</tr>
<tr>
<td>WNB-3D-400-P</td>
<td>230*</td>
<td>4.00 Hz</td>
</tr>
<tr>
<td>WNB-3D-480-P</td>
<td>277*</td>
<td>4.00 Hz</td>
</tr>
</tbody>
</table>

*Note: these are “virtual” line-to-neutral voltages used for delta model power and energy computations.

**Table 8: Power and Energy Parameters**
**Watt-Hours per Pulse**

\[ WHpP = \frac{PpPO \cdot NVac \cdot CtAmps}{FSHz \cdot 3600} \]

**Watt-Hours per Pulse per CT Rated Amp**

There is an alternate way of computing the energy reported by a meter using the variable \( WHpPpA \) (watt-hours per pulse per CT rated amp). If you multiply the \( WHpPpA \) by the amp rating of your CTs, the result will be the watt-hours measured each time the meter generates a pulse.

\[ \text{EnergyPerPulse (WH)} = WHpPpA \cdot CtAmps \]

The standard \( WHpPpA \) values are listed in the following table. These only apply for models with a 4.00 Hz full-scale pulse frequency.

<table>
<thead>
<tr>
<th>WattNode Models</th>
<th>Watt-Hours per Pulse per CT Rated Amp (FSHz = 4.00)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard and Option DPO Outputs</td>
</tr>
<tr>
<td>WNB-3Y-208-P</td>
<td>0.02500</td>
</tr>
<tr>
<td>WNB-3Y-400-P</td>
<td>0.04792</td>
</tr>
<tr>
<td>WNB-3Y-480-P</td>
<td>0.05771</td>
</tr>
<tr>
<td>WNB-3Y-600-P</td>
<td>0.07229</td>
</tr>
<tr>
<td>WNB-3D-240-P</td>
<td>0.02500</td>
</tr>
<tr>
<td>WNB-3D-400-P</td>
<td>0.04792</td>
</tr>
<tr>
<td>WNB-3D-480-P</td>
<td>0.05771</td>
</tr>
</tbody>
</table>

*Table 9: Watt-Hours per Pulse per CT Rated Amp*

For example: a WNB-3Y-208-P with a full-scale pulse frequency of 4.00 Hz has a \( WHpPpA \) value of 0.0250. With 15 amp CTs, it will output one pulse for every 0.375 watt-hours.

\((0.025) \cdot (15.0 \text{ amp}) = 0.375 \text{ watt-hours}\)

It is easy to use the \( WHpPpA \) value to compute energy:

\[ \text{Energy (Wh)} = WHpPpA \cdot CtAmps \cdot \text{PulseCount} \]

For non-standard models, you can compute \( WHpPpA \) as follows:

\[ WHpPpA = \frac{PpPO \cdot NVac}{FSHz \cdot 3600} \]

**Energy Equation**

The following equation computes the energy (watt-hours) associated with a pulse output channel. By using the \textbf{PulseCount} for different periods of time (day, week, month, etc.), you can measure the energy over different time periods. You can convert this to kilowatt-hours by dividing by 1000. The 3600 term in the denominator converts from watt-seconds to watt-hours. Note: use \( NVac \) value from *Table 8* above.

\[ \text{Energy (WH)} = \frac{NVac \cdot PpPO \cdot CtAmps \cdot \text{PulseCount}}{FSHz \cdot 3600} \]

**Pulses per Watt-Hour**

\[ PpWH = \frac{FSHz \cdot 3600}{NVac \cdot PpPO \cdot CtAmps} \]
Pulses Per Kilowatt-Hour

\[ PpKWH = \frac{FSHz \cdot 3600 \cdot 1000}{NVac \cdot PpPO \cdot CtAmps} \]

Full-Scale Power Equation

The following equation computes the nominal full-scale power associated with a pulse output channel. For bidirectional output models, this is the full-scale power for all phases together. For per-phase output models, this is the full-scale power for a single phase. Note: use \( NVac \) value from Table 8: Power and Energy Parameters above.

\[ \text{Full-Scale Power (W)} = NVac \cdot PpPO \cdot CtAmps \]

Power Equation

The following equation computes the power associated with a pulse output. The \( PulseFreq \) value may be measured or averaged over different time periods to compute the average power (also called demand). Note: use \( NVac \) value from Table 8 above.

\[ \text{Power (W)} = \frac{NVac \cdot PpPO \cdot CtAmps \cdot PulseFreq}{FSHz} \]

Maintenance and Repair

The WattNode Pulse meter requires no maintenance. There are no user serviceable or replaceable parts except the pluggable screw terminals.

The WattNode meter should not normally need to be cleaned, but if cleaning is desired, power must be disconnected first and a dry or damp cloth or brush should be used.

The WattNode meter is not user serviceable. In the event of any failure, the meter must be returned for service (contact CCS for an RMA). In the case of a new installation, follow the diagnostic and troubleshooting instructions before returning the meter for service, to ensure that the problem is not connection related.
## Specifications

### Models

<table>
<thead>
<tr>
<th>Model</th>
<th>Nominal Vac Line-to-Neutral</th>
<th>Nominal Vac Line-to-Line</th>
<th>Phases</th>
<th>Wires</th>
</tr>
</thead>
<tbody>
<tr>
<td>WNB-3Y-208-P</td>
<td>120</td>
<td>208–240</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>WNB-3Y-400-P</td>
<td>230</td>
<td>400</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>WNB-3Y-480-P</td>
<td>277</td>
<td>480</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>WNB-3Y-600-P</td>
<td>347</td>
<td>600</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>WNB-3D-240-P</td>
<td>120*</td>
<td>208–240</td>
<td>3</td>
<td>3–4</td>
</tr>
<tr>
<td>WNB-3D-400-P</td>
<td>230*</td>
<td>400</td>
<td>3</td>
<td>3–4</td>
</tr>
<tr>
<td>WNB-3D-480-P</td>
<td>277*</td>
<td>480</td>
<td>3</td>
<td>3–4</td>
</tr>
</tbody>
</table>

*Note: the delta models have an optional neutral connection that may be used for measuring wye circuits. In the absence of neutral, voltages are measured with respect to ground. Delta WattNode models use the phase A and phase B connections for power.

### Model Options

Any of these models are available with the following options:

- **Bidirectional Outputs** - *(this is the standard model)* This model has two pulse output channels. P1 generates pulses in proportion to the total real positive energy, while P2 generates pulses in proportion to the total real negative energy. The individual phase energies are all added together every 200 ms. If the result is positive, it is accumulated for the P1 output; if negative, it is accumulated for the P2 output. If one phase has negative power (-100 W), while the other two phases have positive power (+100 W each), the negative phase will subtract from the positive phases, resulting in a net of 100 W, causing pulses on P1, but no pulses on P2. There will only be pulses on P2 if the sum of all three phases is negative.

- **Option P3: Per-Phase Outputs** - Models with this option have three pulse output channels: P1, P2, and P3. Each generates pulses in proportion to the real positive energy measured on one phase (phases A, B, and C respectively).

- **Option DPO: Dual Positive Outputs** - This option is like the standard model with bidirectional outputs, but with the addition of the P3 output channel. The P3 channel indicates positive real energy, just like the P1 channel. This is useful when the meter needs to be connected to two different devices, such as a display and a data logger. See Manual Supplement MS-11: Option DPO (Dual Positive Outputs) for details.

- **Option PV: Photovoltaic** - The photovoltaic option measures residential PV systems. It allows one WattNode meter to measure the bidirectional total house energy, and the PV (or wind) generated energy. See Manual Supplement MS-10: Option PV (Photovoltaic) for details.

- **Option Hz: Custom Pulse Output Frequency** - WattNode meters are available with custom full-scale pulse output frequencies ranging from 0.01 Hz to 600 Hz (150 Hz maximum for Options P3, DPO, and PV). For custom frequencies, specify Option Hz=nnn, where nnn is the desired full-scale frequency. To specify different frequencies for P1, P2, and P3, use Option Hz=rrr/sss/ttt, where P1 frequency = rrr, P2 frequency = sss, P3 frequency = ttt.

- **Option SSR: Solid State Relay Output** - Replaces the standard optoisolator outputs with solid state relays capable of switching 500 mA at up to 40 Vac or ±60 Vdc. See Option SSR Outputs below for details.

- **Option TVS=24** - Install 24 V bidirectional TVS protection diodes across P1, P2, and P3 outputs. Used with Option SSR when driving 12 Vdc electromechanical counters to protect the solid-state relays from the inductive kickback of the counter.
• **Option PW: Pulse Width** - This specifies the pulse ON (closed or conducting) period in milliseconds. For example, **Opt PW=100** configures 100 millisecond pulse ON periods. See Manual Supplement MS-17: Option PW (Pulse Width) for details.

• **Option Kh: Watt-hour Constant** - This specifies the watt-hour constant, or the number of watt-hours that must accumulate for each pulse generated by the meter. Each pulse includes an ON (conducting) and OFF period. The number of watt-hours may be small, even less than one, or large. For example, **Opt Kh=1000** specifies one pulse per 1000 watt-hours (one pulse per kilowatt-hour). See [http://www.ccontrolsys.com/w/Option_Kh](http://www.ccontrolsys.com/w/Option_Kh).

• **Option CT: Current Transformer Rated Amps** - This specifies the rated amps of the attached current transformers. This is only used in conjunction with **Option Kh**. It may be specified as **Opt CT=xxx** or **Opt CT=xxx/yyyy/zzz** if there are CTs with different rated amps on different phases. See [http://www.ccontrolsys.com/w/WattNode_Pulse_-_Option_CT_-_CT_Rated_Amps](http://www.ccontrolsys.com/w/WattNode_Pulse_-_Option_CT_-_CT_Rated_Amps).

**Accuracy**

The following accuracy specifications do not include errors caused by the current transformer accuracy or phase angle errors. “Rated current” is the current that generates a CT output voltage of 0.33333 Vac.

**Condition 1 - Normal Operation**
- Line voltage: -20% to +15% of nominal
- Power factor: 1.0
- Frequency: 48 - 62 Hz
- Ambient Temperature: 25°C
- CT Current: 5% - 100% of rated current
  - Accuracy: ±0.5% of reading

**Condition 2 - Low CT Current**
- All conditions the same as Condition 1 except:
  - CT Current: 1% - 5% of rated current
  - Accuracy: ±1.0% of reading

**Condition 3 – Very Low CT Current**
- All conditions the same as Condition 1 except:
  - CT Current: 0.2% - 1% of rated current
  - Accuracy: ±3.0% of reading

**Condition 4 - High CT Current**
- All conditions the same as Condition 1 except:
  - CT Current: 100% - 120% of rated current
  - Accuracy: ±1.0% of reading

**Condition 5 - Low Power Factor**
- All conditions the same as Condition 1 except:
  - Power factor: 0.5 (±60 degree phase shift between current and voltage)
  - Additional Error: ±0.5% of reading

**Condition 6 - Temperature Variation**
- All conditions the same as Condition 1 except:
  - Ambient Temperature: -30°C to +55°C
  - Additional Error: ±0.75% of reading
Note: Option PV WattNode models may not meet these accuracy specifications for the P3 output channel when measuring a two-phase inverter or multiple inverters.

Measurement

Creep Limit: 0.067% (1/1500th) of full-scale. Whenever the apparent power (a combination of the real and reactive power values) for a phase drops below the creep limit, the output power (real) for the phase will be forced to zero. Also, if the line voltage for a phase drops below 20% of nominal Vac, the output power for the phase will be set to zero. These limits prevent spurious pulses due to measurement noise.

Update Rate: ~200 milliseconds. Internally, the consumed energy is measured at this rate and used to update the pulse output rate.

Start-Up Time: approximately 500 milliseconds. The meter starts measuring power and generating pulses 500 milliseconds after AC voltage is applied.

Current Transformer Phase Angle Correction: 1.0 degree leading. Current transformers (CTs) typically have a leading phase angle error ranging from 0.2 degrees to 2.5 degrees. The WattNode meter is normally programmed to correct for a 1.0 degree phase lead to provide good accuracy with typical CTs.

Over-Voltage Limit: 125% of nominal Vac. If the line voltage for one or more phases exceeds this limit, the status LEDs for these phases will flash alternating red-green as a warning. Extended over-voltage operation can damage the meter and void the warranty. See Line Voltage Too High (p. 21).

Over-Current Limit: 120% of rated current. Exceeding 120% of rated current will not harm the WattNode meter but the current and power will not be measured accurately.

Pulse Outputs

Factory Programmable Full-Scale Pulse Frequencies:
- Standard (All Models): 4.00 Hz
- Custom (Bidirectional Output Models): 0.01 Hz to 600 Hz
- Custom (Option P3, Option PV, Option DPO): 0.01 Hz to 150 Hz

Absolute Maximum Pulse Output Frequencies:
- Standard Models (Bidirectional Outputs): 900 Hz
- Option P3, Option PV, Option DPO: 200 Hz

Output Waveform: square-wave, ~50% duty cycle
- Option PW: programmable pulse ON (closed or conducting period, 1 to 65535 milliseconds

Optoisolator Outputs:
- Isolation: 5000 Vac RMS
- Breakdown Voltage (collector–emitter): 60 V (exceeding this may destroy the outputs)
- Maximum Reverse Voltage (emitter–collector): 5 Vdc (exceeding may destroy the outputs)
- Maximum Leakage (OFF) Current (collector–emitter): 100 nA
- Recommended Load Current (collector–emitter): 1 μA (microamp) to 5 mA (milliamp)
- Maximum Load (collector–emitter) Current: ~8 mA
- Approximate ON Resistance (as measured by a DMM): 100 Ω to 2000 Ω
- Approximate OFF Resistance (as measured by a DMM): > 50 MΩ
Saturation Voltage vs. Load Current: this is the typical voltage (at room temperature) measured between the COM terminal and P1, P2, or P3 when the optoisolator is on (conducting). Ideally, this voltage would be zero, but instead, it varies with the load current.

Output Rise Time (microseconds): approximately $R_{\text{pullup}} / 100$, where $R_{\text{pullup}}$ is the pull-up resistor value (in ohms) and the pull-up voltage is 5 Vdc. Rise time is defined as the time for the output voltage to rise from 20% to 80% of the pull-up voltage.

Output Fall Time: approximately 2-3 microseconds with a 5 Vdc pull-up voltage.

Option SSR Outputs:
- **Isolation:** 5000 Vac RMS
- **Breakdown Voltage:** ±60 Vdc or 40 Vac; can switch positive, negative or AC voltages
- **Maximum Leakage (Off) Current:** 1000 nA (1 μA)
- **On Resistance:** 1.0 to 2.5 Ω
- **Maximum Load Current:** 500 mA
- **Output Turn On Time (milliseconds):** 1.8 ms typical, 5.0 ms maximum
- **Output Turn Off Time (milliseconds):** 0.5 ms typical, 2.0 ms maximum
- **Maximum Recommended Pulse Frequency:** 30 Hz

**Electrical**

**Power Consumption:** The following table shows typical power consumption and power factor values with all three phases powered at nominal line voltages. The power supply draws most of the total power consumed, while the measurement circuitry draws 1-10% of the total (6-96 milliwatts per phase, depending on the model). Due to the design of the power supply, WattNode meters draw slightly more power at 50 Hz.
Table 11: Power Supply Characteristics

*Note: This is the maximum rated power at 115% of nominal Vac at 50 Hz. This is the same as the rated power that appears on the front label of the meter.

Maximum Operating Power Supply Voltage Range: -20% to +15% of nominal (see table above). For the WNB-3D-240-P, this is -20% of 208 Vac (166 Vac) to +15% of 240 Vac (276 Vac).

Operating Frequencies: 50/60 Hz

Measurement Category: CAT III

Measurement category III is for measurements performed in the building installation. Examples are measurements on distribution boards, circuit-breakers, wiring, including cables, bus-bars, junction boxes, switches, socket-outlets in the fixed installation, and equipment for industrial use and some other equipment, for example, stationary motors with permanent connection to the fixed installation.

The line voltage measurement terminals on the meter are rated for the following CAT III voltages (these ratings also appear on the front label):

Table 12: WattNode CAT III Ratings

Current Transformer Inputs:

Nominal Input Voltage (At CT Rated Current): 0.33333 Vac RMS
Absolute Maximum Input Voltage: 5.0 Vac RMS
Input Impedance at 50/60 Hz: 23 kΩ
Certifications

**Safety:** UL 61010-1; CAN/CSA-C22.2 No. 61010-1-04; IEC 61010-1

**Immunity:** EN 61326: 2002 (Industrial Locations)

- **Electrostatic Discharge:** EN 61000-4-2: 4 kV contact, 8 kV air: (B) Self-Recovering
- **Radiated RF Immunity:** EN 61000-4-3: 10 V/m: (A) No Degradation
- **Electrical Fast Transient / Burst:** EN 61000-4-4: 2 kV: (B) Self-Recovering
- **Surge Immunity:** EN 61000-4-5: 1 kV I/O, 4 kV AC: (B) Self-Recovering
- **Conducted RF Immunity:** EN 61000-4-6: 3 V: (A) No Degradation
- **Voltage Dips, Interrupts:** EN 61000-4-11: (B) Self-Recovering

**Emissions:** FCC Part 15, Class B; EN 55022: 1994, Class B

Environmental

- **Operating Temperature:** -30°C to +55°C (-22°F to 131°F)
- **Altitude:** Up to 2000 m (6560 ft)
- **Operating Humidity:** non-condensing, 5 to 90% relative humidity (RH) up to 40°C, decreasing linearly to 50% RH at 55°C.
- **Pollution:** POLLUTION DEGREE 2 - Normally only non-conductive pollution; occasionally, a temporary conductivity caused by condensation must be expected.
- **Indoor Use:** Suitable for indoor use.
- **Outdoor Use:** Suitable for outdoor use when mounted inside an electrical enclosure (Hammond Mfg., Type EJ Series) that is rated NEMA 3R or 4 (IP 66).

Mechanical

- **Enclosure:** High impact, ABS and/or ABS/PC plastic
- **Flame Resistance Rating:** UL 94V-0, IEC FV-0
- **Size:** 153 mm × 85 mm × 38 mm (6.02 in × 3.35 in × 1.50 in)
- **Weight:** 285 gm (10.1 oz) 314 gm (11.1 oz)
- **Connectors:** Euroblock style pluggable terminal blocks
  - **Green:** up to 12 AWG (2.5 mm²), 600 V
  - **Black:** up to 12 AWG (2.5 mm²), 300 V

Current Transformers

WattNode meters use CTs with built-in burden resistors generating 0.33333 Vac at rated AC current. The maximum input current rating is dependent on the CT frame size (see the tables below). Exceeding the maximum input current rating may damage CTs, but should not harm the meter.

None of these CTs measure DC current and the accuracy can be degraded in the presence of DC currents, as from half-wave rectified loads. The solid-core CTs are most susceptible to saturation due to DC currents.

WattNode meters should only be used with UL recognized current transformers, which are available from Continental Control Systems. Using non-approved transformers will invalidate the meter UL listing. The following sections list approved UL recognized current transformers.
Common CT Specifications

- **Type:** voltage output, integral burden resistor
- **Output Voltage at Rated Current:** 0.33333 Vac (one-third volt)
- **Standard CT Wire Length:** 2.4 m (8 feet)
- **Optional CT Wire Length:** up to 30 m (100 feet)

### Split-Core CTs

Also called "opening" current transformers. These are UL recognized under UL file numbers E96927 or E325972: CTM-0360-xxx, CTS-0750-xxx, CTS-1250-xxx, CTS-2000-xxx, where xxx indicates the full scale current rating between 0005 and 1500 amps.

The accuracy of the split-core CTs are specified from 10% to 100% of rated AC current. The phase angle is specified at 50% of rated current (amps). Some low current split-core CTs have unspecified phase angle errors.

<table>
<thead>
<tr>
<th>Model</th>
<th>Inside Diameter</th>
<th>Rated Amps (-xxx)</th>
<th>Accuracy / Phase Angle</th>
<th>Maximum Amps</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTM-0360-xxx</td>
<td>0.30&quot; (7.5 mm)</td>
<td>5, 15, 30, 50, 70</td>
<td>±1% / &lt;2°</td>
<td>100</td>
</tr>
<tr>
<td>CTS-0750-xxx</td>
<td>0.75&quot; (19.0 mm)</td>
<td>5, 15, 30, 50</td>
<td>±1% / not spec.</td>
<td>200</td>
</tr>
<tr>
<td>CTS-0750-xxx</td>
<td>0.75&quot; (19.0 mm)</td>
<td>70, 100, 150, 200</td>
<td>±1% / &lt;2°</td>
<td>200</td>
</tr>
<tr>
<td>CTS-1250-xxx</td>
<td>1.25&quot; (31.7 mm)</td>
<td>70, 100</td>
<td>±1% / not spec.</td>
<td>600</td>
</tr>
<tr>
<td>CTS-1250-xxx</td>
<td>1.25&quot; (31.7 mm)</td>
<td>150, 200, 250, 300, 400, 600</td>
<td>±1% / &lt;2°</td>
<td>600</td>
</tr>
<tr>
<td>CTS-2000-xxx</td>
<td>2.00&quot; (50.8 mm)</td>
<td>600, 800, 1000, 1200, 1500</td>
<td>±1% / &lt;2°</td>
<td>1500</td>
</tr>
</tbody>
</table>

Table 13: Split-core CTs

### Split-Core Bus Bar CTs

These current transformers are referred to as “bus bar” CTs because they are available in larger and custom sizes appropriate for use with bus bars or multiple large conductors. These are UL recognized under UL file number E325972: CTB-wwwxhhh-xxx, where www and hhh indicate the width and height in inches, and xxx indicates the full scale current rating.

The accuracy of the split-core bus bar CTs is specified from 10% to 100% of rated current. The phase angle is specified at 50% of rated current (amps).

<table>
<thead>
<tr>
<th>Model</th>
<th>Opening</th>
<th>Rated Amps</th>
<th>Accuracy / Phase Angle</th>
<th>Maximum Amps</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTB-1.5x3.5-0600</td>
<td>1.5&quot; x 3.5&quot; (38.1 mm x 88.9 mm)</td>
<td>600</td>
<td>±1.5% / &lt;1.5°</td>
<td>750</td>
</tr>
<tr>
<td>CTB-4.0x4.0-0800</td>
<td>4.0&quot; x 4.0&quot; (101.6 mm x 101.6 mm)</td>
<td>800</td>
<td>±1.5% / &lt;1.5°</td>
<td>1000</td>
</tr>
<tr>
<td>CTB-4.0x4.0-1200</td>
<td>4.0&quot; x 4.0&quot; (101.6 mm x 101.6 mm)</td>
<td>1200</td>
<td>±1.5% / &lt;1.5°</td>
<td>1500</td>
</tr>
<tr>
<td>CTB-4.0x4.0-2000</td>
<td>4.0&quot; x 4.0&quot; (101.6 mm x 101.6 mm)</td>
<td>2000</td>
<td>±1.5% / &lt;1.5°</td>
<td>2500</td>
</tr>
<tr>
<td>CTB-4.5x4.0-3000</td>
<td>4.5&quot; x 4.0&quot; (114.3 mm x 101.6 mm)</td>
<td>3000</td>
<td>±1.5% / &lt;1.5°</td>
<td>3750</td>
</tr>
<tr>
<td>CTB-wwwxhhh-xxx</td>
<td>Custom (www by hhh inches)</td>
<td>xxx</td>
<td>±1.5% / &lt;1.5°</td>
<td>4000</td>
</tr>
</tbody>
</table>

Table 14: Split-core Bus Bar CTs

### Solid-Core CTs

The accuracy of the solid-core CTs is specified from 10% to 100% of rated current. The phase angle error is specified at 50% of rated current. The CT suffix xxx is the rated current. The “N” at the end of the part number indicates a nickel core material, which is the only core material available for our solid-core CTs.

<table>
<thead>
<tr>
<th>Model</th>
<th>Inside Diameter</th>
<th>Rated Amps (-xxx)</th>
<th>Accuracy / Phase Angle</th>
<th>Maximum Amps</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTT-0300-xxxN</td>
<td>0.30” (7.6mm)</td>
<td>5, 15, 20, 30</td>
<td>±1% / &lt;1°</td>
<td>30</td>
</tr>
<tr>
<td>CTT-0500-xxxN</td>
<td>0.50” (12.7mm)</td>
<td>15, 20, 30, 50, 60</td>
<td>±1% / &lt;1°</td>
<td>60</td>
</tr>
<tr>
<td>CTT-0750-xxxN</td>
<td>0.75” (19.0mm)</td>
<td>30, 50, 70, 100</td>
<td>±1% / &lt;1°</td>
<td>100</td>
</tr>
<tr>
<td>CTT-1000-xxxN</td>
<td>1.00” (25.4mm)</td>
<td>50, 70, 100, 150, 200</td>
<td>±1% / &lt;1°</td>
<td>200</td>
</tr>
<tr>
<td>CTT-1250-xxxN</td>
<td>1.25” (31.7mm)</td>
<td>70, 100, 150, 200, 250, 300, 400</td>
<td>±1% / &lt;1°</td>
<td>400</td>
</tr>
</tbody>
</table>

Table 15: Solid-core CTs

---

**Warranty**

All products sold by Continental Control Systems, LLC (CCS) are guaranteed against defects in material and workmanship for a period of five years from the original date of shipment. CCS’s responsibility is limited to repair, replacement, or refund, any of which may be selected by CCS at its sole discretion. CCS reserves the right to substitute functionally equivalent new or serviceable used parts.

This warranty covers only defects arising under normal use and does not include malfunctions or failures resulting from: misuse, neglect, improper application, improper installation, water damage, acts of nature, lightning, product modifications, alterations or repairs by anyone other than CCS.

Except as set forth herein, CCS makes no warranties, expressed or implied, and CCS disclaims and negates all other warranties, including without limitation, implied warranties of merchantability and fitness for a particular purpose.

**Limitation of Liability**

In no event shall CCS be liable for any indirect, special, incidental, punitive or consequential damages of any kind or nature arising out of the sale or use of its products whether such liability is asserted on the basis of contract, tort or otherwise, including without limitation, lost profits, even if CCS has been advised of the possibility of such damages.

Customer acknowledges that CCS’s aggregate liability to Customer relating to or arising out of the sale or use of CCS’s products, whether such liability is asserted on the basis of contract, tort or otherwise, shall not exceed the purchase price paid by Customer for the products in respect of which damages are claimed. Customer specifically acknowledges that CCS’s price for the products is based upon the limitations of CCS’s liability set forth herein.
CTL Series - 1.25 Inch Window - 250 and 400 Amps

The CTL revenue-grade, split-core current transformers provide IEEE C57.13 class 0.6 accuracy, with UL listing for energy management equipment. They combine the ease of installation of an opening current transformer with the accuracy normally associated with solid-core current transformers. They are an ideal companion to the WattNode® Revenue meter for revenue-grade electric power metering applications.

- **Very low phase angle error**: essential for accurate power and energy measurements
- **IEEE/ANSI C57.13 and IEC 60044-1 accuracy** over the full temperature range
- **Glove-friendly** operation with one hand

**Specifications**

All specifications are for operation at 60 Hz.

- **Accuracy**:
  - ±0.50% from 15% to 100% of rated primary current
  - ±0.75% from 1% to 15% of rated primary current
- **Phase angle**:
  - ±0.25 degrees (15 minutes) from 50% to 100% of rated current
  - ±0.50 degrees (30 minutes) from 5% to 50% of rated current
  - ±0.75 degrees (45 minutes) from 1% to 5% of rated current
- **Accuracy standards**: IEEE C57.13 class 0.6, IEC 60044-1 class 0.5S
- **Primary rating**: 250 or 400 Amps, 600 Vac, 60 Hz nominal
- **Output**: 333.33 mVac at rated current
- **Operating temperature**: -30°C to 55°C
- **Safe**: integral burden resistor, no shorting block needed
- **Standard lead length**: 8 ft (2.4 m), 18 AWG
- **Approvals**: UL recognized, CE mark, RoHS
- **Assembled in USA**: qualified under Buy American provision in ARRA of 2009

<table>
<thead>
<tr>
<th>Models</th>
<th>Amps</th>
<th>MSRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTL-1250-250 Opt C0.6</td>
<td>250</td>
<td>$66</td>
</tr>
<tr>
<td>CTL-1250-400 Opt C0.6</td>
<td>400</td>
<td>$66</td>
</tr>
</tbody>
</table>
HOBO UX120 4-Channel Analog Logger

Flexible, Accurate, 4-channel Analog Logger

The HOBO UX120-006M Analog Logger is a high-performance, LCD display data logger for building performance monitoring applications.

As Onset’s highest-accuracy data logger, it provides twice the accuracy of previous models, a deployment-friendly LCD, and flexible support up to four external sensors for measuring temperature, current, CO2, voltage, and more.

**Supported Measurements:** Temperature, 4-20mA, AC Current, AC Voltage, Air Velocity, Carbon Dioxide, Compressed Air Flow, DC Current, DC Voltage, Gauge Pressure, Kilowatts, Volatile Organic Compound (sensors sold separately)

**Key Advantages:**

- Twice the accuracy over previous models
- 16-bit resolution
- Flexible support for a wide range of external sensors
- LCD confirms logger operation and displays near real-time measurement data
- Provides minimum, maximum, average, and standard deviation logging options
- On-screen alarms notify you when a sensor reading exceeds set thresholds
- Stores 1.9 million measurements for longer deployments between offloads

For complete information and accessories, please visit: [www.onsetcomp.com](http://www.onsetcomp.com)

<table>
<thead>
<tr>
<th>Part number</th>
<th>UX120-006M (4-Channel Analog)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory</td>
<td>1.9 Million</td>
</tr>
<tr>
<td>Logging Rate</td>
<td>1 second to 16 hours, user selectable</td>
</tr>
<tr>
<td>Logging Modes</td>
<td>Normal, Burst, Statistics</td>
</tr>
<tr>
<td>Memory Modes</td>
<td>Wrap when full or stop when full</td>
</tr>
<tr>
<td>Time Accuracy</td>
<td>±1 minute per month at 25°C (77°F)</td>
</tr>
<tr>
<td>Battery Life</td>
<td>1 year typical with logging rate of 1 minute and sampling interval of 15 seconds or greater, user replaceable, 2 AAA</td>
</tr>
<tr>
<td>Dimensions</td>
<td>10.8 x 5.41 x 2.54 cm (4.25 x 2.13 x 1 in.)</td>
</tr>
<tr>
<td>Operating Range</td>
<td>Logging: -20° to 70°C (-4° to 158°F); 0 to 95% RH (non-condensing)</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±0.1 mV ±0.1% of reading</td>
</tr>
<tr>
<td>CE Compliant</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*USB cable included with software
HOBO® UX120 4-Channel Thermocouple Logger
Log type J, K, T, E, R, S, B, or N thermocouples

The HOBO UX120 Thermocouple Logger is a four-channel LCD data logger for measuring and recording temperature in a range of monitoring applications. The logger makes it easy and convenient to record temperatures over a broad range (-260 to 1820°C) and can accept up to four J, K, T, E, R, S, B, or N type probes.

In addition to accepting four thermocouple probes, the logger features an internal temperature sensor for logging ambient temperatures, further extending the application possibilities.

**Supported Measurements:** Temperature

**Key Advantages:**
- Easy-to-view LCD display confirms logger operation and battery status
- Near real-time readout of current temperatures as well as minimum, maximum, average and standard deviation statistics
- On-screen alarms notify you if temperatures exceed high or low thresholds
- Large memory capacity capable of storing 1.9 million measurements
- Start, stop, and restart pushbuttons
- User-upgradeable firmware

For complete information and accessories, please visit: [www.onsetcomp.com](http://www.onsetcomp.com)

<table>
<thead>
<tr>
<th>Part number</th>
<th>UX120-014M (Thermocouple)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal Temperature</strong></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>-20° to 70°C (-4° to 158°F)</td>
</tr>
<tr>
<td>Accuracy</td>
<td>±0.21°C from 0° to 50°C (±0.38°F from 32° to 122°F)</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.024°C at 25°C (0.04°F at 77°F)</td>
</tr>
<tr>
<td>Drift</td>
<td>&lt;0.1°C (0.18°F) per year</td>
</tr>
<tr>
<td><strong>Logger</strong></td>
<td></td>
</tr>
<tr>
<td>Logging Rate</td>
<td>1 second to 18 hours, 12 minutes, 15 seconds</td>
</tr>
<tr>
<td>Logging Modes</td>
<td>Normal, Burst, Statistics</td>
</tr>
<tr>
<td>Memory Modes</td>
<td>Wrap when full or stop when full</td>
</tr>
<tr>
<td>Time Accuracy</td>
<td>±1 minute per month at 25°C (77°F)</td>
</tr>
<tr>
<td>Battery Life</td>
<td>1 year typical with logging rate of 1 minute and sampling interval of 15 seconds or greater, user replaceable, 2 AAA</td>
</tr>
<tr>
<td>Dimensions</td>
<td>10.8 x 5.41 x 2.54 cm (4.25 x 2.13 x 1 in.)</td>
</tr>
<tr>
<td>Operating Range</td>
<td>Logging: -20° to 70°C (-4° to 158°F); 0 to 95% RH (non-condensing)</td>
</tr>
<tr>
<td>CE Compliant</td>
<td>Yes</td>
</tr>
</tbody>
</table>

The HOBO UX120 Thermocouple Logger is a four-channel LCD data logger for measuring and recording temperature in a range of monitoring applications. The logger makes it easy and convenient to record temperatures over a broad range (-260 to 1820°C) and can accept up to four J, K, T, E, R, S, B, or N type probes.

**Thermocouple Range Accuracy Resolution**

<table>
<thead>
<tr>
<th>Thermocouple (probes sold separately)</th>
<th>Range</th>
<th>Accuracy</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type J</td>
<td>-210° to 760°C (-346° to 1,400°F)</td>
<td>±0.6°C (±1.08°F) ± thermocouple probe accuracy</td>
<td>0.03°C (0.06°F)</td>
</tr>
<tr>
<td>Type K</td>
<td>-260° to 1,370°C (-436° to 2,498°F)</td>
<td>±0.7°C (±1.26°F) ± thermocouple probe accuracy</td>
<td>0.04°C (0.07°F)</td>
</tr>
<tr>
<td>Type T</td>
<td>-260° to 400°C (-436° to 752°F)</td>
<td>±0.6°C (±1.08°F) ± thermocouple probe accuracy</td>
<td>0.02°C (0.03°F)</td>
</tr>
<tr>
<td>Type E</td>
<td>-260° to 950°C (-436° to 1,742°F)</td>
<td>±0.6°C (±1.08°F) ± thermocouple probe accuracy</td>
<td>0.03°C at (0.05°F)</td>
</tr>
<tr>
<td>Type R</td>
<td>-50° to 1,550°C (-58° to 2,822°F)</td>
<td>±2.2°C (±3.96°F) ± thermocouple probe accuracy</td>
<td>0.08°C (0.15°F)</td>
</tr>
<tr>
<td>Type S</td>
<td>-50° to 1,720°C (-58° to 3,128°F)</td>
<td>±2.2°C (±3.96°F) ± thermocouple probe accuracy</td>
<td>0.08°C (0.15°F)</td>
</tr>
<tr>
<td>Type B</td>
<td>+60° to 1,820°C (1,022° to 3,308°F)</td>
<td>±2.5°C (±4.5°F) ± thermocouple probe accuracy</td>
<td>0.1°C (0.18°F)</td>
</tr>
<tr>
<td>Type N</td>
<td>-260° to 1,300°C (-436° to 2,372°F)</td>
<td>±1.0°C (±1.8°F) ± thermocouple probe accuracy</td>
<td>0.06°C (0.11°F)</td>
</tr>
</tbody>
</table>

*USB cable included with software*
The HOBO UX120 4-Channel Pulse data logger is a highly versatile, 4-channel energy data logger that combines the functionality of four separate energy loggers into one compact unit. It enables energy management professionals – from energy auditors to building commissioners – to easily track building energy consumption, equipment runtimes, and water and gas flow rates.

**Supported Measurements:** Pulse Signals, Event, Runtime, State, AC Current, AC Voltage, Amp Hour, Kilowatt Hours, Kilowatts, Motor On/Off, Power Factor, Volt-Amps, Watt Hours, Watts, Volt-Amp Reactive, Volt-Amp Reactive Hour

**Key Advantages:**
- Simultaneously measures and records pulse signals, events, state changes, and runtimes
- Stores over 4 million measurements, enabling longer deployments with fewer site visits
- Streamlines deployment via range of start/stop options, logger status LEDs, and high-speed USB 2.0 data offload
- Works with Onset’s E50B2 Power & Energy Meter to measure Power Factor, Reactive Power, Watt Hours, and more

**Minimum System Requirements:**

<table>
<thead>
<tr>
<th>Part number</th>
<th>UX120-017</th>
<th>UX120-017M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory</td>
<td>520,000 measurements</td>
<td>4,000,000 measurements</td>
</tr>
<tr>
<td>Sampling rate</td>
<td>1 second to 18 hours</td>
<td></td>
</tr>
<tr>
<td>Battery life</td>
<td>1 year typical, user replaceable, 2 AA</td>
<td></td>
</tr>
<tr>
<td>External contact Input</td>
<td>Electronic solid state switch closure or logic driven digital signals to 24V</td>
<td></td>
</tr>
<tr>
<td>Max pulse frequency</td>
<td>120 Hz</td>
<td></td>
</tr>
<tr>
<td>Max state, event, runtime frequency</td>
<td>1 Hz</td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td>Pulse: 1 pulse, Runtime: 1 second, State and Event: 1 state or event</td>
<td></td>
</tr>
<tr>
<td>Bits</td>
<td>4 - 32 bits depending on pulse rate and logging interval</td>
<td></td>
</tr>
<tr>
<td>Lockout time</td>
<td>0 to 1 second in 100 ms steps</td>
<td></td>
</tr>
<tr>
<td>Operating temperature range</td>
<td>Logging: -40º to 70ºC (-40º to 158ºF); 0 to 95% RH (non-condensing)</td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td>11.4 x 6.3 x 3.3 cm (4.5 x 2.5 x 1.3 inches)</td>
<td></td>
</tr>
<tr>
<td>CE compliant</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

For complete information and accessories, please visit: [www.onsetcomp.com](http://www.onsetcomp.com)

**Contact Us**
- **Sales** (8am to 5pm ET, Monday through Friday)
  - Email [sales@onsetcomp.com](mailto:sales@onsetcomp.com)
  - Call 1-800-564-4377
  - Fax 1-508-759-9100
- **Technical Support** (8am to 8pm ET, Monday through Friday)
  - [www.onsetcomp.com/support/contact](http://www.onsetcomp.com/support/contact)
  - Call 1-877-564-4377
The HOBO 4-Channel Pulse Input data logger records electronic pulses and mechanical or electrical contact closures from external sensing devices. Using HOBOware®, you can easily configure each of its four channels to monitor and record pulse, event, state, or runtime data in a wide variety of applications, including tracking building energy consumption, monitoring mechanical equipment, and recording water and gas flow rates. Plus, when combined with the E50B2 Energy & Power Meter (T-VER-E50B2), this logger provides extensive power and energy monitoring capabilities. There are two models of the HOBO 4-Channel Pulse Input data logger: the UX120-017 stores more than 500,000 measurements while the UX120-017M holds more than 4,000,000 measurements.

Specifications

Inputs

External Contact Input: Electronic solid state switch closure or logic driven digital signals to 24 V

Maximum Pulse Frequency: 120 Hz

Maximum State, Event, Runtime Frequency: 1 Hz

Bits: 4–32 bits depending on pulse rate and logging interval

Maximum Pulses Per Interval: 7,863,960 (using maximum logging rate)

Driven Logic Signal: Input Low: ≤ 0.4 V; Input High: 3 to 24 V

Absolute Maximum Rating: Maximum Voltage: 25 V DC

Solid State Switch Closure: Input Low: < 10 KΩ; Input High: > 500 KΩ

Internal Weak Pull-Up: 100 KΩ

Input Impedance: Solid state switch closure: 100 KΩ pull up; Driven signal: 4.5 KΩ

Minimum Pulse Width: Contact closure duration: 500 uS; Driven logic signal: 100 uS

Lockout Time: 0 to 1 second in 100 ms steps

Edge Detection: Falling edge, Schmitt Trigger buffer

Preferred Switch State: Normally open or Logic “1” state

Logging

Resolution: Pulse: 1 pulse, Runtime: 1 second, State and Event: 1 State or Event

Logging Rate: 1 second to 18 hours, 12 minutes, 15 seconds

Time Accuracy: ±1 minute per month at 25°C (77°F) (see Plot A on next page)

Battery Life: 1 year, typical with logging intervals greater than 1 minute and normally open contacts

Battery Type: Two AA alkaline or lithium batteries

Memory

Memory: UX120-017: 520,192 measurements (assumes 8-bit)

UX120-017M: 4,124,672 measurements (assumes 8-bit)

Download Type: USB 2.0 interface

Download Time: 30 seconds for UX120-017; 1.5 minutes for UX120-017M

Physical

Operating Range: Logging: -40° to 70°C (-40° to 158°F); 0 to 95% RH (non-condensing)

Launch/Readout: 0° to 50°C (32° to 122°F) per USB specification

Weight: 149 g (5.26 oz)

Size: 11.4 x 6.3 x 3.3 cm (4.5 x 2.5 x 1.3 inches)

Environmental Rating: IP50

The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).
Specifications (continued)

![Plot A: Time Accuracy](image)

Logger Components and Operation

Start/Stop Button: Press this button for 3 seconds to start or stop logging data. This requires configuring the logger in HOBOware with a Button Start and/or a Button Stop (see Setting up the Logger). You can also press this button for 1 second to record an internal event (see Recording Internal Logger Events).

LEDs: There are three types of LEDs on the logger to indicate logger operation: Logging, Waiting, and Activity. Note that all LEDs will blink when the logger is initially powered (i.e. when the batteries are installed).

<table>
<thead>
<tr>
<th>LED</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logging (green)</td>
<td>Blinks every 2 seconds when the logger is recording data. Disable this LED by selecting the Turn Off LEDs option in HOBOware.</td>
</tr>
<tr>
<td>Waiting (orange)</td>
<td>Blinks every 2 seconds when awaiting a start because the logger was configured with Start At Interval, Delayed Start, or Button Start settings in HOBOware.</td>
</tr>
<tr>
<td>Activity (red)</td>
<td>There is one Activity LED per input channel. Press the Test button to activate all four Activity LEDs for 10 minutes to determine the state of the four input channels. When the logger is recording data, the Activity LED for the corresponding channel will blink at every pulse signal. Note: If you press the Test button during logging, then the Activity LED will remain illuminated for any channel that has not been configured to record data.</td>
</tr>
</tbody>
</table>

Inputs: There are 4 input channels to connect the logger to external sensors/devices.

Terminal Blocks: There are 4 terminal blocks included with the logger to plug into the inputs for connecting devices.

Test Button: Press this button to activate the Activity Lights for 10 minutes to test for contact resistance or voltage signal in any of the four input channels (see the LED table).

Mounting Holes: There are four mounting holes, two on each side, that you can use to mount the logger to a surface (see Mounting the Logger).

USB Port: This is the port used to connect the logger to the computer or the HOBO U-Shuttle via USB cable (see Setting up the Logger and Reading Out the Logger).

Setting up the Logger

Use HOBOware Pro to set up the logger, including selecting the start and stop logging options, configuring the input channels for specific sensor types, and entering scaling factors. It may be helpful to set up the logger with a Delayed Start or a Button Start first and then bring it to the location where you will mount it to connect the external sensors/devices and test the connections before logging begins.

1. Connect the logger and open the Launch window. To connect the logger to a computer, plug the small end of the USB cable into the side of the logger and the large end into a USB port on the computer. Click the Launch icon on the HOBOware toolbar or select Launch from the Device menu.

   Important: USB specifications do not guarantee operation outside this range of 0°C (32°F) to 50°C (122°F).

2. Select Sensor Type. Each of the input channels can be configured to log the following:

   - **Pulse.** This records the number of pulse signals per logging interval (the logger records a pulse signal when the input transitions to the logic low). There are built-in scaling factors you can select for supported devices and sensors, or you can set your own scaling when you select raw pulse counts. You can also adjust the maximum pulse frequency and lockout time as necessary.

   - **State.** This records how long an event lasts by storing the date and time when the state of the signal or switch changes (logic state high to low or low to high). The logger checks every second for a state change, but will only record a time-stamped value when the state change occurs. One state change to the next represents the event duration.

   - **Event.** This records the date and time when a connected relay switch or logic low transition occurs (the logger records an event when the input transitions to the logic low). This is useful if you need to know when an event occurred, but do not need to know the duration of the event. You can also adjust the lockout time to debounce switches.

   - **Runtime.** This records the number of state changes that happen over a period of time. The logger checks the state of the line once a second. At the end of each logging
3. Choose the logging interval, from 1 second to a maximum of 18 hours, 12 minutes, and 15 seconds (available for Pulse or Runtime logging only).

4. Choose when to start logging:
   - Now. Logging begins immediately.
   - At Interval. Logging will begin at the next even interval.
   - Push Button. Logging will begin once you press the Start/Stop logging button for 3 seconds.
   - On Date/Time. Logging will begin at a date and time you specify.

5. Choose when to stop logging:
   - When Memory Fills. Logging will end once the logger memory is full.
   - Never (wrapping). The logger will record data indefinitely, with newest data overwriting the oldest.
   - Push Button. Logging will end once you press the Start/Stop logging button for 3 seconds. **Note:** If you also configured a Push Button start, then you must wait 5 minutes after logging begins before you can use the button to stop logging.
   - Specific Stop Date. Logging will end at a date and time you specify.

6. Select any other logging options as desired and finish the launch configuration. Depending on the start type, verify that the logging or waiting LED is blinking.

### Connecting Sensors, Transducers, or Instruments to the Logger

You can connect the logger to an external sensing device using the four input channels. To connect a device to the logger:

1. Follow the instructions and wiring diagrams in the user manual for the device.
2. Connect the device to the terminal block as directed in the device instructions.
3. Plug in the terminal block into one of the four inputs (labeled 1 through 4).
4. Press the Test button as needed to activate the Activity LEDs and check whether the logger reads the pulse signal.
5. Configure logger launch settings if you have not already.

### Notes:
- Be sure that all devices are connected before logging begins. Any sensors/devices attached after logging begins will not record accurate data.
- If connecting an E50B2 Energy & Power Meter (T-VER-E50B2), you have the option to use the default meter settings or your own custom settings.
- If any channels have been configured to record raw pulse counts or events in HOBOware, there is also an option to specify lockout time. This can prevent false readings from mechanical contact/closure bouncing. For more information on setting lockout time, see the HOBOware Help.

#### Determining Logging Duration for Event/State Data

The logger's storage capacity and logging duration varies depending on several factors, including logging interval, number of channels configured, and the type of data being recorded. This table estimates the logging duration based on recording event or state changes on one input channel with logging set to stop when the memory is full. To estimate logging duration for multiple event or state channels, divide the logging duration by the number of active channels. If you want to know exactly how long the logger will run, use pulse or runtime modes.

<table>
<thead>
<tr>
<th>Time Between Events</th>
<th>Approximate Total Data Points</th>
<th>Approximate Logging Duration (1 Year Battery Life)</th>
<th>Logger Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 15 seconds</td>
<td>346,795</td>
<td>4 to 60 days</td>
<td>UX120-017</td>
</tr>
<tr>
<td></td>
<td>2,740,781</td>
<td>32 days to 1.3 years</td>
<td>UX120-017M</td>
</tr>
<tr>
<td>16 seconds to 4.2 minutes</td>
<td>260,096</td>
<td>48 days to 2.1 years</td>
<td>UX120-017</td>
</tr>
<tr>
<td></td>
<td>2,062,336</td>
<td>1 to 16.6 years</td>
<td>UX120-017M</td>
</tr>
<tr>
<td>4.3 to 6.8 minutes</td>
<td>208,077</td>
<td>1.6 to 27 years</td>
<td>UX120-017</td>
</tr>
<tr>
<td></td>
<td>1,649,869</td>
<td>13 to 214 years</td>
<td>UX120-017M</td>
</tr>
<tr>
<td>68.3 minutes to 18.2 hours</td>
<td>173,397</td>
<td>22.5 to 360 years</td>
<td>UX120-017</td>
</tr>
<tr>
<td></td>
<td>1,374,891</td>
<td>17.8 to 285 decades</td>
<td>UX120-017M</td>
</tr>
</tbody>
</table>

**Notes:**
- Typical battery life is 1 year.
- The logger can record battery voltage data in an additional channel. This is disabled by default. Recording battery voltage reduces storage capacity and is generally not used except for troubleshooting.

### Setting Maximum Pulse Frequency

When recording raw pulse counts, the logger dynamically adjusts its memory usage from 4 to 32 bits instead of a typical fixed width. This results in the ability to store more data using less space, which in turn extends logging duration. The default pulse rate is 120 Hz, which is also the maximum. You can adjust this rate in HOBOware (see the HOBOware Help for details). Decreasing the rate will increase logging duration. The following table shows examples of how pulse rate and logging interval affect logging duration.

<table>
<thead>
<tr>
<th>Logging Interval</th>
<th>Pulse Rate (Hz)</th>
<th>Number of Bits Required</th>
<th>Approximate Total Data Points</th>
<th>Approximate Logging Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 minute</td>
<td>4</td>
<td>8</td>
<td>520,192</td>
<td>361 days</td>
</tr>
<tr>
<td>1 minute</td>
<td>50</td>
<td>12</td>
<td>346,795</td>
<td>240 days</td>
</tr>
<tr>
<td>1 minute</td>
<td>120</td>
<td>16</td>
<td>260,096</td>
<td>180 days</td>
</tr>
</tbody>
</table>

### Reading Out the Logger

There are two options for reading out the logger: connect it to the computer with a USB cable and read out it with HOBOware, or connect it to a HOBO U-Shuttle (U-DT-1, firmware version 1.14m030 or higher) and then offload the datafiles from the
Recording Internal Logger Events

The logger records several internal events to help track logger operation and status. These events, which are unrelated to state and event logging, include the following:

<table>
<thead>
<tr>
<th>Internal Event Name</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Connected</td>
<td>The logger was connected to the computer.</td>
</tr>
<tr>
<td>Started</td>
<td>The Start/Stop button was pressed to begin logging.</td>
</tr>
<tr>
<td>Stopped</td>
<td>The logger received a command to stop recording data (from HOBOware or by pushing the Start/Stop button).</td>
</tr>
<tr>
<td>Button Up/Button Down</td>
<td>The Start/Stop button was pressed for 1 second.</td>
</tr>
<tr>
<td>Safe Shutdown</td>
<td>The battery level is 1.8 V; the logger shut down.</td>
</tr>
</tbody>
</table>

Mounting the Logger

There are three ways to mount the logger using the materials included:

- Screw the logger to a surface with a Phillips-head screwdriver and the four mounting screws, using the following dimensions.

- Attach the two magnets to the back of the logger and then place the logger on a magnetic surface.

- Use the hook-and-loop tape to affix the logger to a surface.

Protecting the Logger

The logger is designed for indoor use and can be permanently damaged by corrosion if it gets wet. Protect it from condensation. If it gets wet, remove the battery immediately and dry the circuit board. It is possible to dry the logger with a hair dryer before reinstalling the battery. Do not let the board get too hot. You should be able to comfortably hold the board in your hand while drying it.

Note: Static electricity may cause the logger to stop logging. The logger has been tested to 4 kV, but avoid electrostatic discharge by grounding yourself to protect the logger. For more information, search for “static discharge” in the FAQ section on onsetcomp.com.

Battery Information

The logger is shipped with two AA alkaline batteries. You can also use 1.5 V AA lithium batteries when deploying the logger in cold environments. Expected battery life varies based on the temperature where the logger is deployed and the frequency (the logging interval and the rate of state changes and/or events) at which the logger is recording data. A new battery typically lasts one year with logging intervals greater than one minute and when the input signals are normally open or in the high logic state. Deployments in extremely cold or hot temperatures, logging intervals faster than one minute, or continuously closed contacts may reduce battery life.

The logger can also be powered through the USB cable connected to the computer. This allows you to read out the logger when the remaining battery voltage is too low for it to continue logging. Connect the logger to the computer, click the Readout button on the toolbar, and save the data as prompted. Replace the batteries before launching the logger again.

To replace the batteries:

1. Disconnect the logger from the computer.
2. Unscrew the logger case using a Phillips-head screwdriver.
3. Carefully remove the two batteries.
4. Insert two new AA batteries (alkaline or lithium) observing polarity. When batteries are inserted correctly, all LEDs blink briefly.
5. Carefully realign the logger case and re-fasten the screws.

WARNING: Do not cut open, incinerate, heat above 85°C (185°F), or recharge the lithium batteries. The batteries may explode if the logger is exposed to extreme heat or conditions that could damage or destroy the battery cases. Do not dispose of the logger or batteries in fire. Do not expose the contents of the batteries to water. Dispose of the batteries according to local regulations for lithium batteries.

HOBOware provides the option of recording the current battery voltage at each logging interval, which is disabled by default. Recording battery life at each logging interval takes up memory and therefore reduces logging duration. It is recommended you only record battery voltage for diagnostic purposes.
APPENDIX 5: ALCS START UP DOCUMENTATION
# ENCELUM® Energy Management System

## REQUEST FOR START UP SERVICES

**Project Name:** Watermelon Music  
**Project Number:**

**OSRAM Project Manager:** Horace Allen  
**Telephone:** 201-508-6549

**Installer Contact Name:** Daniel Sedillo  
**Telephone:** 530-753-1551  
**Cell:** 916-208-1551  
**Email:** dsedillo@cal.net

**Customer Contact Name:** Jeff Simons  
**Telephone:** 530-758-4010  
**Cell:** 530-758-4010  
**Email:** heffy@watermelonmusic.com

**Customer IT Contact Name:** Jeff Simons  
**Telephone:** 530-758-4010  
**Cell:** 530-758-4010  
**Email:** heffy@watermelonmusic.com

**Job Site Address:**  
207 E St.  
Davis, CA 95616

---

1. ✔ All associated lighting fixtures and controls are installed and energized.
2. ✔ All ENCELUM EMS equipment is installed according to specifications.  
   - ✔ SSU is installed and connected to a UPS backup 120V power source.
   - ✔ All ECUs and Network Switch(s) are installed and connected to non-backup 120V power source.
   - ✔ ECUs are interconnected via supplied CAT5 cable to the Network Switch (if more than one ECU is present).
   - ✔ All ENCELUM control devices are installed as per drawings and specifications.
   - ✔ GreenBus cables are installed, terminated, secured, and strain relieved per installation drawing or as-built.
   - ✔ All channel end nodes have been tested with ENCELUM GreenBus Diagnostic Tool (GBDT) or Installation Test Tool (ITT).
3. ✔ ENCELUM EMS equipment has been connected to customer LAN (if applicable).
4. □ Remote Access is configured and connected (if applicable).

**Additional Comments:**

---

5. ✔ The following equipment is available, to the Start Up Technician if required  
   - ✔ Qualified electrician (for troubleshooting installation)
   - ✔ Ladder
   - □ Extension Ladder
   - □ Lift equipment with qualified operator

6. ✔ Access for technician to all building areas with ENCELUM EMS components is available.  
   - □ Security card or key access is required on this site.  
   - □ Access restricted to the following hours:

7. □ Special authorization, safety training, or PPE (personal protective equipment) is required for access to this site.  
   **Details:**

8. ✔ Person responsible for EMS operation after start up -  
   **Name:** Jeff Simons  
   **Cell:** 530-758-4010  
   **Email:** heffy@watermelonmusic.com

9. ✔ Recipients of Administrator Training have been identified.  
   □ List of personnel attached

10. ✔ Training has been scheduled for (date/time):  
    **November 10, 2014**

---

**Minimum two weeks advanced notice is required to schedule startup services.**

**Requested Start Up Date:** 11/10/14  
**Authorized Requestor:** Nicole Graebner  
**Signature:** ______________________  
**Date:**

---

11. By signing this form, you are certifying that the ENCELUM EMS will be installed according to specifications and tested prior to the requested start-up date and that all information provided is accurate. You also acknowledge that OSRAM SYLVANIA is relying on your representations to schedule personnel and commit resources (including travel costs and expenses), and that you may be liable for any additional costs incurred by OSRAM SYLVANIA as a result of an incomplete, untested, or faulty installation.

12. Please return this form by e-mail to your OSRAM SYLVANIA Project Manager at:
Watermelon Music Demonstration Details

After the installation of the TLEDs and advanced control system (Encelium), each of the following control strategies will be monitored for a period of at least 14 days to evaluate the energy savings of each strategy. Initial commissioning will allow for each of the strategies to be implemented without needing the Encelium team on site. To allow for this, it is recommended that the four strategies be set up as scenes during initial commissioning, or an equivalent approach.

Control Strategies/Scenes:

1. **Scheduled, Full Output**: Lighting system operating per the customer's operating schedule at full light output. (See spreadsheet for details.)
2. **Scheduled + Tuned**: Lighting system operating per Watermelon Music's operating schedule (Control Strategy 1) at the desired, task-tuned, light level to be determined during the commissioning process with store owner (Jeff Simons).
3. **Scheduled + Tuned + Occupancy Control**: Lighting system operating per the customer's operating schedule at the desired, task-tuned, light level (Control Strategy 2) with occupancy sensor control enabled as appropriate per zone type.
4. **Scheduled + Tuned + Occupancy Control + Daylight Control**: Lighting system operating per the customer’s operating schedule at the desired, task-tuned light level, with occupancy sensor (Control Strategy 3) and daylight control enabled as appropriate per zone type.

---

Zone 1 (Purple): Front Area – Display Lighting
Zone 2 (Red): Front Area – Ambient Lighting
Zone 3 (Orange): Main Area – Ambient Lighting
Zone 4 (Green): Main Area – Display Lighting
Zone 5 (Dark Blue): Storage Area
Zone 6 (Light Blue): Instrument Repair Area
Zone 7 (Pink): Restroom 1
Zone 8 (Yellow): Restroom 2
<table>
<thead>
<tr>
<th>Strategies</th>
<th>Task Timing</th>
<th>Shopping Control</th>
<th>Smart Time Scheduling</th>
<th>Eavesdropping</th>
<th>Manual ON/OFF Control (Mycon/ILC)</th>
<th>Program Control (Scene Controller)</th>
<th>Manual Control of Zones (Scene Controlled)</th>
<th>Task Load Threshold</th>
<th>General Data</th>
<th>Advanced Functionality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Level Set Points</td>
<td>Task Level</td>
<td>Task Level</td>
<td>Task Level</td>
<td>Task Level</td>
<td>Task Level</td>
<td>Task Level</td>
<td>Task Level</td>
<td>Task Level</td>
<td>Task Level</td>
<td>Task Level</td>
</tr>
<tr>
<td>Control Strategy 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>100%</td>
<td>100%</td>
<td>None</td>
<td>N/A</td>
<td>100%</td>
<td>100%</td>
<td>None</td>
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APPENDIX 6: PHOTOMETRIC MEASUREMENTS
Watermelon Music Site – Photometric Measurements

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Illuminance Data

Pre-retrofit and post-retrofit illuminance data taken at four foot measurements is provided for circulation areas, feature displays and general retail applications for points of measurement shown in red. Pre-retrofit data includes illuminance data for as-is store conditions and relamped store conditions. Post-retrofit illuminance data is for the fully commissioned TLED and ALCS lighting system.

FIGURE 1: WATERMELON MUSIC SITE - PHOTOMETRIC MEASUREMENT LOCATIONS
**Figure 2:** Watermelon Music Site - Entry Area

**Figure 3:** Watermelon Music Site - General Retail Area
Figure 4: Watermelon Music Site - Display Area

Table 1 contains horizontal illuminance measurements taken at grade for as-is, re-lamped and post-retrofit store conditions. Counter measurements were taken at the task plane. N/A indicates measurement locations that were not available for additional measurements due to changes made to the store layout. Location type refers to the space use at the time of measurement, however due to the dynamic nature of the product displays and circulation areas it is assumed that all areas of the store will be used for multiple purposes over the lifetime of the light system.

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Luminance Data

Pre- and post-retrofit luminance mapping and luminance ratio calculations are provided for points of measurement shown in red in Figures 5 and 6. Pre-retrofit data includes luminance mapping for as-is store conditions and relamped store conditions. Post-retrofit luminance mapping is collected for the fully commissioned TLED system and ALCS system taken after dark.

FIGURE 5: WATERMELON MUSIC ENTRY WAY – LUMINANCE MAPPING LOCATIONS
Luminance mapping with calculation areas identified for luminaire-adjacent areas and luminaire areas are provided in the following sections for each measurement location. Pre-retrofit as-is, pre-retrofit relamped and post-retrofit fully commissioned scenarios are included.
Location 1
Pre-Retrofit, As-Is

**Figure 7:** Location 1, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit As-Is

**Figure 8:** Location 1, Luminaire Luminance Mapping for Pre-Retrofit As-Is
Pre-Retrofit, Relamped

**Figure 9: Location 1, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit Relamped**

**Figure 10: Location 1, Luminaire Luminance Mapping for Pre-Retrofit Relamped**
Post-Retrofit TLED, Fully Commissioned

**Figure 11: Location 1, Luminaire-Adjacent Luminance Mapping for Post-Retrofit**

**Figure 12: Location 1, Luminaire Luminance Mapping for Post-Retrofit**
Location 2
Pre-Retrofit, As-Is

FIGURE 13: LOCATION 2, LUMINAIRE-ADJACENT LUMINANCE MAPPING FOR PRE-RETROFIT AS-IS

FIGURE 14: LOCATION 2, LUMINAIRE LUMINANCE MAPPING FOR PRE-RETROFIT AS-IS
Pre-Retrofit, Relamped

**Figure 15: Location 2, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit Relamped**

**Figure 16: Location 2, Luminaire Luminance Mapping for Pre-Retrofit Relamped**
Post-Retrofit TLED, Fully Commissioned

**Figure 17: Location 2, Luminaire-Adjacent Luminance Mapping for Post-Retrofit**

**Figure 18: Location 2, Luminaire Luminance Mapping for Post-Retrofit**
Location 3
Pre-Retrofit, As-Is

**Figure 19: Location 3, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit As-Is**

**Figure 20: Location 3, Luminaire Luminance Mapping for Pre-Retrofit As-Is**
Pre-Retrofit, Relamped

**Figure 21:** Location 3, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit Relamped

**Figure 22:** Location 3, Luminaire Luminance Mapping for Pre-Retrofit Relamped
Post-Retrofit TLED, Fully Commissioned

**Figure 23: Location 3, Luminaire-Adjacent Luminance Mapping for Post-Retrofit**

**Figure 24: Location 3, Luminaire Luminance Mapping for Post-Retrofit**
Location 4
Pre-Retrofit, As-Is

**Figure 25: Location 4, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit As-Is**

**Figure 26: Location 4, Luminaire Luminance Mapping for Pre-Retrofit As-Is**
Pre-Retrofit, Relamped

**Figure 27: Location 4, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit Relamped**

**Figure 28: Location 4, Luminaire Luminance Mapping for Pre-Retrofit Relamped**
Post-Retrofit TLED, Fully Commissioned

**Figure 29:** Location 4, Luminaire-Adjacent Luminance Mapping for Post-Retrofit

**Figure 30:** Location 4, Luminaire Luminance Mapping for Post-Retrofit
Location 5
Pre-Retrofit, As-Is

**Figure 31:** Location 5, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit As-Is

**Figure 32:** Location 5, Luminaire Luminance Mapping for Pre-Retrofit As-Is
Figure 33: Location 5, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit Relamped

Figure 34: Location 5, Luminaire Luminance Mapping for Pre-Retrofit Relamped
Post-Retrofit TLED, Fully Commissioned

**Figure 35: Location 5, Luminaire-Adjacent Luminance Mapping for Post-Retrofit**

**Figure 36: Location 5, Luminaire Luminance Mapping for Post-Retrofit**
Location 6
Pre-Retrofit, As-Is

**Figure 37: Location 6, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit As-Is**

**Figure 38: Location 6, Luminaire Luminance Mapping for Pre-Retrofit As-Is**
Pre-Retrofit, Relamped

**Figure 39: Location 6, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit Relamped**

**Figure 40: Location 6, Luminaire Luminance Mapping for Pre-Retrofit Relamped**
Pre-Retrofit TLED, Fully Commissioned

**Figure 41:** Location 6, Luminaire-Adjacent Luminance Mapping for Post-Retrofit

**Figure 42:** Location 6, Luminaire Luminance Mapping for Post-Retrofit
Location 7
Pre-Retrofit, As-Is

**Figure 43: Location 7, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit As-Is**

**Figure 44: Location 7, Luminaire Luminance Mapping for Pre-Retrofit As-Is**
Pre-Retrofit, Relamped

**Figure 45:** Location 7, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit Relamped

**Figure 46:** Location 7, Luminaire Luminance Mapping for Pre-Retrofit Relamped
Post-Retrofit TLED, Fully Commissioned

**Figure 47:** Location 7, Luminaire-Adjacent Luminance Mapping for Post-Retrofit

**Figure 48:** Location 7, Luminaire Luminance Mapping for Post-Retrofit
Location 8
Pre-Retrofit, As-Is

**Figure 49: Location 8, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit As-Is**

**Figure 50: Location 8, Luminaire Luminance Mapping for Pre-Retrofit As-Is**
Pre-Retrofit, Relamped

**Figure 51:** Location 8, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit Relamped

**Figure 52:** Location 8, Luminaire Luminance Mapping for Pre-Retrofit Relamped
Post-Retrofit TLED, Fully Commissioned

FIGURE 53: LOCATION 8, LUMINAIRE-ADJACENT LUMINANCE MAPPING FOR POST-Retrofit

FIGURE 54: LOCATION 8, LUMINAIRE LUMINANCE MAPPING FOR POST-Retrofit
Location 9
Pre-Retrofit, As-Is

**Figure 55: Location 9, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit As-Is**

**Figure 56: Location 9, Luminaire Luminance Mapping for Pre-Retrofit As-Is**
**Figure 57: Location 9, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit Relamped**

**Figure 58: Location 9, Luminaire Luminance Mapping for Pre-Retrofit Relamped**
Post-Retrofit TLED, Fully Commissioned

**Figure 59: Location 9, Luminaire-Adjacent Luminance Mapping for Post-Retrofit**

**Figure 60: Location 9, Luminaire Luminance Mapping for Post-Retrofit**
Location 10
Pre-Retrofit, As-Is

**Figure 61: Location 10, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit As-Is**

**Figure 62: Location 10, Luminaire Luminance Mapping for Pre-Retrofit As-Is**
Pre-Retrofit, Relamped

**Figure 63:** Location 10, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit Relamped

**Figure 64:** Location 10, Luminaire Luminance Mapping for Pre-Retrofit Relamped
Post-Retrofit TLED, Fully Commissioned

**Figure 65:** Location 10, Luminaire-Adjacent Luminance Mapping for Post-Retrofit

**Figure 66:** Location 10, Luminaire Luminance Mapping for Post-Retrofit
Location 11
Pre-Retrofit, As-Is

**Figure 67: Location 11, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit As-Is**

**Figure 68: Location 11, Luminaire Luminance Mapping for Pre-Retrofit As-Is**
Pre-Retrofit, Relamped

Figure 69: Location 11, Luminaire-Adjacent Luminance Mapping for Pre-Retrofit Relamped

Figure 70: Location 11, Luminaire Luminance Mapping for Pre-Retrofit Relamped
Post-Retrofit TLED, Fully Commissioned

**Figure 71: Location 11, Luminaire-Adjacent Luminance Mapping for Post-Retrofit**

**Figure 72: Location 11, Luminaire Luminance Mapping for Post-Retrofit**
APPENDIX 7: WATERMELON MUSIC COST INFORMATION
Lighting Package – Watermelon Music

The required materials, labor and purchasing information for the lighting design at Watermelon Music located in Davis, California is provided in this document. It includes pricing/quotes compiled from online vendors, electrical distributors, the selected installation contractor and the advanced lighting controls company.

The list of required materials are commercially available and no substitutions will be accepted without approval from CLTC.

CLTC Contact:
Nicole Graeber
Development Engineer
California Lighting Technology Center
University of California – Davis
633 Pena Drive, Davis, CA
Phone: 530.747.3847 | negraeber@ucdavis.edu

Required Materials and Labor

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Detailed Purchasing Information

Vendors

1000bulbs.com

- Cree CR-6 Downlight
  - Cree CR6-800L-27K-12-E26 (quantity 9)

Home Depot

- LED Cree Edison Lamp
  - BA19-08027OMF-12DE26-2U100 (quantity 4)

EarthLED.com

- Sylvania PAR-30
  - LED15PAR30/DIM/P/930/FL40 (quantity 47)

Electrical Distributor

Granite Electrical

- Cree Tubular LED Products
  - UR2-24-36L-40K-10V-FD (quantity 8)
  - UR2-48-45L-40K-10V-FD (quantity 84)
- Quote attached
- Contact:
  - Sean Callahan
  - scallahan@graniteelectrical.com
  - Granite Electrical Supply, Inc.
  - Office (916) 852-7555
  - Mobile (916) 730-4686
  - [www.graniteelectrical.com](http://www.graniteelectrical.com)
Electrical Contractor
Sedillo Company, Inc.

- Installation of new lighting system for first floor of Watermelon Music
- Quote attached
- Contact:
  
  Daniel Sedillo  
  Sedillo Company, Inc.  
  Remodeling Design & Construction  
  General Building Contractor #611115  
  
  dsedillo@cal.net  
  www.SedilloCompany.com  
  (530) 753-1551 office  
  (916) 208-1551 mobile

Advanced Lighting Controls - Manufacturer Representative
CAL Lighting, representing Encelium

- Encelium Advanced Lighting Controls System
- Quote, terms and conditions, and design attached
- Contact:
  
  Troy Peterson  
  CAL Lighting  
  Lighting Controls Specialist  
  troy.peterson@cal-lighting.com  
  916-718-2726 - Mobile  
  916-366-0111 - Office
TO:  UC DAVIS CAL LTG TECH CTR
     ONE SHIELDS AVE
     DAVIS, CA 95616

Project Info:
Project:  CLTC
Job #:  #LL-052014-2601
Bid Date:  05/20/14
Bid Time:  02:00 PM
Quoter:  BILL MELLIAR

Expiration Date:  06/19/14

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<td>CREE LIG</td>
<td>UR2-48-45L-40K-S-FD-10V</td>
<td>UR Troffer Upgrade, 4 ft, 2 lightbar, 4500 Lumen, 4000K, 0-10v Driver, 80 CRI, UL</td>
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<td>8</td>
<td>CREE LIG</td>
<td>UR2-24-36L-40K-S-FD-10V</td>
<td>UR Troffer Upgrade, 2 ft, 2 lightbar, 3600 Lumen, 4000K, 0-10v Driver, 80 CRI, UL IN STOCK AS OF 5/15/14: UR2-48-45L-40K-10V-FD (161), UR2-24-36L-40K-10V-FD(459) FROM WI.</td>
<td></td>
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From:
GRANITE SACRAMENTO
916-648-3900
1701 NATIONAL DRIVE, STE 200
SACRAMENTO*, CA 95834
Printed By: BILL MELLIAR
Bill Melliar
Granite Electrical Supply, Inc.
916.679.6888

Total 12,375.00

Notes
Hello My,

Here’s my estimate of costs for each of the scenarios you propose. Please see my notes in red below.

1 – Version 1 – Installation for 1st and 2nd floor $37,600
2 – Version 2 – Installation for 1st and 2nd floor $28,900
3 – Version 1 – Installation for the 1st floor $13,680
4 – Version 1 – Installation for the 2nd floor $23,920
4 – Version 2 – Installation for the 1st floor $12,000
6 – Version 2 – Installation for the 2nd floor $16,900

Please note that I have incorporated (into each version’s estimate) the costs for the initial re-lamping of the entire facility which will be required to establish a baseline for testing store “as is” or with all existing fixtures.

We can assume that the more involved TLED US Global product would add upwards to 10% of overall project costs. But for now this estimate includes the CREE UR-2 series product.

Thanks for your patience waiting for this information. Please let me know if there is any more information required to assist you in determining how you will move forward with the project at the Watermelon facility.

Thanks for your consideration.

Sincerely,

Daniel Sedillo
Sedillo Company, Inc.
Remodeling Design & Construction
General Building Contractor #611115

dsedillo@cal.net
www.SedilloCompany.com
(530) 753-1551 office
(916) 208-1551 mobile
Hi Daniel,

I’ve attached two version of the control strategy for the site. Version 1 would be the ideal strategy that we and PG&E would like, however with the possible cost for labor being very substantial for this version. I have created Version 2, Version 2 has a lot less controls for the second floor and reduced amount for the first floor.

Version 1, basically the entire store 1st and 2nd will be on the Encelium control, except for the closets and janitors room.

Version 2, for the first floor the bathrooms and storage rooms will just have occupancy switches and the rest of the store is Encelium. The second floor most of the rooms will just have occupancy switches except for the offices which will be on the Encelium control.

We wanted to ask to have six labor pricing quote that we can present to PG&E;
1 – Version 1 – Installation for 1st and 2nd floor
2 – Version 2 – Installation for 1st and 2nd floor
3 – Version 1 – Installation for the 1st floor
4 – Version 1 – Installation for the 2nd floor
4 – Version 2 – Installation for the 1st floor
6 – Version 2 – Installation for the 2nd floor

Also we wanted to ask about labor for installing the new TLED, there is the US Global Glow spec sheets that I gave you and we talked about its wiring and how involved that would be. There is the CREE UR2 Series (http://www.cree.com/Lighting/Products/Indoor/Upgrade-Solutions/UR-Series) that is a much simpler installation if we could get the cost estimate for those installation.

I know it’s a lot to ask of you, but we want to make sure the plan will be best for Watermelon Music.

Regards,

My

My Nguyen
Development Engineer
California Lighting Technology Center

633 Pena Dr
Davis CA 95618
Phone: 530-747-3804
mmmnguyen@ucdavis.edu
CAL Lighting
4000 Executive Parkway, Suite 350
San Ramon CA 94583
Phone: 855.9CALLTG
Fax: 855.9CALFAX
From: Luana Jonsson
Quoter Ph: email: luana.jonsson@cal-lighting.com

Date: Jun 24, 2014

Project: WATERMELON MUSIC
Location: DAVIS CA
Quote: NORCAL14-65394-1

To: Nicole Greaber
California Lighting Technology Center
633 Pena Drive
Davis CA 95618
Phone: (530) 747-3838
EMail: negraeber@ucdavis.edu

For: California Lighting Technology Center
Bid Date: Jun 24, 2014
Expires: Aug 8, 2014

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<td><strong>FIRST FLOOR ONLY</strong></td>
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<td>GBI ECS LITE</td>
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<td>1</td>
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<td>GREENBUS INSTALLTION TOOL</td>
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<td>LUMINAIRE CONTROL MODULE - ISOLATED</td>
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<td>(4) SENSOR INTERFACE MOUDLE (OCC SENSOR)</td>
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<td>(2) SENSOR INTERFACE MOUDLE (PHOTO SENSOR)</td>
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<td>POWER BAR - RACK MOUNT</td>
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<td>MOUNTING RACK, WALL 4U</td>
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<td>NETWORK CROSS-OVER CABLE - CAT5E (7FT)</td>
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<td>ENCEL</td>
<td>GREENBUS II CONNECTORS (QTY 50)</td>
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### Project
**WATERMELON MUSIC**

### Location
**DAVIS CA**

### Quote
**NORCAL14-65394-1**

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<td>AREA LIGHTING CONTROLLER - HEAVY DUTY REALY W/0-10V DIM</td>
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**Total:** $17,315.85

### Terms and conditions of sale:
Variations to this quote may result in changes to the quoted price. Unless specifically noted in the Bill Of Material, fixtures quoted herein include standard factory finishes U.O.N. Acceptance of order is contingent upon credit approval by the manufacturers represented on this quotation.
Quotation is based on one release per manufacturer. Exceptions must be agreed to, in writing, by both parties.
This quotation is based upon CAL Lighting's interpretation of contractor and/or distributor furnished PRE-BID documents.
Unless specifically noted in the Bill Of Material, this quote does not include special mounting hardware, fixture options or accessories.

**Mfg Terms:**
- ENCEL Encelium

**Freight Allowance**

**Minimum Order**
1. Prices
All quotations are effective for 120 days from date of issue, where delivery is authorized within a further 120 days from receipt of purchase order. Prices are otherwise subject to change without notice. Pricing includes any US or Canadian import duties where applicable.

2. Delivery Terms
Terms are ExWorks (Incoterms 2010) OSI’s facilities at Versailles, KY or Richmond Hill, ON. Freight is prepaid and allowed on orders exceeding cost of $5,000, using Standard UPS ground or freight equivalent as a single shipment within the continental USA or Canada. Any orders placed with special shipping instructions (Next Day Air, multiple destinations, multiple releases, other carriers, etc.) or orders under $5,000, will be shipped prepaid and billed to the customer. Customer shall bear all risk of loss or damage in transit. Seller reserves the right to make delivery in installments and backorder goods unless Customer expressly states otherwise in Customer’s purchase order. All such installments and backorders shall be separately invoiced and paid for when due, without regard to subsequent deliveries. Delay in delivery of an installment or backorder shall not relieve Customer of its obligation to accept remaining deliveries.

3. Payment & Credit
Payment is due thirty (30) days from the date of invoice. Customer agrees to pay taxes appearing on the invoice or furnish Seller with a valid resale/exemption certificate no later than the time of payment. Seller reserves the right to determine the suitability of the method of payment where payment is other than cash, certified check or money order. Seller reserves the right to deny credit to Customer and reserves the right to revoke credit previously extended to Customer because of Customer’s failure to pay for goods when due or for any other reason deemed good and sufficient by Seller. Seller may require subsequent shipments to be paid for in advance or on delivery. Past due balances shall be subject to interest charges at the maximum rate permitted by law.

4. Cancellation
Hold for release Purchase orders that are cancelled, or any Purchase Orders not yet shipped, will be subject to a cancellation fee equal to the greater of 15% of the order value or seller’s actual costs & expenses incurred for handling, inspection, restocking, engineering services (drawings), freight and invoicing charges as applicable. If goods have been shipped, cancelled orders must be returned to Seller within 30-days at Customer’s expense. Restocking fees will apply in addition to any applicable cancellation fee.

In the event of any termination of Services or a Statement of Work, Customer will pay Seller for all Services performed and expenses incurred up to and including the date of termination plus any termination fee if one is set forth in the applicable Statement of Work. In such event Customer will also pay Seller for any out-of-pocket demobilization or other direct costs resulting from termination.

5. Taxes
Any taxes which Seller may be required to pay or collect, under any existing or future law, upon or with respect to the sale, purchase, delivery, storage, processing, use or consumption of any of the material covered hereby, including taxes upon or measured by the receipts from the sale thereof, shall be paid for by Customer. Seller will collect and pay taxes when required to do so unless Customer furnishes a valid resale/exemption certificate to Seller relieving Seller of the requirement to collect and pay such taxes. If the certificate furnished to Seller is held invalid Customer agrees to pay the taxes (plus interest) not collected as a result of relying on Customer’s invalid certificate.

6. Delay
Seller shall be excused for any delay in performance or delivery due to acts of God, war, riot, embargoes, acts of civil or military authorities, fire, floods, accidents, quarantine restrictions, factory conditions, strikes, labor disputes, delays in transportation, shortage of transport vehicles, labor or materials, or any circumstance or cause beyond the control of Seller in the reasonable conduct of its business. Seller further reserves the right, in its full discretion, to allocate inventories and current production and to substitute suitable materials when, in its opinion, circumstances warrant such allocation or substitution.

7. Limitations on Usage
The Customer shall not use any goods delivered hereunder for any purpose other than that identified in Seller’s catalogs and literature as the intended use of such goods. Customer agrees to install and use all goods in compliance with all applicable regulations, including but not limited to applicable electrical, lighting, safety, and construction codes. Any warranty granted by Seller to the Customer shall be deemed void if any goods covered by such warranty are used for any purpose or in a manner not permitted hereunder. In addition, the Customer shall indemnify Seller and hold Seller harmless from and against any and all claims, damages, losses, costs, expenses and other liability of whatever nature that Seller suffers or incurs by reason of any such unintended use.

8. Initial Returns
Customer may inspect, or provide for inspection at the point of receipt of shipment. Customer shall inspect goods immediately. All claims for alleged defects in goods are waived unless Seller is notified of a claim for defective goods within 30 days after receipt of shipment. No claim shall be effective if made after the goods have been altered. Customer shall afford Seller prompt and reasonable opportunity to inspect all goods to which any claim is made. No material shall be returned without Seller’s express consent, a return authorization, and return instructions.

Any returns other than for warranty-eligible defects must be in as-new re-salable condition, and may be subject to a restocking charge. The re-stocking charge shall be 25% on OSRAM SYLVANIA manufactured products. For non-OSRAM SYLVANIA manufactured products, returns are subject to the original manufacturer’s limitations and restocking fees + 5% handling and administration fee. Lamps, special-order items, customized items, and other items designated as ‘NCNR’ shall be non-cancellable non-returnable.

9. Returns for Warranty and Repair
No returns shall be accepted without first obtaining a RGA (Returned Goods Authorization). All returns must have prior approval and must have a Returns Goods Authorization number (RGA) issued by OSRAM SYLVANIA. All paperwork must be marked with the RGA Number. End Users may contact either their Reseller or OSRAM SYLVANIA for warranty/repairs. Resellers must call OSRAM SYLVANIA’s Technical Support Desk –toll free 1-888-531-7573 or by email at technicalsupport@ENCELIUM.com and request an RGA number from the factory and provide a brief reason for the return. All returns received without a RGA number will be refused. All returns are to be sent Freight Prepaid to OSRAM SYLVANIA at the address below, or other address as instructed by OSRAM SYLVANIA:

OSRAM SYLVANIA Inc.
68 Leek Crescent, Unit A
Richmond Hill, Ontario L4B 1H1
(905) 731-7678
ATTN: Technical Help Desk, RGA (number)

10. Additional Terms
Except as expressly agreed by the parties, all purchase orders or contract for goods and services received by OSRAM SYLVANIA will be subject to these Terms and Conditions, and the current Limited Warranty, incorporated by reference. Use of any software products will be subject to the current Software End User License Agreement, incorporated by reference, without exception. Any additional or conflicting terms contained in any work order or purchase order shall not apply, even if the quote is referenced in the work or purchase order.

11. Applicable Law
Sales to U.S. locations are subject to the laws of the Commonwealth of Massachusetts, exclusive of its conflicts of law provisions. Sales to Canadian locations are governed by the laws of Canada. The United Nations Convention on Contracts for the International Sale of Goods is excluded.
Limited Warranty

1. Definitions

Installation Date shall mean the date upon which OSRAM SYLVANIA Inc. Hardware or Software, as the case may be, is installed.

OSI Hardware shall mean system hardware components produced and supplied by OSI, excluding Third Party Hardware

Third Party Hardware shall mean any third party hardware components supplied (but not manufactured by) OSI including but not limited to ballasts, lamps, sockets, occupancy sensors, photo sensors, power relays, energy meters, current transformers and related third party accessories.

2. OSRAM SYLVANIA Inc. Hardware Warranty

Scope. OSI warrants that the OSI Hardware is free from defects in materials and workmanship on the Installation Date. If a defect in materials or workmanship that was present in the OSI Hardware on the Installation Date manifests within forty-eight (48) months from the Installation Date, OSI will repair any such defect, or in lieu of repair, and at its sole option, replace the OSI Hardware. This Limited Hardware Warranty is not a warranty of future performance within the meaning of UCC §2-725(2). Where OSI elects to repair the Hardware pursuant to this warranty, that repair may, in the discretion of OSRAM SYLVANIA, be performed at the customer’s premises. Where OSRAM SYLVANIA elects to replace the OSRAM SYLVANIA Hardware pursuant to this warranty, the cost of shipping of replacement products is the sole responsibility of OSRAM SYLVANIA. OSRAM SYLVANIA shall not be responsible in any manner whatsoever for labor or other ancillary costs associated with the installation of replacement products.

Limitations and Exclusions. OSI does not warrant any Third Party Hardware which may be supplied with the system, and Customer agrees to look only to such third party vendors for any warranty claim relating thereto. This warranty is not applicable to any OSI Hardware that is not installed or operated in accordance with applicable federal, state, provincial or local electrical codes, the standards for safety of Underwriter’s Laboratories, Inc. (UL), Canadian Standards Association (CSA) or equivalent standards body, and all OSI system and equipment specifications, instructions and connection diagrams. This warranty is void if the customer fails to maintain electrical power and environmental conditions prescribed in any OSI specifications or instructions, or if the system, or any part thereof, has been subject to any unauthorized modification, use with any unauthorized device or feature, accident, neglect, misuse, use of unauthorized software or media, tampering, or any event other than ordinary use. OSI does not warrant defects caused by failure to provide a suitable operating environment for the product as prescribed by OSI’s published technical specifications, damage to the product caused by disasters such as fire, flood, wind, and lightning, or damage by other external causes.

Disclaimer of Other Warranties. THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY FOR OSI HARDWARE. ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE DISCLAIMED

3. Warranty Claims And Exclusive Remedy

OSI’s sole obligation and the customer’s sole and exclusive remedy for any warranty claim is limited to the adjustment, repair or replacement of such defective Hardware. THE ABOVE ARE THE CUSTOMER’S EXCLUSIVE REMEDIES FOR BREACH OF WARRANTY. IN NO EVENT SHALL OSRAM SYLVANIA BE LIABLE FOR ANY DAMAGES IN EXCESS OF THE PURCHASE PRICE OF THE SYSTEM. OSRAM SYLVANIA SHALL NOT IN ANY EVENT BE LIABLE FOR ANY INDIRECT, SPECIAL, INCIDENTAL, CONSEQUENTIAL, PUNITIVE OR LIQUIDATED DAMAGES OR PENALTIES BASED UPON ANY LEGAL THEORY, UNLESS PRECLUDED UNDER APPLICABLE STATE OR PROVINCIAL LAW, EVEN IF OSI HAD OR SHOULD HAVE HAD ANY KNOWLEDGE, ACTUAL OR CONSTRUCTIVE, OF THE POSSIBILITY OF SUCH DAMAGES.

4. Notice

Warranty claims must be submitted to OSI in writing within the prescribed warranty period, and within thirty (30) days of the alleged failure, c/o OSRAM SYLVANIA, 68 Leek Crescent, Richmond Hill, Ontario Canada L4B 1H1 or by fax at (905) 731-1401. Performance under the Limited Warranty is expressly conditioned upon strict compliance with this notice provision.
Software End User License Agreement

THIS SOFTWARE END USER LICENSE AGREEMENT ("AGREEMENT") IS A LEGAL AGREEMENT BETWEEN YOU (AS EITHER AN INDIVIDUAL OR A SINGLE ENTITY, the "LICENSEE" or "YOU") AND OSRAM SYLVANIA INC., 100 ENDICOTT STREET, DANVERS, MASSACHUSETTS 01923, ("OSI") THAT GOVERNS YOUR USE OF ANY SOFTWARE PROGRAM INSTALLED ON OR PROVIDED BY OSI FOR USE IN WITH YOUR OSI PRODUCT.

YOU SHOULD CAREFULLY READ THE AGREEMENT. IF YOU DO NOT ACCEPT ALL OF THE TERMS OF THIS AGREEMENT YOU HAVE NO RIGHT TO USE THE SOFTWARE AND MUST RETURN THE SOFTWARE AND ASSOCIATED OSI PRODUCT IMMEDIATELY. BY CLICKING ON "ACCEPT", OR BY USING THE SOFTWARE OR OSI PRODUCT, YOU HEREBY CONFIRM THAT YOU HAVE READ THE AGREEMENT AND CONSENT TO BE BOUND BY ALL OF ITS TERMS AND CONDITIONS.

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(b) "Documentation" means the explanatory printed or electronic materials provided by OSI with the Software and OSI Product, including, but not limited to, license specifications, instructions on how to use the Software and technical specifications.

(c) "OSI Product" means ENCELUM® lighting management systems, lighting products, and any related components or equipment sold by OSI that may contain, or be distributed with, the Software.

(d) "Software" means: any version of Polaris or any firmware, including components, extensions and modules, related updates and upgrades; firmware, licensed materials, including the Documentation, that is licensed by OSI to Licensee, whether incorporated into, distributed, or for use with the OSI Product.

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Customer Responsibilities and Prohibited Actions. (a) Confidentiality. Pursuant to this Agreement, OSI will share the Software and other confidential business information of OSI and its third party suppliers with Licensee. Licensee will hold such information in confidence and take the precautions necessary to safeguard the confidentiality of such information.

(b) Prohibited Actions. Licensee shall not, and shall not allow any third party to: (i) Allow the use, inspection or examination of the Software or OSI Products by anyone other than an Authorized User; (ii) Distribute, rent, loan, lease, sell, sublicense or otherwise transfer all or any portion of the Software or associated OSI Product to any other person without the prior written consent of OSI; (iii) Reverse engineer, decompile, translate, disassemble, or otherwise attempt to discover the source code of the Software; or create any derivative works of the Software or OSI Product; (iv) Circumvent, or attempt to circumvent, any license management, security devices, access logs, or other measures provided with the Software or OSI Product; or (v) Delete, tamper with, or modify any of OSI’s or any Third Party Licensor’s names, logos, copyright notices, trademarks, tags, and other proprietary markings.

(c) The obligations under this Section shall survive any termination of the Agreement.

Warranty. (a) OSI warrants to the Licensee only that for a period of 90 (ninety) days from the date of installation of the Software or OSI product at the Licensee Site, that the Software will, at the time of delivery, substantially conform to the Documentation. OSI will pass through any manufacturer’s warranty for hardware and any software provided by a third party manufacturer.

(b) During the Software Warranty Period OSI will respond to hotline requests to initially troubleshoot and identify failures in system operation and if the Software is found to be defective, OSI will provide reasonable programming services to fix bugs and provide workarounds and patch releases and will replace defective media. All notices of Software malfunctions shall be in writing with details sufficient to diagnose or reproduce said failure. THIS SHALL BE CUSTOMER’S SOLE AND EXCLUSIVE REMEDY AND OSI’S SOLE OBLIGATION FOR ANY DEFECTIVE SOFTWARE.

(c) This is a limited warranty and will apply only if OSI determines that the Software or OSI Product was not: (i) altered or modified, other than by OSI; (ii) improperly installed by Licensee or a third party; (iii) used in a manner other than as specified by OSI; or (iv) damaged by external factors such as, but not limited to, failure of electrical power.

(d) DISCLAIMER - THERE ARE NO OTHER WARRANTIES, EXPRESSED, IMPLIED, OR IMPLIED, BY OPERATION OF LAW OR OTHERWISE, FOR THE SOFTWARE AND DOCUMENTATION. OSI DISCLAIMS ANY AND ALL IMPLIED WARRANTIES OF TITLE, NON-INFRINGEMENT, MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. WITHOUT LIMITING THE FOREGOING, OSI DOES NOT WARRANT THAT THE FUNCTIONS CONTAINED IN SOFTWARE WILL OPERATE IN THE COMBINATION CUSTOMER SELECTS OR THAT OPERATION OF SOFTWARE WILL BE UNINTERRUPTED OR ERROR-FREE.

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Miscellaneous. (a) Complete Agreement. This Agreement contains the entire understanding of the parties with respect to the use and operation of the Software by Licensee. Any terms and conditions contained in a Licensee purchase order will not apply. This Agreement may be modified only by a writing executed by OSI and Licensee.

(b) Non-Waiver. The delay or failure of either party to exercise any right provided in the Agreement shall not be deemed a waiver, if any provision is held invalid, all others shall remain in force.

(c) Notice. All notices that are required under this Agreement will be in writing and will be considered effective upon receipt, provided that there is proof of delivery by a third party or written acknowledgement by the recipient. The notices addressed to Licensee shall be sent to its address set forth in the applicable price quotation. The notices addressed to OSI shall be sent to its address set out above, Attn: Legal Department.

(d) Assignment. Licensee may not assign, delegate or otherwise transfer the Agreement or any of its rights or obligations hereunder to any third party without OSI’s prior written consent and payment of any applicable fees. Any sale of all or substantially all of the assets of Licensee, or any change in possession of a controlling interest in Licensee shall be deemed to be an assignment for purposes of the Agreement. Subject to the above, the Agreement shall bind and inure to the benefit of the respective parties hereto, and their successors and permitted assigns.
Zone 1: Lights near entrance
Zone 2: Tracks and Downlight by entrance and window
Zone 3: Main store lights
Zone 4: Tracks around perimeter of interior
Zone 5: Repair Station and storage room, Men’s and Women’s Bathrooms
2nd Floor Version 1

Zone 1: Music training rooms (occupied after ~5pm) and break room
Zone 2: Corridors
Zone 3: Offices
Zone 4: Janitors closet and maintenance closets
2nd Floor Version 2

Zone 1: Music training rooms (occupied after ~5pm) and break room
Zone 2: Corridors
Zone 3: Offices
# SEDILLO COMPANY, INC.
## WATERMELON MUSIC SALES SUMMARY
### June 1, 2014 through February 25, 2015

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<th>Type</th>
<th>Date</th>
<th>Num</th>
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<th>Sales Price</th>
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