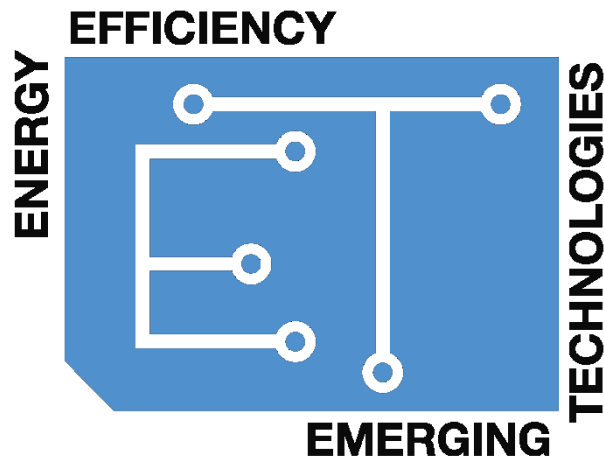


# Easily Commissioned Lighting Control Phase 3 Report

November 15, 2016



A Report of BPA's Energy Efficiency Emerging Technologies Initiative

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## **Abstract**

The Lighting Research Center (LRC) at Rensselaer Polytechnic Institute conducted a field study of three selected LED luminaire systems with integrated occupancy and daylight harvesting controls to independently monitor installation, commissioning, and operational parameters. The LRC also recorded power demand and light levels under field conditions.

The purpose of this study was to evaluate “easily commissioned lighting controls” using the default settings and following the manufacturers’ commissioning instructions.

The field study was limited to one open office space. System power and light levels were logged in each space, but occupancy was not independently monitored. Daylight conditions and occupancy varied from day to day, and as a result the different system results are not comparable with one another.

All of the tested lighting systems met or exceeded the target light levels prior to commissioning the daylight photosensors. Once the photosensors were commissioned, and the daylight harvesting systems were “tuned” to their environment, the measured light levels were similar to the target light levels.

However, none of the three tested systems were easy to commission, even for an experienced specifier who had significant experience commissioning lighting control systems. Insufficient commissioning documentation was the primary reason two of the three tested systems had a long setup/commissioning time. The other system had sufficient documentation, but its wireless switch was difficult to commission and pair with the installed luminaires. An experienced specifier addressed these shortcomings, but a significant amount of time and effort was required to address them. Less experienced personnel might be more likely to use the system “out-of-the-box” and not capture the potential energy savings the system could afford.

In addition, each of the tested systems had some operational shortcomings with the default settings, either the lights would turn on during vacancy and/or the lights would turn off when the space was occupied.

When properly commissioned, the tested lighting systems have the potential to both meet the desired light levels and save energy. Actual light levels and power demand will depend on the operating environment and the commissioning process.

## **An Emerging Technologies for Energy Efficiency Report**

The following report was funded by the Bonneville Power Administration (BPA) as an assessment of the state of technology development and the potential for emerging technologies to increase the efficiency of electricity use. BPA is undertaking a multi-year effort to identify, assess and develop emerging technologies with significant potential for contributing to efficient use of electric power resources in the Northwest.

BPA does not endorse specific products or manufacturers. Any mention of a particular product or manufacturer should not be construed as an implied endorsement. The information, statements, representations, graphs and data presented in these reports are provided by BPA as a public service. For more reports and background on BPA's efforts to "fill the pipeline" with emerging, energy-efficient technologies, visit Energy Efficiency's Emerging Technology (E3T) website at [http://www.bpa.gov/energy/n/emerging\\_technology/](http://www.bpa.gov/energy/n/emerging_technology/).

The Lighting Research Center (LRC) at Rensselaer Polytechnic Institute is the world's leading center for lighting research and education. Established in 1988 by the New York State Energy Research and Development Authority (NYSERDA), the LRC has been pioneering research in energy and the environment, light and health, transportation lighting and safety, and solid-state lighting for more than 25 years. Internationally recognized as the preeminent source for objective information on all aspects of lighting technology and application, LRC researchers conduct independent, third-party testing of lighting products in the LRC's state of the art photometric laboratories, the only university lighting laboratories accredited by the National Voluntary Laboratory Accreditation Program (NVLAP Lab Code: 200480-0). LRC researchers are continuously working to develop new and better ways to measure the value of light and lighting systems, such as the effects of light on human health. The LRC believes that by accurately matching the lighting technology and application to the needs of the end user, it is possible to design lighting that benefits both society and the environment.

## **Acknowledgments**

Leora Radetsky and Russ Leslie were co-principal investigators for this project. Leora Radetsky authored the report. LRC thanks Ken Nichols, Karen Janowitz, and Mary Matteson Bryan for their input and reviews.

## **Project Background**

In July 2014, Washington State University Energy Program (WSU) / Bonneville Power Administration (BPA) requested that the LRC create a buying guide for end-users who want to purchase "easily commissioned lighting controls" which reviews and compares currently available products.

The project was conducted in three phases. In the first phase, the LRC reviewed six easily deployed lighting control systems currently in the market, based on product literature and interviews with manufacturer representatives.<sup>1</sup> The second phase pilot tested three of the

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<sup>1</sup> [https://www.bpa.gov/EE/Technology/EE-emerging-technologies/Projects-Reports-Archives/Documents/EasyLightingControlsReview\\_LRC\\_BPA\\_2015Feb.pdf](https://www.bpa.gov/EE/Technology/EE-emerging-technologies/Projects-Reports-Archives/Documents/EasyLightingControlsReview_LRC_BPA_2015Feb.pdf)

reviewed products from phase one in an open office space at the LRC.<sup>2</sup> The LRC's Lighting Energy Alliance (LEA) partnered with BPA on phase two to include one additional luminaire-integrated control system in the report. The third phase tested three more luminaire integrated control systems in the same open office space at the LRC. This third phase is the subject of this report.

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<sup>2</sup> Easily Commissioned Lighting Controls Phase 2 Report [https://www.bpa.gov/ee/technology/ee-emerging-technologies/projects-reports-archives/documents/bpa%20lighting%20controls%20phase%202%20final%20report\\_11302015.pdf](https://www.bpa.gov/ee/technology/ee-emerging-technologies/projects-reports-archives/documents/bpa%20lighting%20controls%20phase%202%20final%20report_11302015.pdf)

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## Background

Recessed LED luminaires (“2 x 4 troffers”) with integrated lighting controls from LG, Eaton Lighting and Finelite with “plug and play”, “automatic configuration” or “easy to commission” setup options were evaluated in a commercial open-office setting in phase three. These systems were selected because they were commercially available as of December 2015 when the research team was evaluating potential luminaires for phase three, had a rated lumen output of 4000 lumens, and were available with a rated CCT of 3500 K. Each troffer also had a rated power factor of 0.9 or higher.<sup>3</sup> The LRC monitored the system commissioning, operation, and power demand of each of these systems over the course of several weeks.

## Luminaire Specification

As in phase two, the LRC located manufacturer-provided photometric files using AGi32 lighting software to simulate the daylighted 4<sup>th</sup> floor office at the LRC. The LRC office has light-colored walls, many windows, a white ceiling and hardwood floors. The office is 1059 sf with a 13-foot ceiling height. The surface reflectances used in the simulation were 70% for the walls and ceiling and 20% for the floor. Luminaires were mounted 10 feet above the floor on 8 x 6-foot centers in the simulation. A light loss factor (LLF) of 1.00 was used. A horizontal illuminance grid was located at a virtual workplane 2.5 feet above the floor, with 2 x 2-foot point spacing. Three manufacturer-provided photometric files were selected to provide about 30 footcandles (fc) (320 lux) average on the workplane (see Table 1), per IES recommendations for reading and writing tasks in office applications.

**Table 1: Predicted light levels in the simulated LRC office (without daylight).**

LED Luminaires (at 100% light output)	Rated Luminaire Power (W)	Rated Luminaire Efficacy (lm/W)	Predicted Average Illuminance (lux)	Calculated Lighting Power Density (W/sf)	Predicted Illuminance Uniformity (average:min)
Eaton Metalux Encounter 24EN-LD1-40-UNV-L835- CD1-SVPD1-U	41.3	98	332	0.31	3.3
Finelite HPR HPRLED-A-2x4-DCO-SO- 3500K-120V-SC-C1-OBB	36	120	321	0.27	4.0
LG Simple Choice LGE-2X4SC-40-35-4000-TB	37.1	108	328	0.28	3.0

### *Luminaires ordered*

The LRC used a local distributor in Troy, NY to purchase 24 commercially available LED recessed 2’ x 4’ luminaires, having a CCT of 3500K and about 4000 lumens, in January-February 2016<sup>4</sup>:

<sup>3</sup> The specification sheets do not specify whether this power factor applies only when the luminaire is operated at full power or also when it is dimmed.

<sup>4</sup> A local distributor was used so that manufacturer would not know that the luminaires were being purchased for the LRC.

- 8 LED luminaires from Eaton Lighting (Metalux) with integrated lighting controls (24EN-LD1-40-UNV-L835-CD1-SVPD1-U)
- 8 LED luminaires from Finelite with integrated WattStopper controls (HPR LED - A - 2x4- DCO - SO - 3500K - 120V - SC - C1 - OBB)
- 8 LED luminaires from LG with integrated lighting controls (LGE-2X4SC-40-35-4000-TB)

### *Integrated lighting control specifications*

In addition to the luminaires, the LRC also ordered commissioning tools and switches (or personal remotes) needed to commission and override the control system, as shown in Table 2. On behalf of the LRC, the local distributor consulted with the manufacturers' to determine that the control components ordered (sensors and switches) were appropriate for the application. Once the luminaires were received, LRC staff contacted manufacturers directly to ask for commissioning instructions, if complete instructions were not available on the manufacturers' websites. LRC obtained commissioning directions from all three manufacturers analyzed in this study. In all three cases, the LRC also contacted the manufacturer's directly to ask for additional assistance with commissioning and clarification about manual-on (vacancy mode) operation.

The luminaires were installed and monitored in the following chronological order: LG, Metalux and Finelite. The LG luminaires were installed and monitored from January 29 through March 28, 2016. The Metalux luminaires were installed on March 29<sup>th</sup> and monitored through May 10, 2016. The Finelite luminaires were installed on May 11<sup>th</sup> and monitored through July 15, 2016.

The LG system can be controlled with a wireless wall-mounted dimming switch. This dimming switch can control one or two groups of luminaires and will turn the groups of luminaires on and off, and increase or decrease light levels. Individual luminaires can be turned on or off, and light levels raised or lowered, using the commissioning app.

The Metalux system is intended to be controlled with a hand held remote control, per the product brochure.<sup>5</sup> This remote control can be used to turn individual luminaires on and off, increase or decrease light levels and select preset light levels (aka scenes). Luminaires cannot be "grouped" together and controlled as a group or zone. A wired 0-10V dimming wall switch is also available.

Finelite's system is also intended to be controlled with a specifiable handheld remote control. This system does not include a 0-10V dimming wall switch but it can be connected to a manual on/off switch. The included commissioning remote control does not turn the luminaires off, either individually or as a group. Users can increase or decrease the light output of an individual luminaire using a specifiable hand held remote control. The commissioning remote control can also be used to increase or decrease the light output of an individual luminaire. When the LRC connected the Finelite system to an existing wall switch at the end of the study, the luminaires were able to be switched on and off as a group.

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<sup>5</sup> 142665\_IntSensControls-11-17-14.pdf

**Table 2: Lighting devices deployed in the study**

Device type	LG Simple Choice LED Luminaires with integrated Sensor Connect control system [Luminaire price: \$169]	Eaton (Metalux) Encounter LED Luminaires with integrated controls [Luminaire price: \$498]	Finelite High Performance Recessed (HPR) LED Luminaires with integrated controls [Luminaire price: \$595]
Sensors	Included in luminaire  (occupancy sensor, daylight dimming sensor)	Included in luminaire  (PIR occupancy sensor, closed loop daylight dimming sensor)	Included in luminaire  WattStopper FD-301 (fixture integrated daylight dimming photosensor)  WattStopper FS-305 (fixture integrated PIR occupancy and light level sensor)
Driver	0-10V driver is standard	0-10V driver for local control	120V/277V Constant Current Reduction dimming driver with 0 – 10V dimming control is standard
Switch	LGE-SWITCH-4B (2-group wireless ZigBee dimming switch)  [Switch price: \$130]	SF10P (wired 0-10 V dimming switch)  [Switch price: \$79]  ISHH-02 (Personal remote)  [Remote price: \$98]	Dimming switch not available from manufacturer.  WattStopper LSR-301-P (An optional occupant remote control that can be ordered to temporarily increase or decrease light levels)
Commissioning Tool	USB Zigbee drive connected to tablet/smartphone with LG commissioning app installed (LG Commissioning App_Ver3.0.1.apk)  [Tablet price: \$191]	HHPRG-MS (programming remote)  [Remote price: \$70]	Wattstopper LSR-301-S (Photosensor setup tool) is included with Finelite system

LG Simple Choice LED luminaires and commissioning / control devices  
 (LG tablet, USB Zigbee drive, and wireless 2-group Zigbee dimming switch)



Eaton (Metalux) Encounter LED luminaires and commissioning / control devices  
 (Personal remote control, commissioning remote control and wired 0-10 V dimming switch)



Finelite High Performance Recessed (HPR) LED luminaires and commissioning remote control



Figure 1: LG, Metalux and Finelite LED luminaires and commissioning / control devices

## Summary of Installation, Commissioning, and Operation

Table 3 shows a summary of the process and procedural time the LRC used to install, commission and troubleshoot the lighting controls systems

**Table 3: Summary of installation, commissioning and operation**

System	LG Simple Choice LED Luminaires with integrated Sensor Connect control system	Eaton (Metalux) Encounter LED Luminaires with integrated controls	Finelite High Performance Recessed (HPR) LED Luminaires with integrated controls
Installation	<p>Instructions: None provided for luminaires, switch had instructions in box</p> <p>Installation time (8 luminaires): &lt; 2 hrs</p> <p>Installation time (switch): &lt; 1 hr</p>	<p>Instructions: in box</p> <p>Installation time (8 luminaires): &lt; 2 hrs</p> <p>Installation time (switch): &lt; 1 hr</p>	<p>Instructions: online</p> <p>Installation time (8 luminaires): &lt; 3 hrs</p> <p>Installation time (switch): N/A</p>
Commissioning	<p>Email/phone exchanges to get instructions: 3</p> <p>Instructions: complete</p> <p>Commissioning time (8 luminaires): &lt; 1 hr</p> <p>Commissioning time (switch): approx. 3 hrs with 5 email/phone exchanges</p>	<p>Email/phone exchanges to get instructions: 3</p> <p>Instructions: incomplete, LRC developed best-practice method (after 3 email/phone exchanges)</p> <p>Commissioning time (8 luminaires): &lt; 1 hr<sup>6</sup></p> <p>Commissioning time (switch): &lt; 1 hr</p>	<p>Email/phone exchanges to get instructions: 1</p> <p>Instructions: incomplete, LRC and Wattstopper tech support discussed best-practice method (2 email/phone exchanges)</p> <p>Commissioning time (8 luminaires): &lt; 1 hr<sup>6</sup></p>
Operation / Troubleshooting	<p>Email/phone exchanges to get support: 11</p> <ul style="list-style-type: none"> <li>• 2 site visits by LG personnel</li> <li>• False ons</li> <li>• False offs</li> </ul>	<p>Email/phone exchanges to get support: 2</p> <ul style="list-style-type: none"> <li>• False ons</li> <li>• One false off</li> </ul>	<p>Email/phone exchanges to get support: 0</p> <ul style="list-style-type: none"> <li>• False ons</li> </ul>

## System installation and monitoring

Eight LED luminaires of each brand were installed in succession in the open office space, at a mounting height of 10 ft. above finished floor (AFF). Each luminaire was installed such that the integrated sensors were in the same relative location every time, on the west side of the luminaire, or in the center of the luminaire in the case of the Metalux products. The mounting

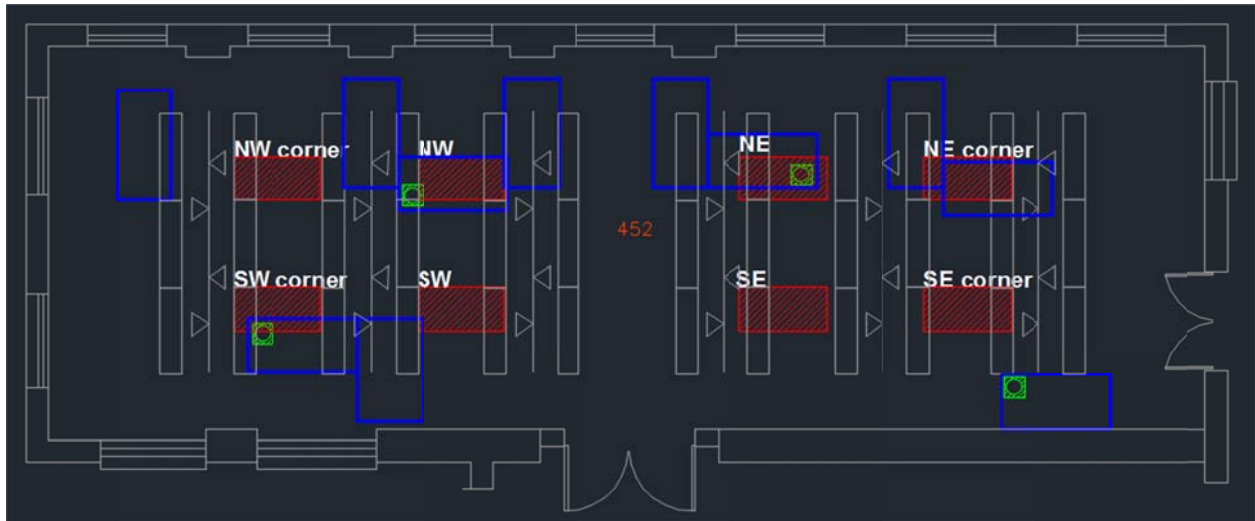
<sup>6</sup> Commissioning time only includes the aggregated time to follow the best practice procedure using the commissioning remote. It does not include time for emails or phone calls or time to develop the commissioning method.

height and luminaire spacing were within the rated mounting height and coverage area ranges given by each manufacturer.

White-louvered blinds were angled upwards to moderate daylight into the space. In the beginning of the phase three demonstrations, the louvers were adjusted to provide about 300 lux average on various desk surfaces under overcast skies, with no electric lighting.<sup>7</sup> One goal of these studies was to determine if the electric lighting would switch off when daylight levels alone were high enough to meet or exceed the target light levels.

Four Daysimeters were deployed in the study and mounted on four desks located in the SW corner, NW, NE and SE corners of the room. The Daysimeters logged the measured horizontal illuminance every three minutes.

A plan view of the LRC open office with desk, luminaire and Daysimeter locations is shown in Figure 2. Figure 3 shows the Finelite LED luminaires on the east side of the office.



**Figure 2: Plan view of the open office space with luminaire locations (filled red rectangles) and labels, desks (blue rectangles), and Daysimeter location on desks (green squares, not to scale).**

<sup>7</sup> Daylight levels were measured at 12:15 PM February 8, 2016. Average illuminance on desks and tables were 280 lux; light levels ranged from 170 – 490 lux. At mid-day, the majority of the measured light levels met or exceeded the target light levels for the space (300 lux), without any electric lighting.



**Figure 3: East side of open office with Finelite LED HPR luminaires**

As previously described in the phase two report,<sup>8</sup> each set of eight LED luminaires was installed, monitored and commissioned using a three-step protocol. After installation, the LED luminaires were operated on a digital timer at full light output for at least one week (on 8 AM – 6 PM) to determine the average power demand as the baseline application. Following that week, the digital timers were removed from the circuits and the luminaire-integrated controls were commissioned following the manufacturer’s instructions. The controls were operated in their default “automatic” or “plug-and-play” operation mode, without any advanced commissioning changes. Each commissioned system was to be deployed and monitored for at least three weeks, and then switches were installed (and commissioned if required) to determine their impact on performance. The LRC wanted to analyze occupant behavior and power demand when the integrated controls were operated in vacancy mode (luminaires switched on manually by occupants, and switched off automatically when the space was vacant). Only one of the three LED systems provided manual-on control (vacancy mode). The other two systems only allowed automatic-on control (luminaires switch on and off automatically based on occupancy and vacancy, respectively).

Occupancy and daylight availability varied from week to week as in phase two. Six LRC staff and graduate students moved into the space as “full-time” occupants of the study. During the

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<sup>8</sup> Easily Commissioned Lighting Controls Phase 2 Report [https://www.bpa.gov/ee/technology/ee-emerging-technologies/projects-reports-archives/documents/bpa%20lighting%20controls%20phase%202%20final%20report\\_11302015.pdf](https://www.bpa.gov/ee/technology/ee-emerging-technologies/projects-reports-archives/documents/bpa%20lighting%20controls%20phase%202%20final%20report_11302015.pdf)

spring semester (January – May 2016), students were frequently in the office space late into the night and on weekends to complete coursework. In June, one less desk was occupied<sup>9</sup>, and the space was predominantly occupied during business hours (8 AM – 6 PM).

Occupants liked the appearance of all three luminaire brands. One occupant commented that all three luminaire models were glary from his desk location, when on at full light output.

### *LG Simple Choice Installation*

The installation of the eight LG Simple Choice luminaires was straightforward. Luminaires were installed in under two hours. Power demand for the LG luminaires was monitored using a plug-load monitor.<sup>10</sup> System current, voltage, power, and power factor were logged every 15 seconds with this device. As previously mentioned, the LG luminaires were connected to a digital timer for baseline monitoring. The timer was set so that the luminaires were powered on from 8 AM to 6 PM every day.

### **Baseline operation**

The occupancy sensors are enabled prior to commissioning and the luminaires turned on and off automatically with occupancy/vacancy. Some of the occupants noticed that the luminaires were frequently getting brighter and dimmer and found this behavior to be distracting. Occupants also noticed that individual luminaires would sometimes turn off even if the space was occupied. Occupants frequently resorted to making large arm motions to keep the lights from switching off around them. During one late night working period, several occupants reported that the luminaires around them suddenly became a lot brighter, even though the space had been continuously occupied for several hours already under night time conditions.

### *Metalux Encounter installation*

Installation of the eight Eaton Metalux LED luminaires was straightforward; all eight luminaires were installed in under two hours. The system was also monitored using the plug-load monitoring device, with the same logging parameters.

### **Baseline operation**

As with the LG luminaires, the Metalux luminaires switched on and off individually in response to occupancy/ vacancy. In general, occupants liked the luminaire appearance and stated that they didn't notice as much fluctuation in light output as with the LG luminaires. A personal remote control was specified to switch and dim the luminaires; this device did not operate the luminaires as a group. Depending on the line-of-sight angle used, the remote control would toggle one to three luminaires on or off at once. To control one specific luminaire, LRC staff had to be directly under the luminaire pointing up at the sensor. One occupant commented that he did not like the abrupt changes in light levels when the luminaires switched on and off. Other occupants were not distracted by this behavior. During the baseline period, there were a few false-off events, where

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<sup>9</sup> After June 15<sup>th</sup>, the SE corner desk was no longer occupied. As a result the Finelite luminaire above this desk was frequently off during the day due to vacancy. However, this luminaire was one of the Finelite luminaires observed to be on at night (false on event).

<sup>10</sup> Onset UX120-018



individual luminaires would not stay on with occupancy<sup>11</sup>. The digital timer was removed from the system two days before the system was commissioned. During this two-day period, a few false-on events also occurred, where the individual luminaires would not turn off with vacancy.<sup>12</sup>

### *Finelite HPR Installation*

Installation of the Finelite luminaires was not as simple as the other two brands. After being powered on, the luminaires turned on and off repeatedly. On inspection, the integrated occupancy sensors were shipped with the minimum time delay (30 seconds) rather than the default time delay (15 minutes). LRC staff followed the manufacturer-provided instructions to set the time delay to approximately 15 minutes. This involved getting on a ladder, unscrewing the occupancy sensor lens assembly in each luminaire, and turning the time-delay trim pot to the desired time delay, then re-attaching the sensor lens. There was no 15-minute indicator line on the time-delay trim pot, so LRC staff selected the 12 minute setting. LRC staff confirmed that the time out period was about 13 minutes after adjusting the time-delay trim pot in each luminaire.

The Finelite luminaires would not operate correctly on the plug load monitor, so the current logging system described in the phase two report was deployed.<sup>13</sup> These devices logged system current every 15 seconds. This logging system does not monitor input voltage, so power factor could not be measured while the system was operational. To calculate system power, LRC used the average input voltage measured from the plug-load device, and applied a power factor of 0.99.<sup>14</sup>

### **Baseline operation**

As with the other two systems, the integrated occupancy sensors switched the individual luminaires on and off with occupancy/vacancy. Occupants noticed there was an audible click when the luminaires turned off after the time delay and several occupants said this was distracting or annoying. There was no way to turn luminaires on or off, either individually or as a

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<sup>11</sup> A red LED in the occupancy sensor blinks on occupancy according to manufacturer's product brochure (Encounter and SkyRidge Series with Integrated Sensor Controls). The red LED was not blinking when two occupants were congregated under luminaire, and then suddenly started blinking. When another occupant walked in to the coverage area, the luminaire turned on.

<sup>12</sup> This false-off behavior did not occur every time. On one night, a single occupant worked until about 10:30 PM. At this time five luminaires were on (four luminaires on east side of room around sole occupant and one luminaire on opposite corner of the room (on west side of room which was vacant). After the occupant left, two luminaires turned off within 30 minutes, a third luminaire turned off 30 minutes later (about 60 minutes after occupant left), the fourth luminaire turned off four hours after vacancy, and the fifth luminaire turned off six hours after vacancy (about 4:30 AM). An LRC staff member who was working through the night also confirmed that one of the luminaires was on around 4:30 AM.

<sup>13</sup> The occupancy sensors would not work when the Onset plug load meter was attached to the Finelite luminaires. In addition, not all of the luminaires would turn on when the plug load meter was installed. As previously noted, the plug load meter was able to be used without any difficulties with the other two LED systems. LRC contacted Finelite and Onset about this incompatibility but wasn't able to get the luminaires to operate correctly with the plug load monitor. Finelite suggested that it was a driver incompatibility and shared the driver specification sheet with LRC. LRC sent the driver information and monitoring data to Onset for technical support but did not receive a solution from Onset after reaching out several times.

<sup>14</sup> To determine the range of power factor, one Finelite LED luminaire was attached to a wattmeter and power and power factor were measured after the luminaire was operational for about one hour. When the luminaire was fully on (low ambient light levels) the measured power factor was 0.99. When the luminaire was fully dimmed (high ambient light levels) the power factor decreased to 0.91.

group with the included remote control. Individual luminaires could be dimmed with the LSR-301-S remote control but not switched off.

## **System commissioning and monitoring**

As previously noted, each of the systems was ordered with a commissioning remote control or tablet (see Table 2), per the manufacturers' instructions. For all three systems, the LRC found that the available online commissioning instructions were not complete, and contacted the manufacturer directly to obtain additional instructions. For the Metalux and Finelite systems, the LRC also contacted the manufacturer directly to determine if manual-on (vacancy mode) operation was possible.

### *LG Simple Choice commissioning and monitoring*

An LG Android tablet was used to commission the LG luminaires. This tablet was recommended by LG because it has a full-size USB port necessary to use the Zigbee USB Drive which communicates with the LG luminaires. The commissioning app and commissioning manual were obtained from LG via email. Once the app was installed on the tablet, the instructions in the commissioning manual were followed to commission the luminaires. In this system a zone describes a set of luminaires in one space (like an open office). Up to 50 devices, such as luminaires and switches, can be included in each zone. Up to 16 groups of devices can be located in one zone. Each group represents devices that are controlled together for occupancy/vacancy and daylight harvesting. The LRC created one zone for the open office. The app detected all eight luminaires, and all eight luminaires were added to one group. The "Open area" application mode was selected and the default parameters for this application mode were used. The LG app was very easy to use. Installing the app on the LG tablet was the most time consuming part of the initial commissioning process.

After the system was commissioned, the luminaires continued to dim up and down as observed in the baseline condition. The false-off events increased soon after the system was commissioned (luminaires would all turn off while the space was occupied) but happened less frequently on subsequent days.<sup>15</sup> The monitoring devices also showed that the luminaires were frequently coming on all night long (false-on events). LG was very responsive to LRC's questions and concerns. They sent their control engineer to the LRC twice to address the false on and false off problems. The wireless devices (dongles) on the luminaires were replaced twice and the control engineer twice updated the software on the Zigbee USB drive and sent over-the-air updates to the dongles on each luminaire. After two visits and many hours of troubleshooting, the false-off events were reduced while the space was occupied and the false-on events at night were greatly reduced.<sup>16,17</sup> There were still intermittent false-on events occurring most nights when the space

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<sup>15</sup> The digital timer was removed from the circuit prior to commissioning. All luminaires in a group would turn on and off at once in response to occupancy/vacancy. The luminaires did not appear to be sufficiently sensitive to fine motion, like typing. To test this, all of the occupants "froze" for 10 seconds and the luminaires subsequently dimmed down and shut off. To keep the lights on, large movements were sometimes required (e.g. waving your arm).

<sup>16</sup> The LG controls engineer recommended that "Private room" might be a better default application mode for the simulated open office than the "Open area" application mode LRC had chosen because only 8 luminaires were in this zone. To maintain continuity throughout the study, LRC continued to use the "Open area" application mode. The Private room application mode has lower maximum and mid-range light levels, a smaller range of dimming

was vacant. Originally, the LRC allocated three weeks to monitor each system after it was commissioned. Troubleshooting the system and going through the process to get the system to work as expected added two more weeks to the evaluation period.

The power demand and light level figures shown in the Results section are for the 4<sup>th</sup> week of operation, after the system was updated a second time by the LG controls engineer (e.g. Figures 4 and 5). After nearly five weeks of monitoring, the LRC staff decided to move forward and add the wireless switch, even though there were still some false-on and false-off events occurring. At the beginning of the 5<sup>th</sup> week, a wireless switch was added to the system following the instructions in the commissioning manual, in order to operate and monitor the system in manual-on (vacancy) mode. One wireless switch includes two pairs of dimming controls and controls two groups of luminaires separately. The LG app was used to detect the wireless switch device and to move the luminaires into two groups, a west side group and an east side group, each having four LED luminaires on that side of the open office. LRC staff had difficulty getting the wireless switches to operate the luminaires correctly and contacted LG support staff to troubleshoot the device.

Over the course of four days, the LRC staff spent several hours recommissioning and troubleshooting the system with LG support. The wireless switch was able to be successfully added to the system and operate two groups of luminaire in manual-on (vacancy) mode, but there were additional operational challenges. The luminaires kept switching off every 15 minutes (false-off events corresponding to the default time out period) and some of the luminaires no longer appeared to be dimming in response to daylight. The false-off events occurring in manual-on mode were particularly frustrating, because the occupants had to walk over to the wall switch every 15 minutes to turn the luminaires back on. Over the course of the troubleshooting process, LG asked the LRC staff to operate one side of the room in auto-on mode and the other side in manual-on mode. LRC operated the system using these modes for one additional week. Halfway through the week, one of the LG luminaires in the manual-on group no longer switched off in response to vacancy (see Figures 14 and 15 for corresponding power data). LRC staff also noticed that there were false-on events occurring more frequently when the space was vacant. At this point the LG system had been in place for eight weeks rather than five weeks and the Metalux system had to be installed to keep the project on track. As mentioned previously, LG staff was very helpful in troubleshooting the system, but LRC simply ran out of time to continue troubleshooting the system with the added wireless switch. Throughout the study, the LRC staff shared its power monitoring data with LG to assist in the troubleshooting process.

### *Metalux Encounter commissioning and monitoring*

Prior to commissioning the system, LRC staff contacted the local manufacturer's representative via email with a list of operational and commissioning questions, including questions regarding toggling individual luminaires on and off with the personal and commissioning remotes,<sup>18</sup> the

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under daylight conditions and slower fade rates by default than the default settings used in the "Open area" application mode.

<sup>17</sup> LG suggested extending the default time out periods as a workaround to minimize the false-off events.

<sup>18</sup> As previously noted, the personal remote would toggle one to three luminaires at once depending on the line-of-sight angle. LRC staff asked the local rep if this response was by design or if there was something wrong with the installed system / setup. This question was not directly answered by the local rep. Subsequently, LRC found

ability to “group” the luminaires together to dim or switch them at once, operation of the available wired dimming switch, and set up of the system up in vacancy mode. A technical support person at Metalux confirmed there was no vacancy mode option available for the Encounter LED system.

The local rep forwarded a programming brochure from Eaton, but this brochure did not explain how to commission the “Daytime Occupied Light Level” (DO) for each luminaire. Another Eaton document explained the process to change the DO light level, but it did not adequately describe how to commission each luminaire independently from its neighbor (142501-programming-6-15-ins.pdf). In other words, this guide did not explain how to preclude electric light from neighboring luminaires when setting the set point of the individual luminaire being commissioned.

Subsequently, LRC staff developed their own method for commissioning the individual luminaires under daylight based on best practices.

- First, the luminaires were commissioned on an overcast day when the ambient daylight levels were 40% - 90% of the target set point of 300 lux (at around 4 PM). At the beginning of the commissioning process, the measured light levels under daylight, with the electric lighting switched off, ranged from 171 – 437 lux. Two desks had ambient light levels above 400 lux; the DO levels for these desks were set to 400 lux instead of 300 lux.
- All of the luminaires were turned off with the HHPRG-MS programming remote except for the luminaire being commissioned.
- An illuminance meter was placed on a 2.5’ tall stool directly below the luminaire being commissioned and the light level with electric light and daylight at that location was recorded.
- The HHPRG-MS programming remote was used to raise/lower the light level until the target set point was reached (300 to 400 lux).
- Once the target set point was reached on the desk, the “SET” button was pressed then the “DO” button was pressed on the remote.
- Once a luminaire had been commissioned, it was turned off with the remote control, and an adjacent luminaire was switched on and the process was repeated.

It took about 20 minutes to commission all eight Metalux luminaires. Sometimes more than one luminaire would turn on during the calibration process, making the procedure somewhat more difficult and frustrating. LRC staff monitored the luminaires during the evening hours following the calibration process and noticed that the luminaires were increasing their light output at night as expected (with no ambient daylight).

One false-off event was noted after commissioning was complete. The SE luminaire did not turn on when an occupant walked in. The occupant walked in and out of the luminaire’s coverage area and could hear a relay clicking, but the luminaire did not turn on. Finally the occupant

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documentation on Eaton’s website that explained that multiple luminaires could be programmed at once if they were in the remote control’s line of sight (142501-programming-6-15-ins.pdf). However, LRC found that the luminaire response for the same line-of-sight angle not consistent. Sometimes one luminaire would respond, other times multiple luminaires would respond.

waived their arms and the luminaire turned on. No other false-off events were reported after commissioning.

There were several false-on events that occurred after commissioning. At the end of most nights, one luminaire would stay on for about 2-4 hours after the default 20-minute time-out period had ended. LRC staff contacted technical support at Metalux to ask them about this behavior and asked them if they had seen this behavior in other installations. LRC staff also sent annotated power data to Metalux showing the longer than expected time out period but received no response.

During the 3rd week of the monitoring period after commissioning, the Metalux LED luminaire located in the SW corner of the room stopped dimming when daylight was present.

The wired 0-10 V dimming switch specified with the Metalux Encounter system included no technical information regarding its override capabilities when attached to luminaires with integrated daylight sensors. To analyze the interactions between the dimmer and the luminaire, LRC staff disconnected the luminaire in the NW corner and connected it to the 0-10 V wall dimming switch. The switch turned the luminaire on and off as expected, but the wall dimmer would not override (increase) the light level set by the daylight sensor. The dimmer could decrease the light levels set by the daylight sensor. The Metalux luminaire was reconnected to the open office circuit and the dimmer was connected via 0-10 V control wires in parallel with the eight Metalux luminaires.<sup>19</sup> The luminaires were operated with the dimming switch in place for one week.<sup>20</sup> Several occupants complained that light levels were much dimmer during the day with the switch in place. Since the dimmer could not override the daylight sensor to increase light levels, occupants were left to work in a dim environment (see Figure 20).<sup>21</sup> Further analysis showed that the connected 0-10 V control wires dimmed all of the connected luminaires based on the dimmest luminaire. At night, when no daylight was present, light levels increased as expected.

To confirm that this behavior would occur when the luminaires were connected without the dimming switch, LRC staff removed the wall dimmer from the circuit but left the 0-10 V control wires connected in parallel in two groups. The luminaires connected in a group continued to dim based on the dimmest luminaire and the raise/lower buttons and scene buttons on the ISHH-02 personal remote dimmed all four connected luminaires as one group. The ISHH-02 personal remote was also able to turn the luminaires on and off individually.

### *Finelite HPR commissioning*

LRC staff contacted Finelite to ask about a recommended procedure for commissioning the individual luminaires given that the luminaires' intensity distributions overlap. The specification

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<sup>19</sup> Connected in parallel using a terminal block in two groups of four luminaires.

<sup>20</sup> The weekend prior to this analysis period, the blind positions were accidentally changed by painting crews. At the beginning of the week, the blinds were repositioned under clear skies to provide about 250 lux on average on the desk and table surfaces in the office (range of 200 – 340 lux). The blinds on the North side of the room needed to be opened more to meet the target set point condition.

<sup>21</sup> The ISHH-02 remote control could have been used to override the daylight sensor, but occupants tended not to use the remote control after the system was commissioned.

sheet did not provide a recommended procedure for commissioning multiple luminaires in turn.<sup>22</sup> In this system, the LSR-301-S commissioning remote is used to set a day and night set point for each luminaire. Day and night commissioning can occur in any order. Finelite directed LRC to contact Wattstopper's technical support department for commissioning questions. The tech support staff at Wattstopper was very helpful and recommended the following procedure. The LSR-301-S commissioning remote was used to dim down all four luminaires on one side of the room to the minimum dim level. The "Lower" button was pressed and held continuously for about 30 seconds to reach the minimum dim level. An illuminance meter was placed on a stool 2.5' below the luminaire being commissioned.<sup>23</sup> The "Raise" button on the LSR-301-S remote control was used to change the daytime set point to about 300 lux. Then the "Day" button was pressed and held for three seconds to lock in the daytime set point. Finally, the "Lower" button was pressed and held continuously for about 30 seconds again to reach the minimum dim level. The illuminance meter was moved under the next luminaire and the process was repeated. It took about 30 minutes to set the daytime set point for all eight luminaires. The sensor responded as expected to the remote control and one didn't need to stand directly below the luminaire to commission the sensor. However, it was uncomfortable to hold and depress the remote button for so long, due to the sensor's relatively slow dimming response.

The process was repeated later that night when no daylight was present. The luminaire were again dimmed to their minimum dim level prior to the night set point being saved for each luminaire (this was also set to approximately 300 lux). The night commissioning procedure was completed in about 15 minutes. A red LED inside the photosensor lens flashes until both Day and Night set points are complete.

Other than the audible click that occurred when the luminaires switched off with vacancy, occupants had no negative comments about this system. The monitoring devices showed that there were intermittent false-on events at night when the space was vacant.

As previously noted, this system did not have a dimmer switch available for specification, and could not be operated in manual-on (vacancy) mode. At the end of the commissioned period, LRC staff connected the luminaires to an existing wired wall switch, where four luminaires were connected to each switch.<sup>24</sup> When the wall switch was set to the On position, the luminaires all turned on and dimmed according to the ambient light levels. After the 12-minute time out period, the luminaires switched off individually as expected with vacancy, then turned on automatically when an occupant entered the coverage area as long as the wall switch remained in the On position. As long as the switch remains on, the system continues to operate in automatic-on mode as before.

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<sup>22</sup> FD-301-Fixture-Integrated-Daylight-Dimming-Photosensor-Cut-Sheet.pdf

<sup>23</sup> The luminaires were commissioned at around 5 PM in May when there was 150 – 200 lux under ambient daylight (electric lighting switched off).

<sup>24</sup> The wall switch is connected to a receptacle at ceiling level.

## Results

Power demand, power factor and light level results are shown below. Power was monitored for all eight LED luminaires collectively, so the results below show the aggregated system power.

### *Power demand*

The figures below show the measured power demand for eight LED luminaires under the baseline conditions, after commissioning, and with a deployed wired or wireless dimming switch (when available). For two of the three systems evaluated, commissioning the systems resulted in lower power demand than the baseline over a 24 hour period, even though the commissioned luminaires were potentially on for longer periods of time over the day. The LG system, however, had a higher power demand over the 24 hour period after commissioning, because, as previously noted, one or more luminaires would switch on frequently when the space was vacant.

Table 4 shows the aggregated power demand of the eight LED luminaires in standby mode, when the luminaires were switched off due to vacancy.

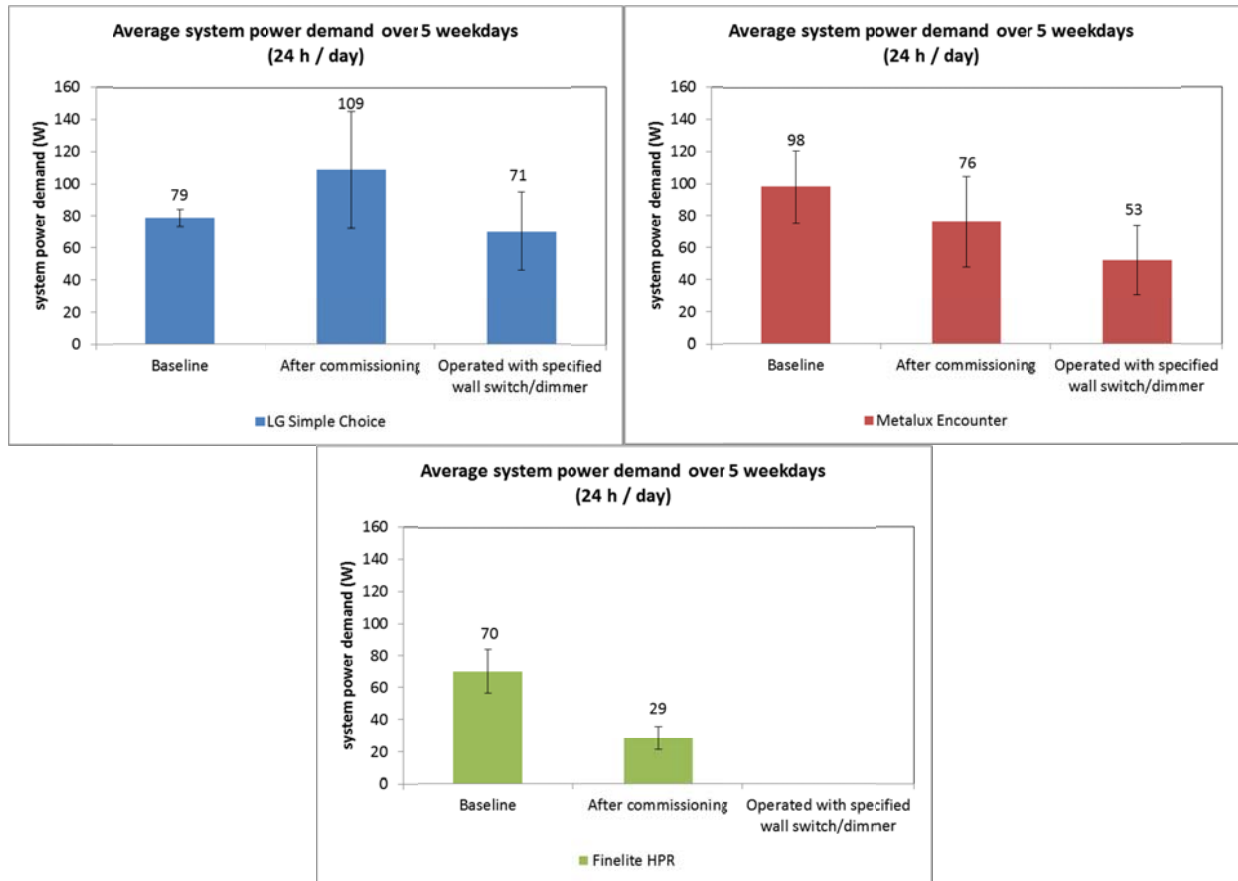
**Table 4: Aggregated standby power during vacancy**

System	Aggregated power demand in standby mode (W)
LG (eight luminaires)	6
Metalux (eight luminaires)	2 (7 W when the dimming switch was installed)
Finelite (eight luminaires)	12

The measured power demand over seven to nine days for each of the analysis conditions (baseline, after commissioning and with a dimming switch) and for one typical day are shown in Appendix A.

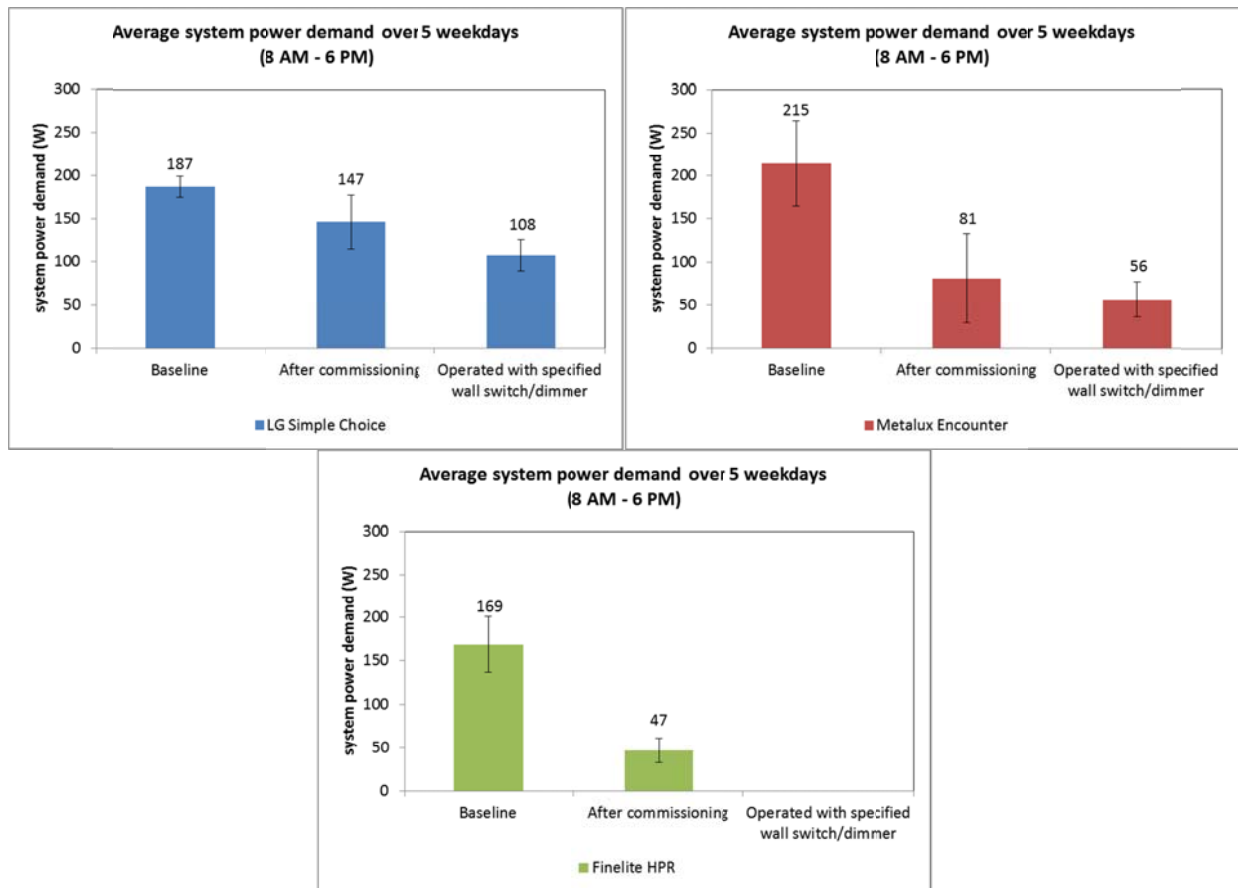
Figures 4 and 5 compare the average power demand of the three systems over a 24 hour time-period each day and over a 10-hour time period each day matching the baseline condition (i.e., the “business day”). As previously noted, occupancy patterns changed over the course of the study, notably when the spring semester was over and students were no longer working evening and nights in the LRC office. This “business day” (8 AM – 6 PM) allows for a more similar comparison of the three systems as the time-of-use period is held constant. The open office space was typically occupied by one or more people over this time period throughout the five month study period. On the other hand, the “business day” comparisons (shown in Figure 5) preclude increased power demand during false-on events which typically happened in the late night hours (typically from 12 AM – 5 AM).

## Power Demand Comparisons Before and After Commissioning



**Figure 4: Average system power demand over five weekdays under the LED luminaire systems with integrated occupancy and daylight sensors, during baseline conditions, with commissioned controls in their default configuration, and with a dimming wall switch. Power demand is averaged over a 24-hour period each day.**





**Figure 5: Average system power demand over five weekdays under the LED luminaire systems with integrated occupancy and daylight sensors, during baseline conditions, with commissioned controls in their default configuration, and with a dimming wall switch. Power demand is averaged over a 10-hour period each day, matching the on-time used during the baseline condition.**

The Metalux and Finelite systems had a lower power demand after commissioning the daylight sensor, compared to the baseline condition, even though the time of use was higher. Under the Metalux system, the average power demand over five weekdays decreased by 22% after the system was commissioned. Under the Finelite system, the average power demand over five weekdays decreased by 59% after the system was commissioned. When the time-of-use period is held constant (8 AM - 6 PM), the power demand savings are even higher after commissioning. The Metalux system used 62% less power on average, from 8 AM – 6 PM, after commissioning. The Finelite system used 72% less power on average, from 8 AM – 6 PM, after commissioning. On the other hand, the LG system had a 39% higher average power demand after commissioning compared to baseline, when the entire 24 hour day is analyzed. With a constant time-of-use analysis, under the “business day” condition, the LG system had a 22% lower power demand on average, after commissioning.

Adding a wall switch further decreased the power demand. In the case of the LG system, the power demand savings can be partly attributed to four of the luminaires being operated in manual-on mode. With a wireless wall switch, the LG system had a 10% lower power demand compared to the baseline. Under the “business day” condition, the LG system had a 42% lower

power demand on average, after the wall switch was added. With a wired dimming switch, the Metalux system had a 46% lower power demand compared to the baseline. In this case, the majority of the power demand savings can be attributed to the over-aggressive dimming resulting from the connected luminaires. Under the “business day” condition, the Metalux system had a 74% lower power demand on average, compared to baseline, after the wall switch was added.

### *Power factor*

The LG LED luminaires had an average power factor of 0.98 when the luminaires were on even when they were dimmed. When the luminaires cycled off due to vacancy, the system power factor ranged from about 0.3 in standby mode (when all eight luminaires were off) up to about 0.9 when only one luminaire was off.

The Metalux LED luminaires have an average power factor of 0.98 (ranging from 0.93 – 0.99) even when the luminaires were fully dimmed. In standby mode, when all eight luminaires were off due to vacancy, the power factor typically ranged from 0.75 – 0.8.

The Finelite LED luminaire had a power factor greater than 0.99 when the luminaire was on at full power. The power factor decreased to 0.91 when the luminaire was fully dimmed. In standby mode, when the luminaire was off due to vacancy, the power factor was 0.45.

### *Light levels on the desks*

The measured light levels over seven to nine days for each of the analysis conditions (baseline, after commissioning and with a dimming switch) are shown in Appendix B.

Generally speaking, daylight levels increased over the course of the study, from winter to summer. Power demand savings after commissioning were higher than the corresponding light level reductions resulting from daylight dimming (comparing Figure 7 with Figures 4 and 5).

All three systems generally met or exceeded the target light levels of 300 lux on most of the measured desks during business hours before and after daylight commissioning. Prior to commissioning, the average light levels on the desk during business hours exceeded the target level by 30-145% (LG: 30% above target; Metalux: 145% above target; Finelite: 97% above target).

Measured light levels under the uncommissioned Metalux system were higher than under the other two uncommissioned systems, under the baseline conditions. This cannot be attributed solely to changing daylight conditions, as the Finelite system had lower average light levels in the summer months (see Figure 6). Under the Metalux system, average light levels during business hours decreased by 51% after the system was commissioned. Compared to the baseline, adding the wired dimming switch to the commissioned system decreased light levels during business hours by 60% on average. Under the Finelite system, average light levels during business hours decreased by 48% after the system was commissioned.

As previously noted, frequent false-on events after commissioning increased the average power demand under the LG system, as well as average light levels. After the LG system was

commissioned, average light levels increased by 27%. This ratio is similar to the increased power demand ratio of 39%, after commissioning for the same time period.

### Light levels under baseline conditions

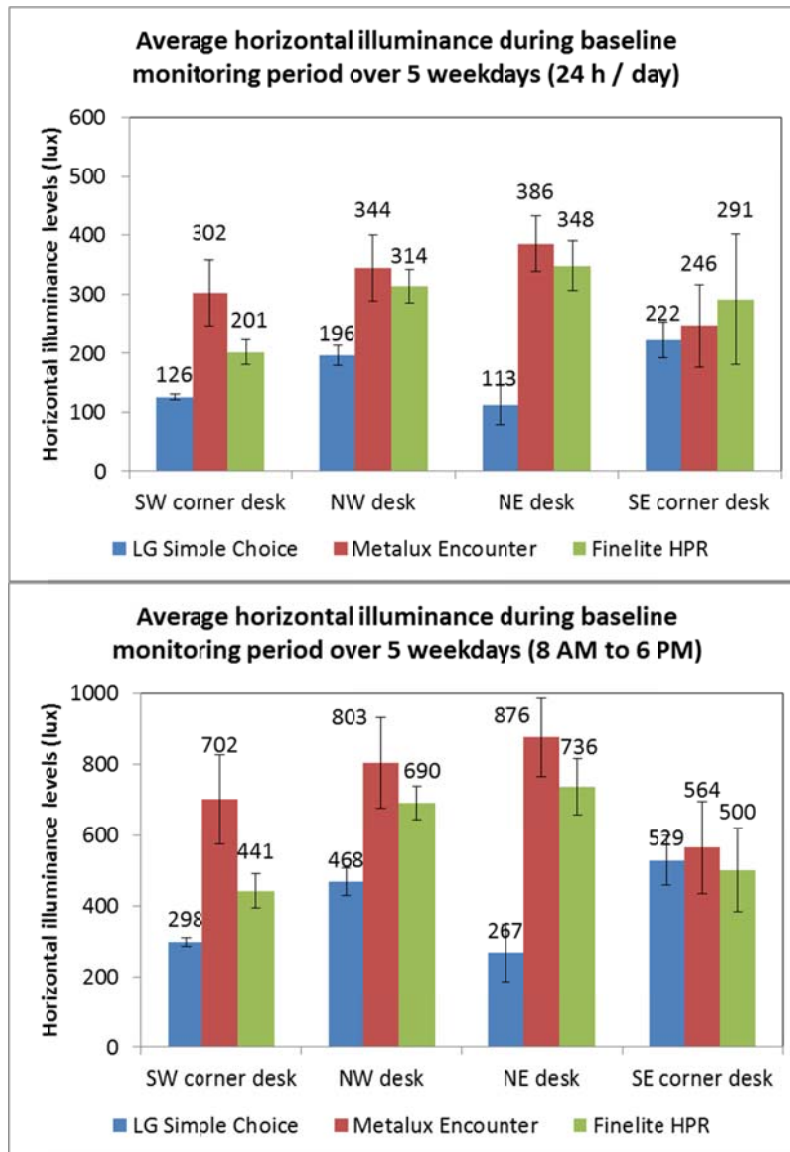
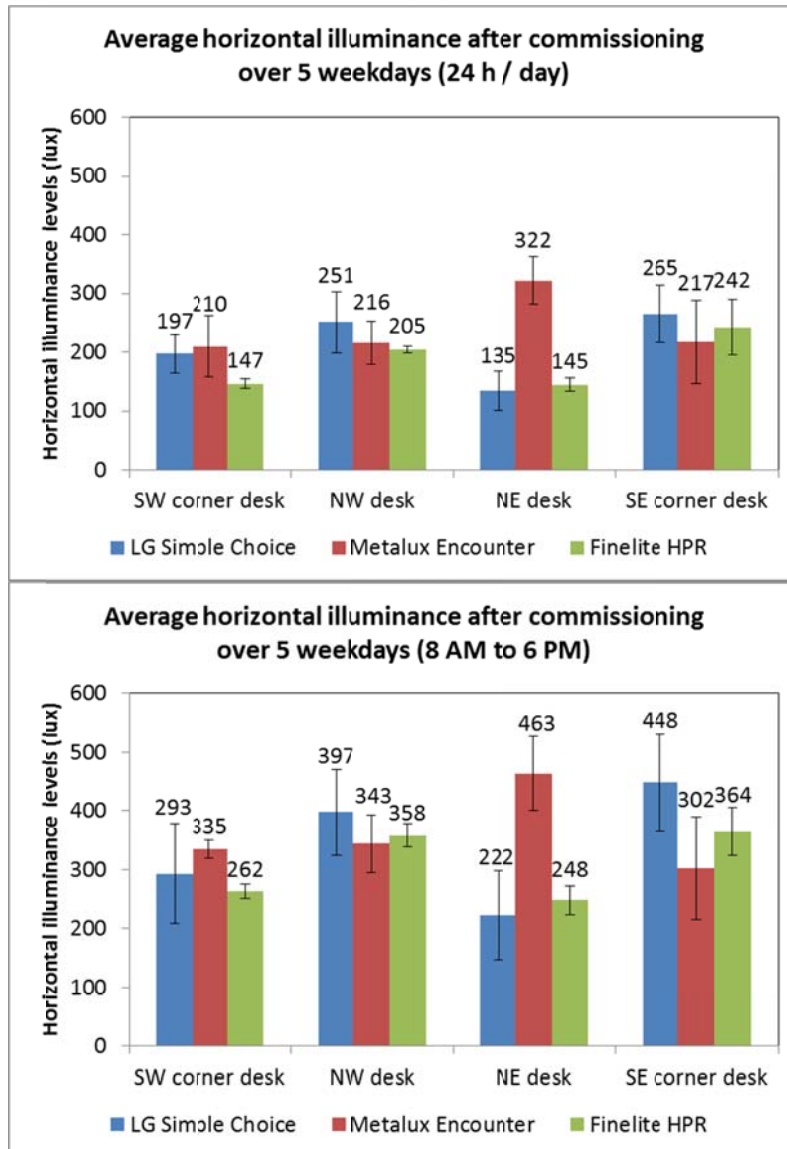


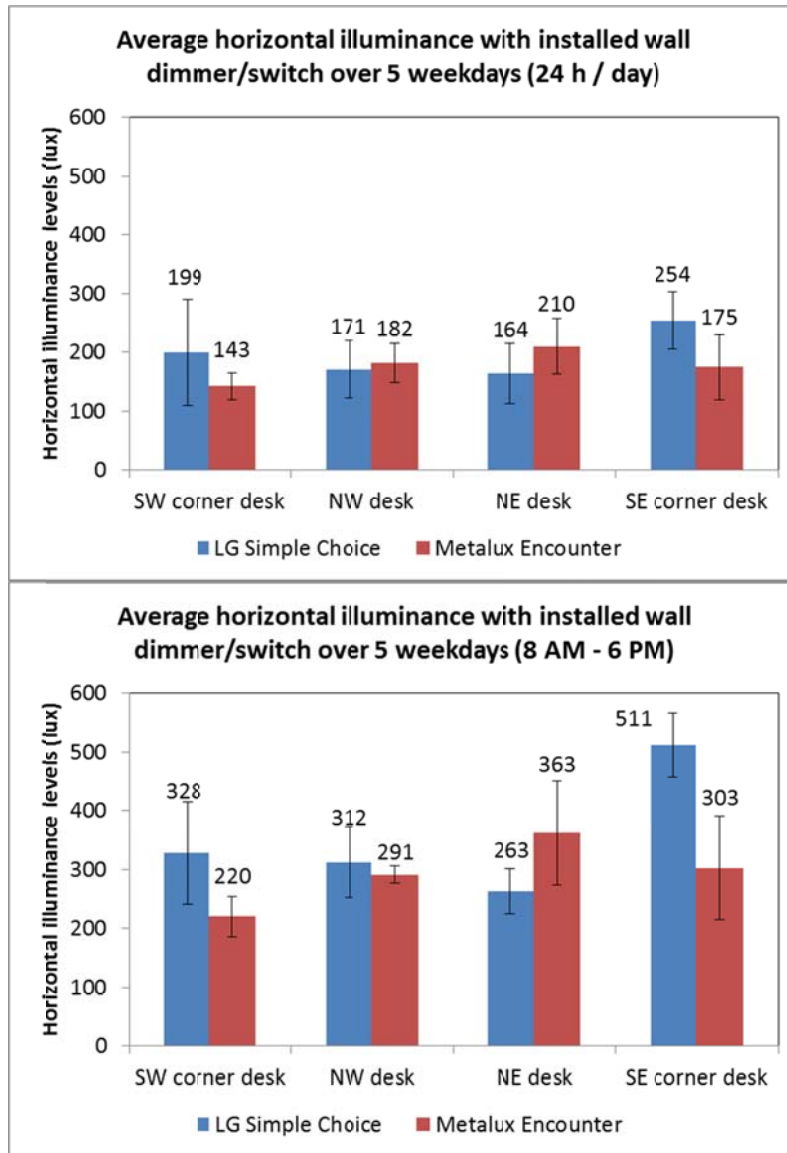
Figure 6: Average horizontal illuminance on four desks in the open office over five weekdays under the LED luminaire systems with integrated occupancy and daylight sensors, during baseline conditions. In the top figure, light levels are averaged over the 24-hour day. In the bottom figure, light levels are over a 10-hour period each day, when the digital timer provided power to the luminaires.

## Light levels after commissioning



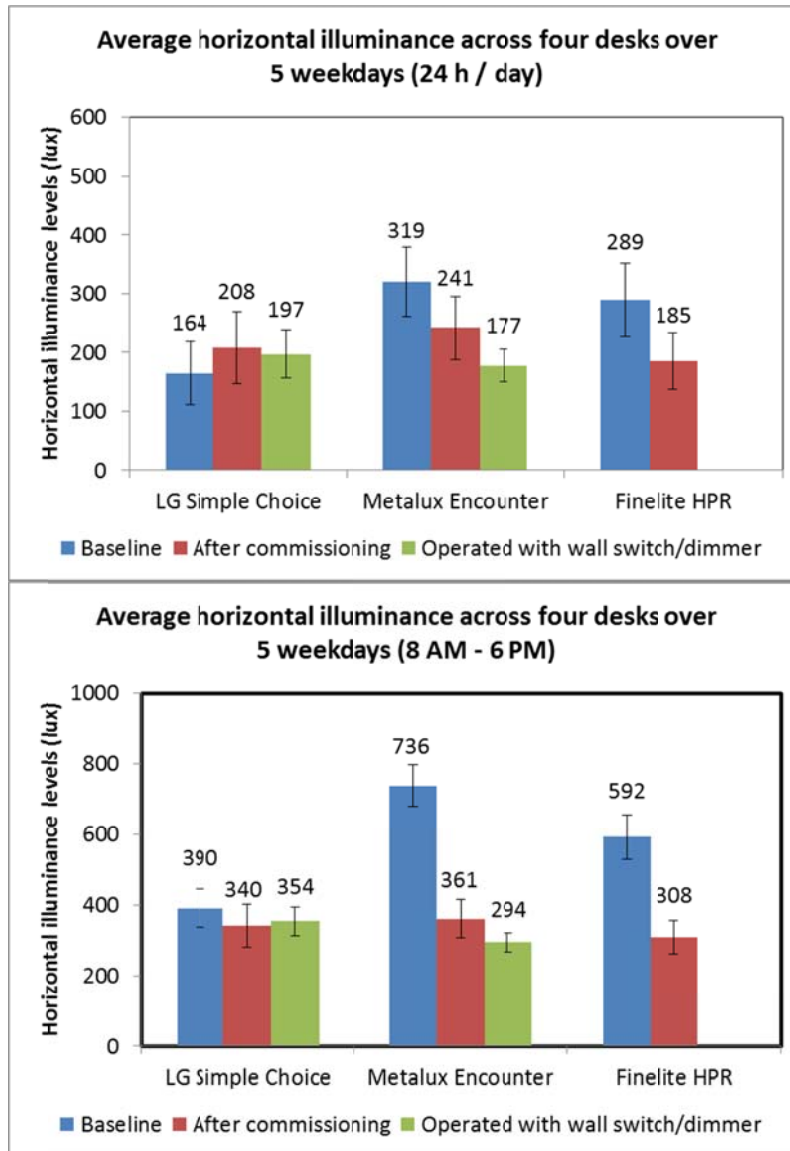
**Figure 7: Average horizontal illuminance on four desks in the open office over five weekdays under the LED luminaire systems with integrated occupancy and daylight sensors, after the systems were commissioned with default settings. In the top figure, light levels are averaged over the 24-hour day. In the bottom figure, light levels are over a 10-hour period each day, matching the on-time used in the baseline condition.**

## Light levels with dimming switch



**Figure 8: Average horizontal illuminance on four desks in the open office over five weekdays under the LED luminaire systems with integrated occupancy and daylight sensors, after dimming switches were added to system. In the top figure, light levels are averaged over the 24-hour day. In the bottom figure, light levels are over a 10-hour period each day, matching the on-time used in the baseline condition.**

## Average light level comparisons



**Figure 9: Average light levels on desks over five weekdays under the LED luminaire systems with integrated occupancy and daylight sensors, during baseline conditions, with commissioned controls in their default configuration, and with a dimming wall switch. In the top figure, light levels are averaged over the 24-hour day. In the bottom figure, light levels are averaged over a 10-hour period each day, matching the on-time used during the baseline condition.**

## Discussion

### *Energy code requirements*

As previously noted in Table 1, the connected lighting load in the LRC office was around 0.3 W/sf. In general, the tested systems comply with Title 24 and ASHRAE 90.1 code requirements as noted in Tables 5 and 6. However, the Finelite system may not be compliant with one of the area control provisions in Title 24 2013. This provision requires that dimmable luminaires be controlled with a “dimmer switch that allows manual ON and OFF functionality, and is capable of manually controlling lighting through all lighting control steps that are required in Section 130.1(b).” A local switch can be wired to this system allowing for manual on and off control, but there was no dimming switch available for specification nor were there dimming control wiring diagrams in the control or luminaire specification sheets.

**Table 5: Tested system compliance with ASHRAE 90.1 mandatory control provisions (using default configurations)**

Control provision in ASHRAE 90.1-2010	LG Simple Choice LED Luminaires with integrated Sensor Connect control system	Eaton (Metalux) Encounter LED Luminaires	Finelite High Performance Recessed (HPR) LED Luminaires
Lighting control (Manual-on or Auto-on to 50% power)	Auto-on by default. User can select Manual-on in app (when wireless switch is connected)	Auto-on to 50% light output by default. Manual-on with handheld remote control or local 0-10V dimming switch	Can be wired to local switch to provide manual on and off control
Automatic lighting shutoff	✓	✓	✓
Space control – manual control device to independently control the general lighting (must have one control step between 30% and 70% of full power)	Can increase/decrease light levels of individual luminaires with wireless dimming switch	Can increase/decrease light levels with handheld remote control or 0-10 V dimming switch (can only decrease light levels with dimmer)	Can increase/decrease light levels of individual luminaires with handheld remote
Space control – occupancy sensor	✓	✓	✓
Automatic daylighting controls for primary sidelighted areas	✓	✓	✓

**Table 6: Tested system compliance with Title 24 mandatory control provisions (using default configurations)**

Control provision in Title 24 2013	LG Simple Choice LED Luminaires with integrated Sensor Connect control system	Eaton (Metalux) Encounter LED Luminaires	Finelite High Performance Recessed (HPR) LED Luminaires
Area Controls 130.1 (a)	Local on control and dimming with wireless dimming switch	Local on control and dimming with handheld remote control or local 0-10V dimming switch	Can be wired to local switch to provide manual on and off control, but no wiring provisions for a dimming switch are given by manufacturer (required for dimmable luminaires in 130.1(a) section 2C)
Multi-Level Lighting Controls 130.1(b)  Connected lighting in LRC office did not exceed 0.5 W/sf; these systems would be exempt from these requirements in this specific application	✓	✓	✓
Shut-OFF Controls 130.1(c)	✓	✓	✓
Automatic daylighting controls for primary sidelighted areas 130.1(d)	✓	✓	✓

### *Commissioning challenges*

None of the three tested systems were easy to commission. Better commissioning instructions would have significantly improved the commissioning process, especially for the systems that required that individual luminaires be commissioned within the system.

A daylight harvesting system needs to be “tuned” to the space in which it is installed in order to meet the desired target light levels. This process may involve specifying the set points for the control algorithm, specifying the sensor and task illuminance values, and/or specifying the incremental electric light level when daylight is present (i.e. the “gain” which is the electric/daylight ratio). Each of the systems tested required that one or more of these parameters were input when the system was commissioned. The ambient light levels present when the system is commissioned are of particular importance as this will set the system “gain”. Instructions that provide clarification with regards to ambient light levels required when the system is commissioned will more likely result in actual light levels that are similar to the target light levels. Once the commissioning process was clear, the best-practice methodology to



commission each system was straightforward. The phase two report<sup>25</sup> also includes suggestions regarding the importance of inputting a more accurate sensor-to-task ratio.

The LG “daylight tuning” process was automated, and thus straightforward from the end user’s point of view. The commissioning challenge with this system was in successfully detecting and pairing the wireless switches with the luminaires and correctly setting up the occupancy/switch groups.

### *Operational shortcomings*

All three of the tested systems had several false-on events occurring throughout the monitoring period. Two of the three tested systems also had one or more false-off events occur. As this study focused on using and reporting on the performance of the default “plug and play” settings, changing the sensitivity parameters of these systems was not part of the study.<sup>26</sup>

### *Study limitations*

This six-month long field study provides power demand and light level results for three tested luminaire systems in one office space. Direct product comparisons should not be made because varying field conditions, such as occupancy and daylight levels, impacted product performance. Only a lab study, with consistent occupant and daylight conditions allows for absolute product-to-product comparisons.

This field study was conducted in an office space under daylight conditions from late January 2016 through July 2016. As a result, the daylight conditions varied from day-to-day and from month to month as previously noted. The systems were also commissioned under different daylight conditions, which would result in different “gains”, as noted earlier. If the tested luminaires were to be installed in an environment with different ambient daylight conditions, the sensor performance, and resulting power demand and light levels, would likely be different.

The LRC staff and students were encouraged to work in the office space as they normally would. As such, their occupancy patterns varied over the course of each week and over the study period.

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<sup>25</sup> Easily Commissioned Lighting Controls Phase 2 Report [https://www.bpa.gov/ee/technology/ee-emerging-technologies/projects-reports-archives/documents/bpa%20lighting%20controls%20phase%202%20final%20report\\_11302015.pdf](https://www.bpa.gov/ee/technology/ee-emerging-technologies/projects-reports-archives/documents/bpa%20lighting%20controls%20phase%202%20final%20report_11302015.pdf)

<sup>26</sup> As previously noted, LG and Metalux were contacted when the LRC observed repeated false-on events in the overnight hours when the space was vacant. LG replaced the transmitters and updated the software to reduce the number of false-on events. The Metalux factory representative did not suggest any system changes to reduce the frequency or duration of the false-on events. LRC did not contact Finelite regarding the intermittent false-on events.

## Summary

This field study monitored installation, commissioning, and operational parameters of three LED luminaire systems with integrated occupancy and daylight harvesting controls. Light levels after commissioning were similar to the target light levels under electric lighting.

Lessons learned:

Ease of use:

- Two of the three tested systems were straightforward to install. One system was delivered with incorrect occupancy sensor settings leading to an increased installation time.
- Two of the three tested systems came without sufficient commissioning documentation leading to an increased commissioning time.
- For one system, pairing the wireless dimming switch was complicated, even with the provided documentation.
- False-on events during vacancy periods were seen in all three tested systems. False-off also occurred with two of the tested systems.
- All three systems met or exceeded the target light level before and after commissioning.
- All three systems had some mode of override capability, either with a handheld remote control or wireless dimming switch. Occupants appreciated having this override capability, even though they only used it occasionally.

Power demand savings:

- Two of the three systems reduced power compared to the baseline condition. The other system had increased power demand compared to baseline due to false-on events.
- Only one of the tested systems had the option of a manual-on (vacancy sensor) mode.
- Power factor for all three luminaires was high ( $> 0.9$ ) even when the luminaires were dimmed. In standby mode, power factor was lower than 0.9.

## Appendix A

The figures below plot the system power over one week, and during a typical day, for each of the 3 lighting control systems studied in phase three. This typical day represents the weekday with the median power demand out of five weekdays in each condition. Some of the figures are annotated with circled numbers to indicate notable events (i.e. examples of false-on events).

### LG Power Demand

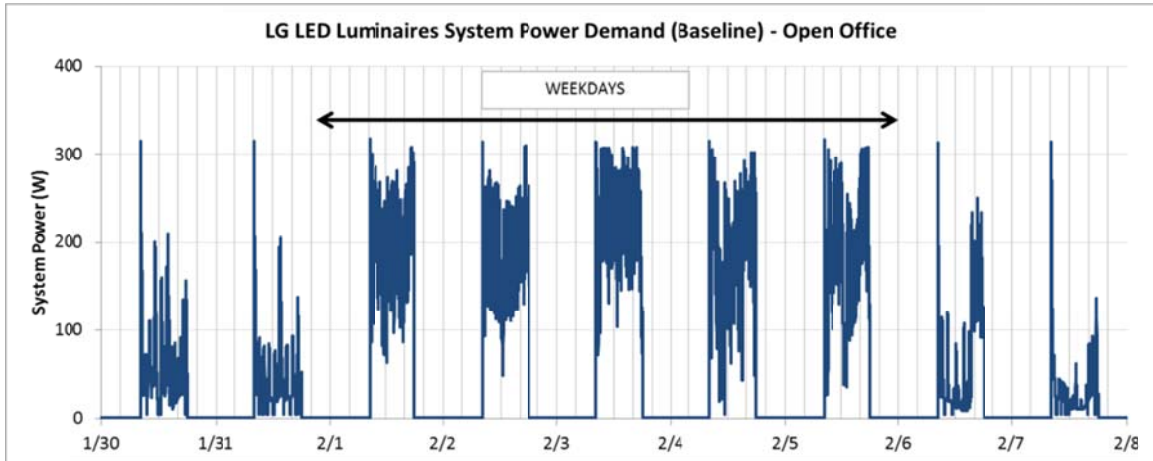


Figure 10: System power demand over one week under the LG LED luminaires during the baseline condition. Digital timers turned the electric lighting on at 8 AM and off at 6 PM.

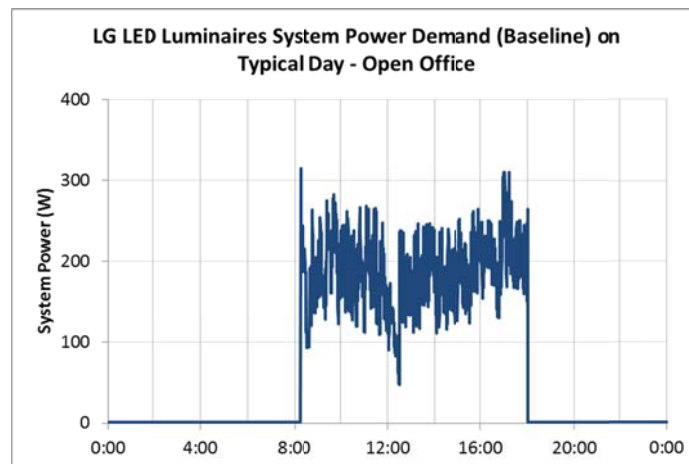
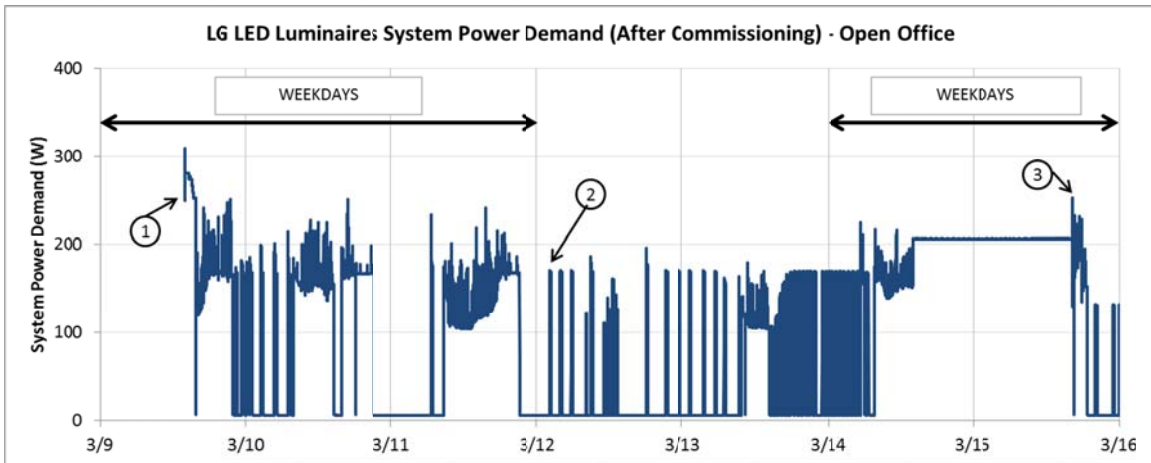
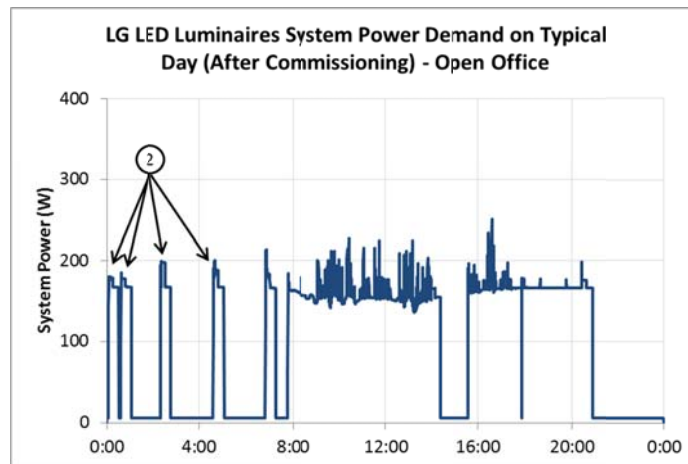


Figure 11: System power demand during a typical day under the LG LED luminaires during the baseline condition. Digital timers turned the electric lighting on at 8 AM and off at 6 PM.



**Figure 12: System power demand over one week under the LG LED luminaires after commissioning with default system parameters. Annotation 1 indicates system power reset after system update (see text). Annotation 2 indicates examples of false-on events when space was vacant. Annotation 3 indicates addition of wireless switch device at end of business day.**



**Figure 13: System power demand during a typical day under the LG LED luminaires after commissioning with default system parameters. Annotation 2 indicates examples of false-on events.**

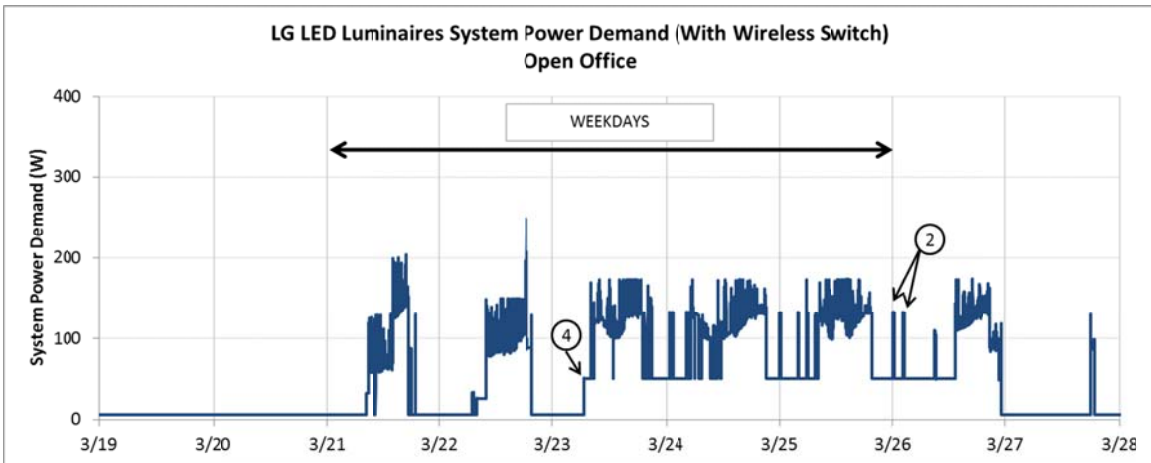


Figure 14: System power demand over one week under the LG LED luminaires after commissioning of the 2-group wireless switch (see text for details). Annotation 2 indicates examples of false-on events. Annotation 4 indicates time point where one LG luminaire switched on and remained on regardless of occupancy for almost four days.

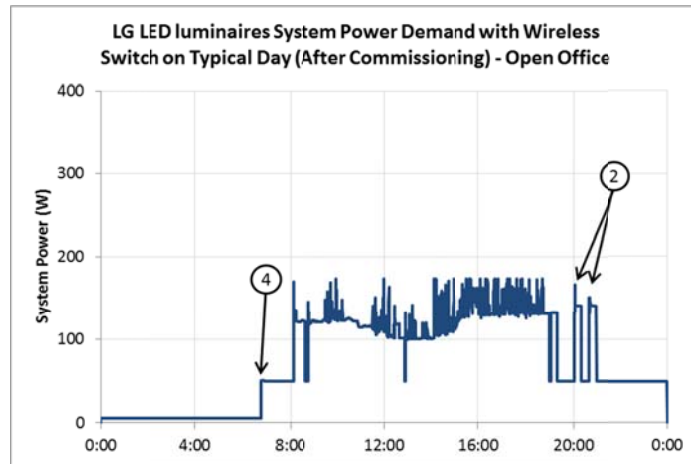


Figure 15: System power demand over one typical day under the LG LED luminaires after commissioning of the 2-group wireless switch. Annotation 2 indicates examples of false-on events. Annotation 4 indicates time point where one LG luminaire switched on and remained on regardless of occupancy for almost four days.

## Metalux Power Demand

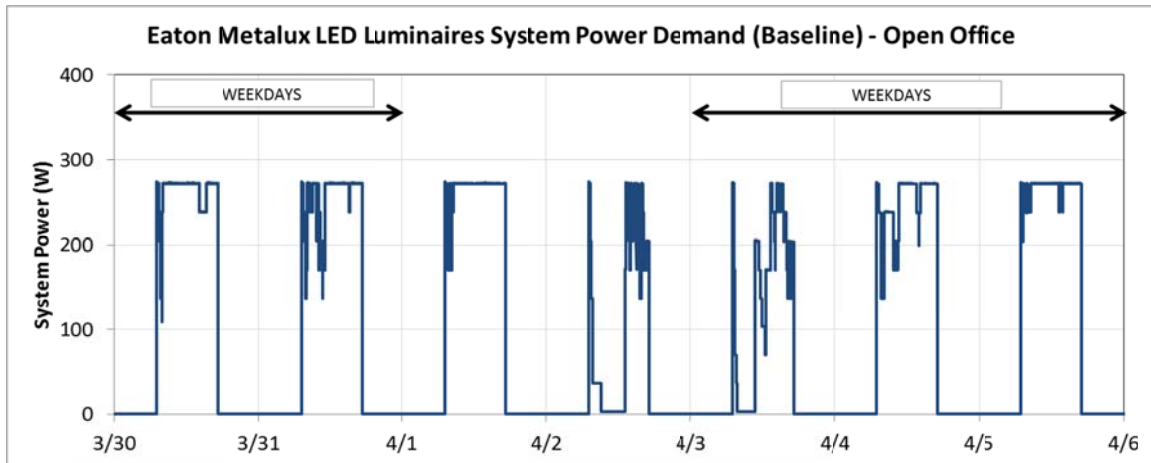


Figure 16: System power demand over one week under the Metalux LED luminaires during the baseline condition. Digital timers turned the electric lighting on at 8 AM and off at 6 PM.

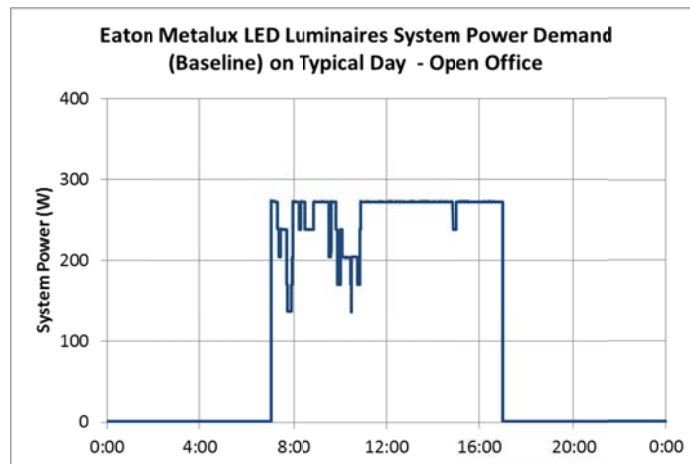
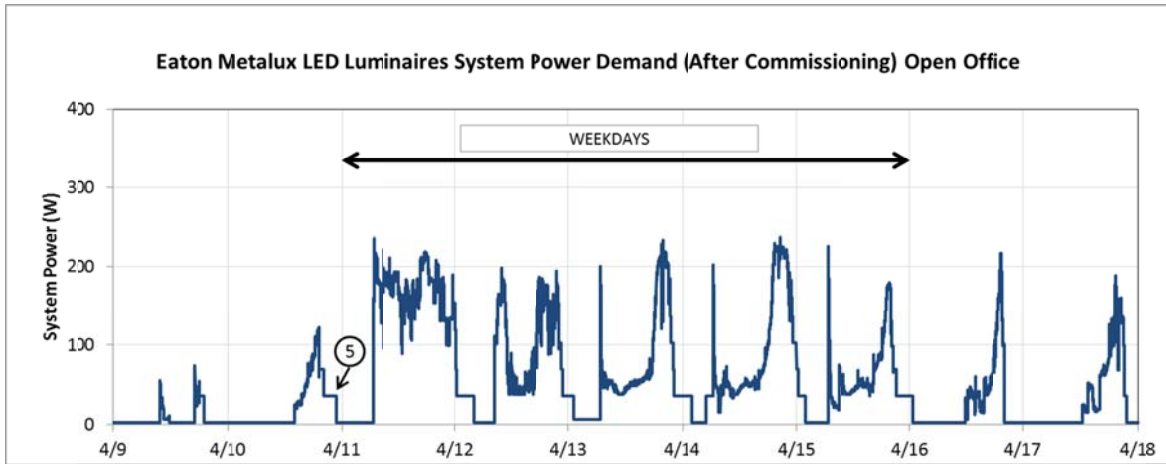
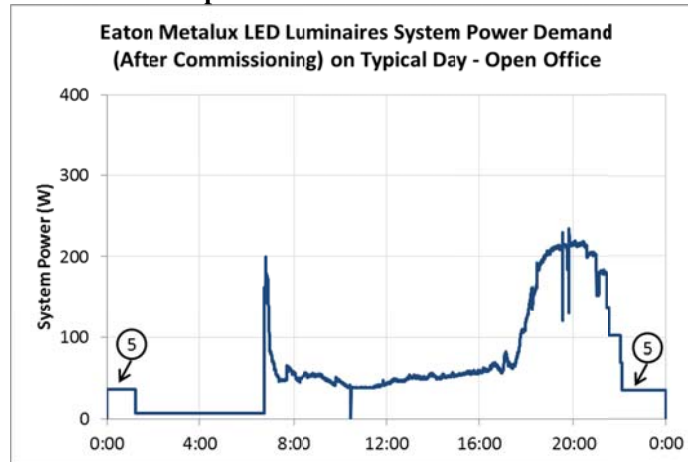


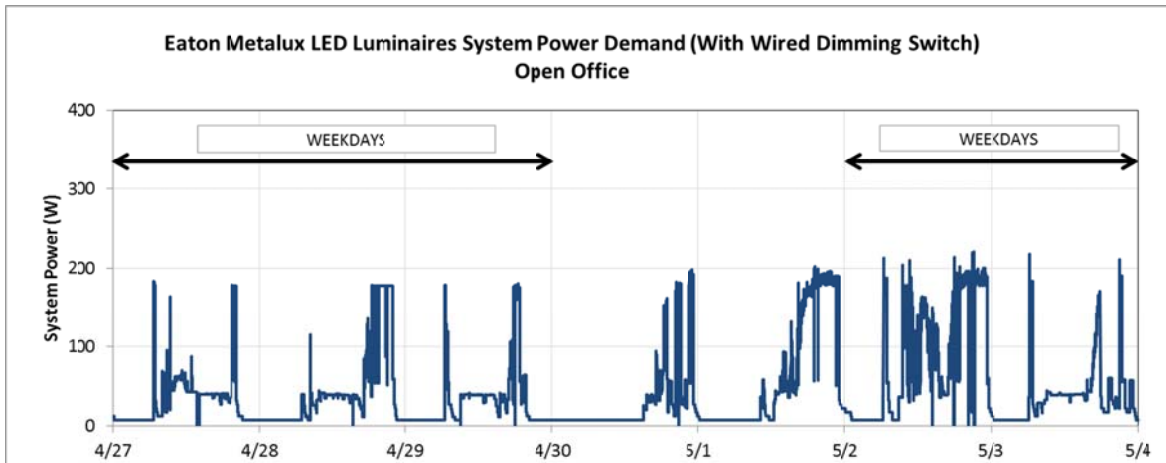
Figure 17: System power demand over one typical day under the Metalux LED luminaires during the baseline condition. Digital timers turned the electric lighting on at 8 AM and off at 6 PM.



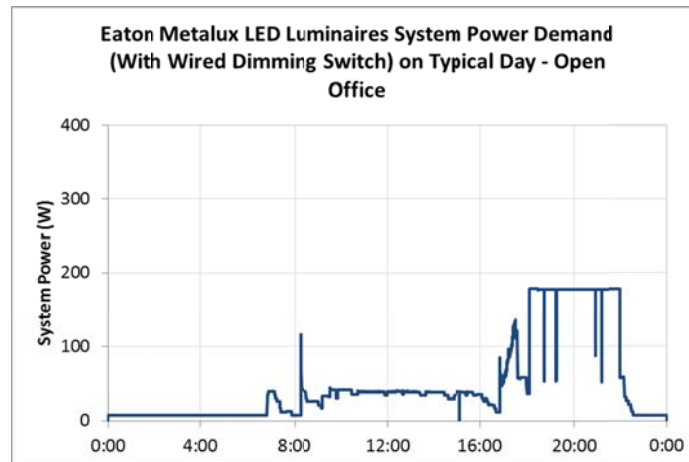
**Figure 18: System power demand over one week under the Metalux LED luminaires after commissioning with default system parameters. Annotation 5 indicates an example of a false-on event where one luminaire remained on for several hours after the space was vacant.**



**Figure 19: System power demand over one typical day under the Metalux LED luminaires after commissioning with default system parameters. Annotation 5 indicates examples of false-on events where one luminaire remained on for several hours after the space was vacant.**



**Figure 20: System power demand over one week under the Metalux LED luminaires after addition of wired wall dimmer. System power is low on most days because all the connected luminaires dim down based on the luminaire with the minimum dimming level according to its sensor signal.**



**Figure 21: System power demand over one typical day under the Metalux LED luminaires after addition of wired wall dimmer. System power is low during the day because all the connected luminaires dim down based on the luminaire with the minimum dimming level according to its sensor signal.**



## Finelite Power Demand

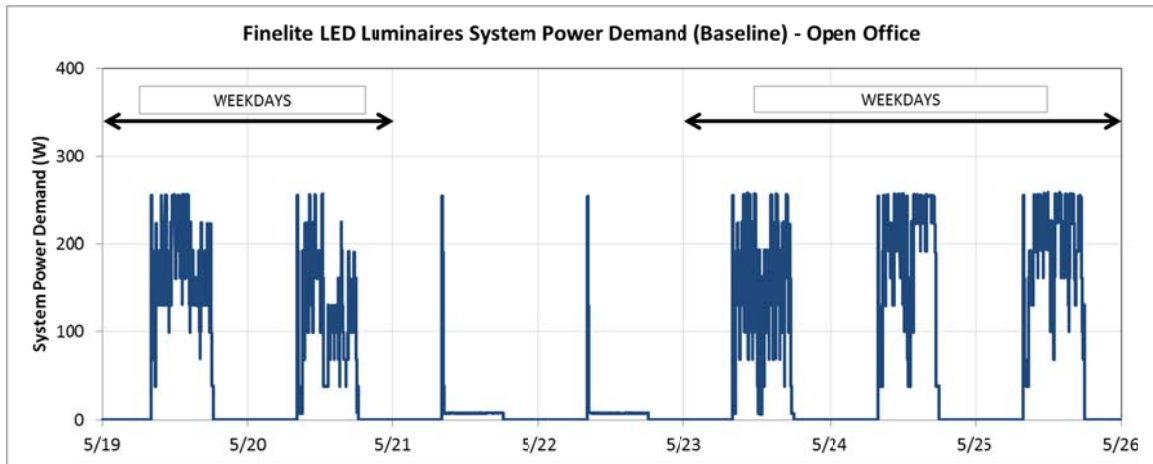


Figure 22: System power demand over one week under the Finelite LED luminaires during the baseline conditions. Digital timers turned the electric lighting on at 8 AM and off at 6 PM.

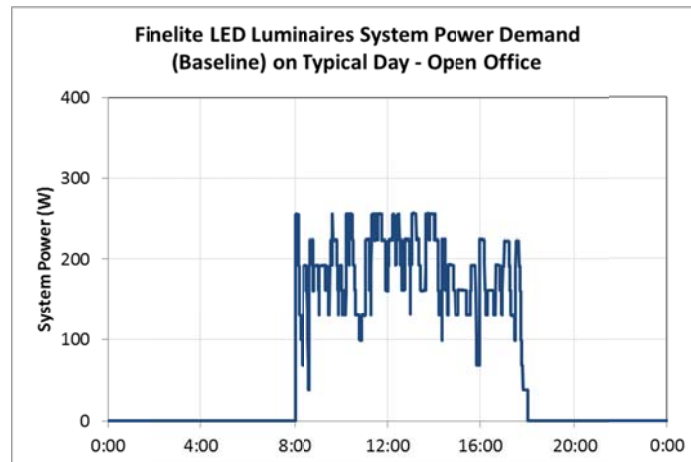


Figure 23: System power demand over one typical day under the Finelite LED luminaires during the baseline condition. Digital timers turned the electric lighting on at 8 AM and off at 6 PM.

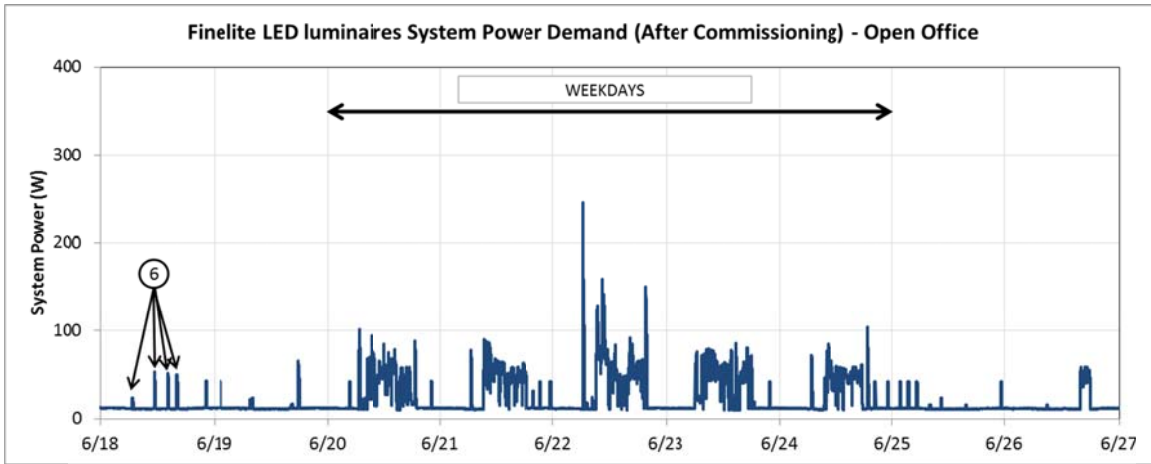


Figure 24: System power demand over one week under the Finelite LED luminaires after commissioning with default occupancy sensor parameters. Annotation 6 indicates examples of false-on events.

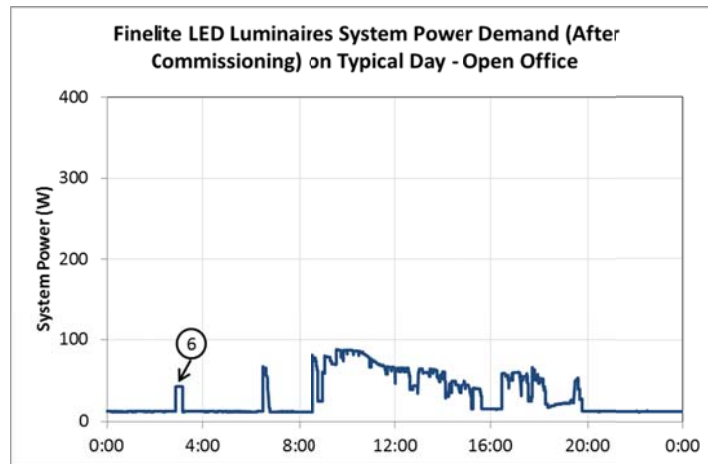


Figure 25: System power demand over one typical day under the Finelite LED luminaires after commissioning with the default occupancy sensor parameters. Annotation 6 indicates an examples of a false-on event.

## Appendix B

The figures in this section plot the measured light levels over seven to nine days for each of the studied lighting systems under each of the analysis conditions (baseline, after commissioning and with a dimming switch).

### Light levels under baseline conditions

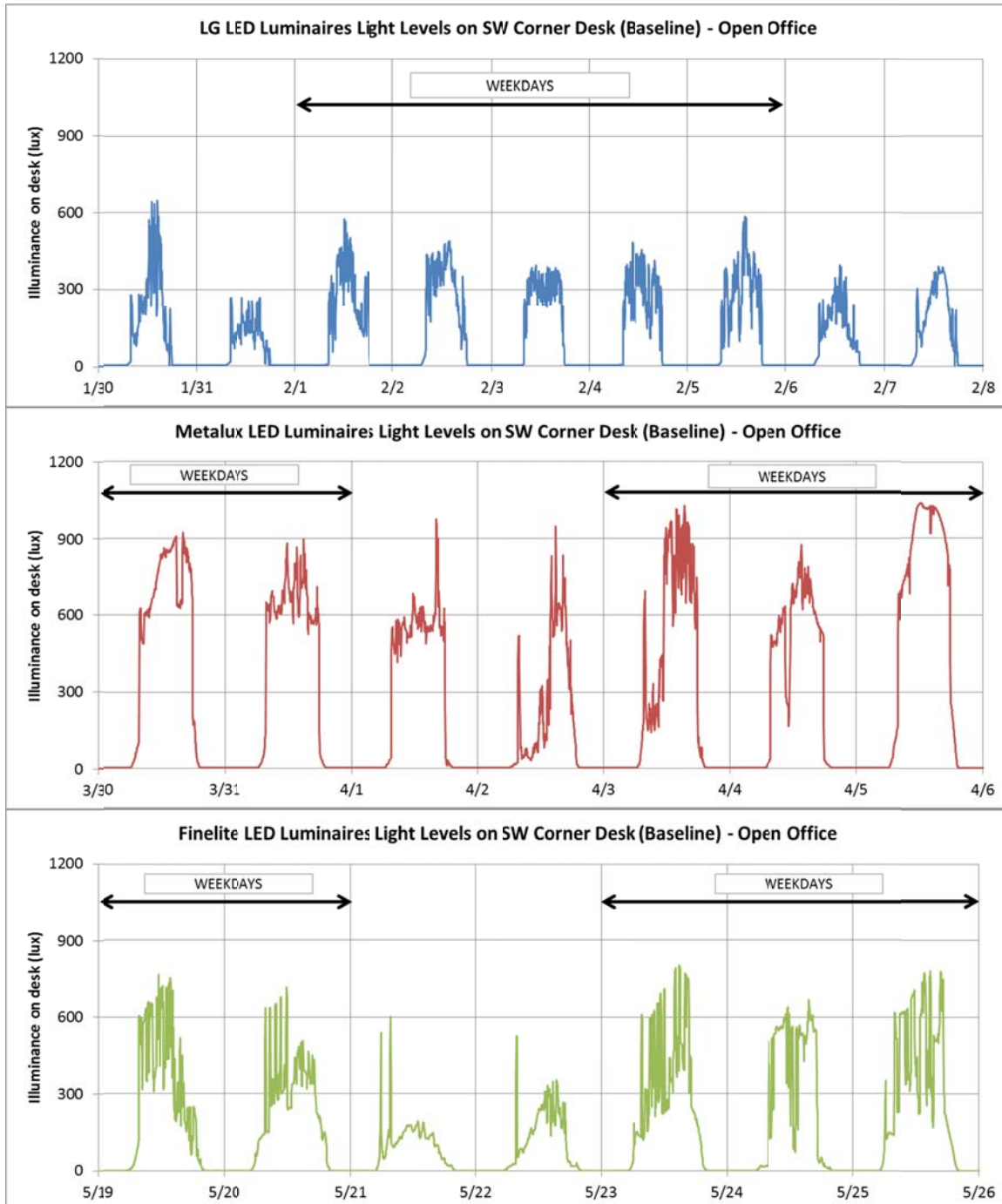


Figure 26: Horizontal illuminance levels on the SW corner desk for one week under baseline conditions under the LG LED luminaires (blue trace), under the Metalux LED luminaires (red trace), and under the Finelite LED luminaires (green trace).

## Light levels after commissioning

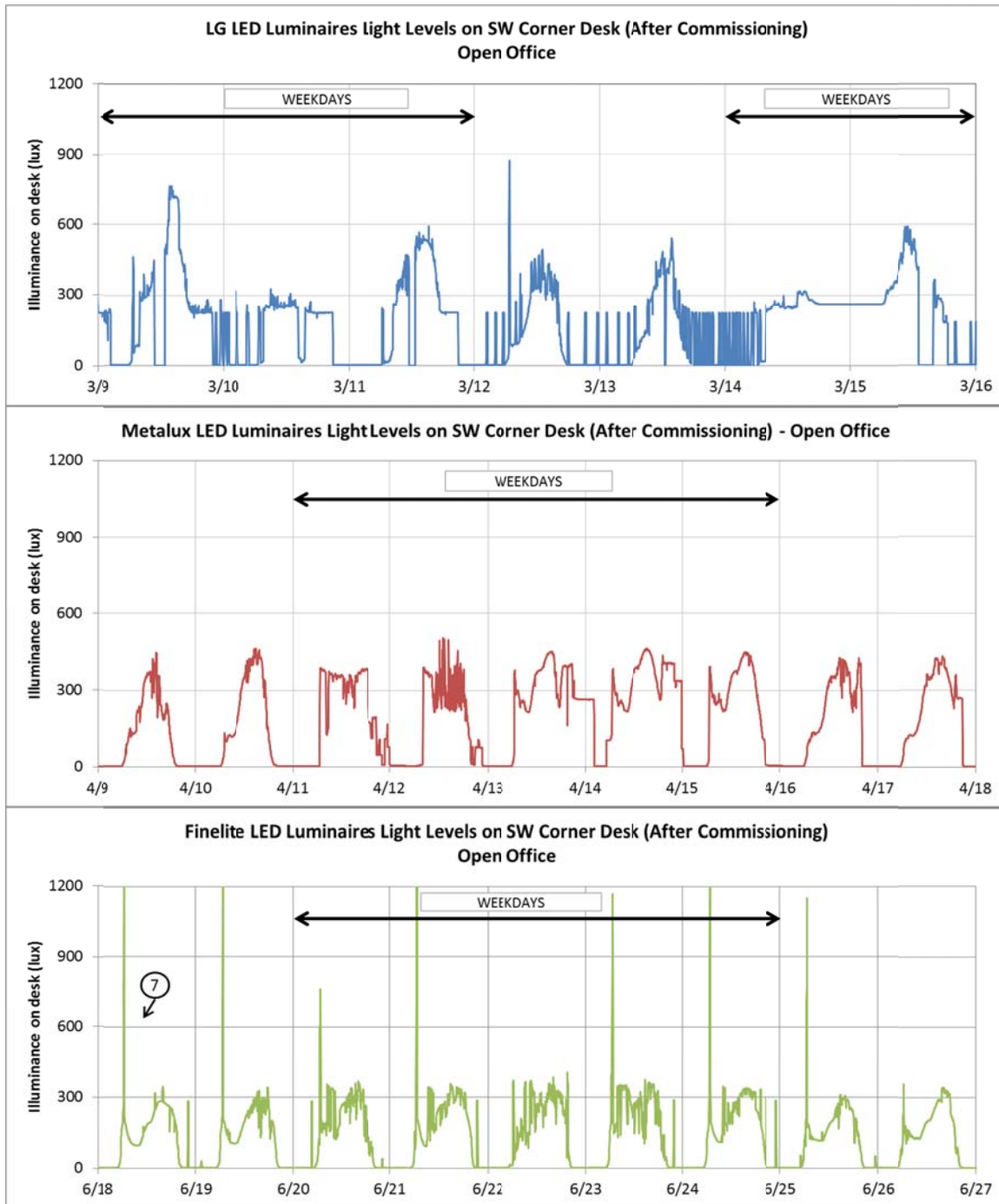


Figure 27: Horizontal illuminance levels on SW corner desk for one week after systems are commissioned using default settings under the LG LED luminaires (blue trace), under the Metalux LED luminaires (red trace), and under the Finelite LED luminaires (green trace). Annotation 7 indicates example of measured sunlight in early morning hours that exceeds 1200 lux.

## Light levels with dimming switch

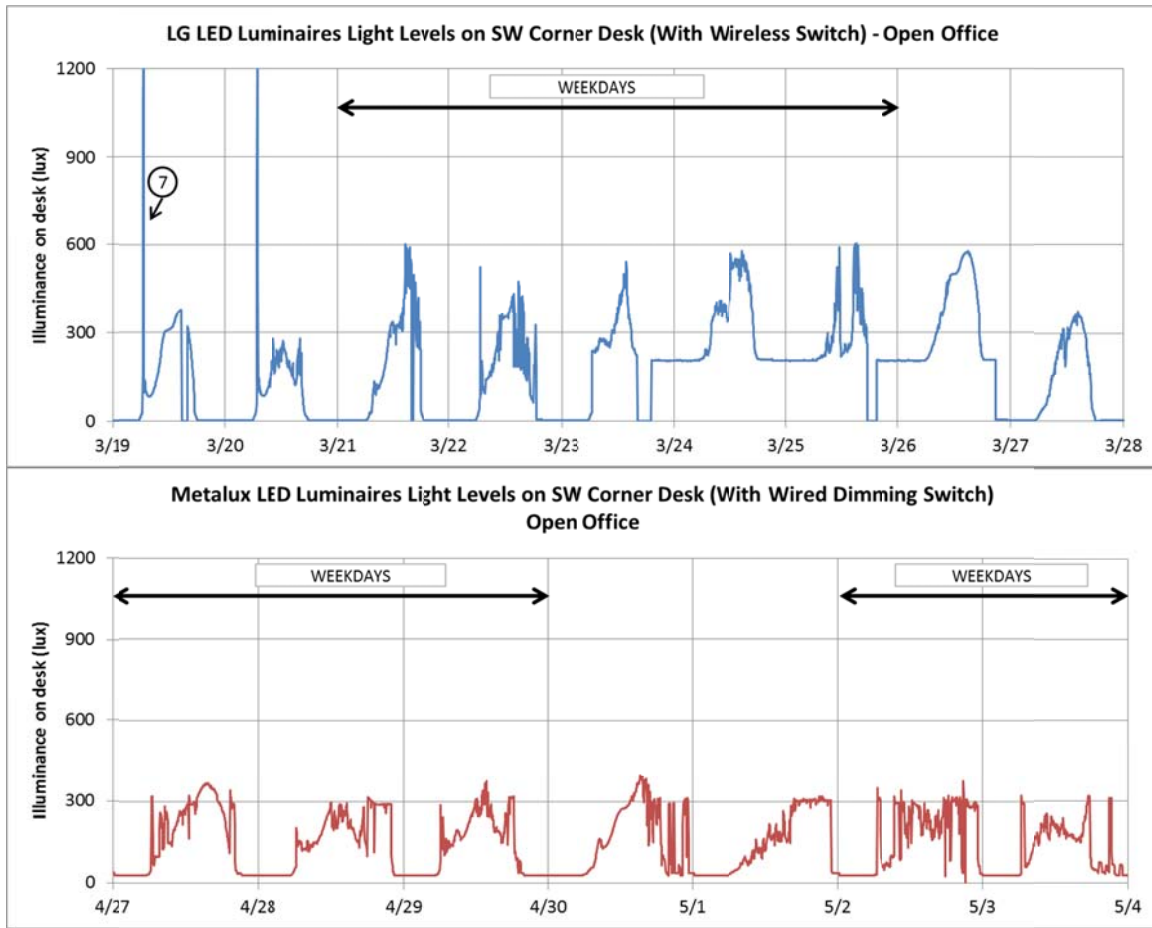


Figure 28: Horizontal illuminance levels on the SW corner desk for one week after dimming wall switch are included in system under the LG LED luminaires (blue trace), and under the Metalux LED luminaires (red trace). Annotation 7 indicates example of measured sunlight in early morning hours that exceeds 1200 lux.