Office Lighting Systems: a Snapshot in Time

Sacramento Municipal Utility District

SMUD™

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About the Customer Advanced Technologies Program…

SMUD's Customer Advanced Technologies (C.A.T.) program works with customers to encourage the use and evaluation of new or underutilized technologies. The program provides funding for customers in exchange for monitoring rights. Completed demonstration projects include lighting technologies, light emitting diodes (LEDs), indirect/direct evaporative cooling, non-chemical water treatment systems, daylighting and a variety of other technologies.

For more program information, please visit:
https://www.smud.org/en/business/save-energy/rebates-incentives-financing/customer-advanced-technologies.htm

1. Executive Summary

During 2012 to 2013, SMUD created the Advanced Lighting Controls program to encourage commercial customers to upgrade their lighting systems and install state-of-the-art controls. Overall, the program was very successful; nineteen projects were completed with energy savings of 50 to 90%. It soon became apparent, however, that although the program was a good fit for industrial and warehouse applications, office applications were very challenging due to relatively high costs and long payback periods. Because of this, SMUD decided to explore several different options for upgrading commercial office lighting systems, as part of the 2014 Customer Advanced Technologies program.

Interior lighting accounts for nearly 29% of the annual electricity use in California's commercial buildings[1.] Many of these spaces use recessed or flush mounted ceiling fixtures (aka fluorescent troffers). Manufacturers now offer a wide variety of control options, new LED fixtures and LED retrofit kit options for these applications. Some of these new products offer impressive performance; they're fully dimmable, have efficacies of over 105 lumens per Watt and ten year warranties. Furthermore, modern lighting controls enable users to track energy consumption / savings and implement a wide variety of sophisticated control strategies:

- Task Tuning (High-end trim): Allows users to adjust the lighting levels according to their needs. Task tuning generally reduces energy consumption by 36%[2].

- Daylight Harvesting: Senses the amount of available ambient light (i.e. daylight) and adjusts the output of the light fixtures to maintain the desired illumination levels. This strategy typically saves an average of 28% in areas where abundant daylighting is available[2].

- Occupancy Control: Turns off lights in unoccupied areas. This strategy saves an average of 28%[2] for office applications, and even more for industrial and warehouse applications.

- Advanced Scheduling: Allows the users to set lighting schedules to meet their needs. The amount of energy savings depends upon how aggressively the lights are turned off when not needed.

- Automatic Demand Response: Provides the capability to automatically dim or turn off lights in certain areas when a demand response event is called.

[1] California Commercial End-Use Study http://capabilities.itron.com/CeusWeb/ChartsSF/Default2.aspx
[2] Report by Lawrence Berkeley National Labs: Williams, A., Atkinson, K. Garbesi, E. Page, and F. Rubenstein (2012). Lighting controls in commercial buildings, Leukos 8(3):161-180. http://www.ies.org/leukos/samples?1_jan12.pdf

More recently, manufacturers introduced LED retrofit kits and fixtures with integrated motion sensors, daylight harvesting sensors and various forms of wireless communication. Over the course of three years, SMUD worked with customers, ADM Associates, and Nexant to field test five different systems ranging from dimmable fluorescents to new LED fixtures.

This report is very different than many of our past efforts. It is intended to briefly describe the experiences of our customers who installed a wide variety of systems during the past three years. This report includes brief descriptions of the technologies tested, high level descriptions about the projects, and project scorecards. The project scorecards are based upon feedback from project participants and observations made during the field tests. *These scorecards are not intended to pick winners or losers, rather to relate the results for specific projects***.** Since LED lighting and the controls industry are both advancing so rapidly, this report represents only a snapshot in time: manufacturers have made many significant improvements to their products since these projects were completed, so please keep that in mind. The project scorecards are based upon the following categories and criteria:

- **Material costs:** Since some of the participants used in-house electricians, while others hired electrical contractors, this category only reflects the costs of the equipment (i.e. light fixtures, sensors, etc.) and reflects the overall simple payback. For example, a project with high material costs and a long payback would score lower than a project with lower costs and a shorter payback.

- **Installation:** This category is based upon the amount of labor that was required to complete the upgrade. Systems that were easier to install received the highest scores for this category.

- **Commissioning:** This category is based upon feedback from the installers and observations made during the commissioning process. Systems that required more time or were frustrating to work with received lower scores.

- **Maintenance:** This category reflects the rated life and serviceability of the system (fixtures, lamps and controls). Systems with longer rated lifetimes and modular construction received the highest scores.

- **End user feedback:** Each of these projects included interviews and/or surveys with employees working in the space as well as the installers. For some projects, the installers were in-house electricians, while others were electrical contractors. People working in the spaces were asked about the lighting, while the installers were asked questions regarding both installation and commissioning of the overall system.

- **Features:** Systems with the most of the following features scored the highest in this category: task tuning, daylight harvesting, occupancy sensing, automatic demand response capability, web access, and energy tracking.

As you will see, each of the various systems has strengths and weakness and a wide range of capabilities. So which is the best system? **It depends!** Each customer and project has unique goals, requirements and budget constraints. The great news is that these systems appear to be getting better and the costs are trending downward.

Acknowledgements

While many people contributed to the success of these projects, we wish to thank Mr. Dan Mendonsa, County of Sacramento Energy Manager, for his outstanding contributions.

2. Case Studies

2.1 Enlighted

System Description

Enlighted's system consists of multifunction sensors, controllers, servers (aka Energy Manager), gateways and user friendly software. The sensors are connected to the lighting controllers within each light fixture via a low voltage cable (Figure 1), and are used to detect occupancy, ambient light, and temperature. The sensors also collect energy consumption data and communicate via wireless technology to the Enlighted Gateways. Finally, the Enlighted Gateways (Figure 2) relay this information to a server-type device called the Enlighted Energy Manager (Figure 3). The entire system is controlled by user-friendly software which enables end users to adjust schedules, task tuning levels and motion sensor settings from any Web enabled device (e.g. smart phones, tablets, laptops, desktop computers).

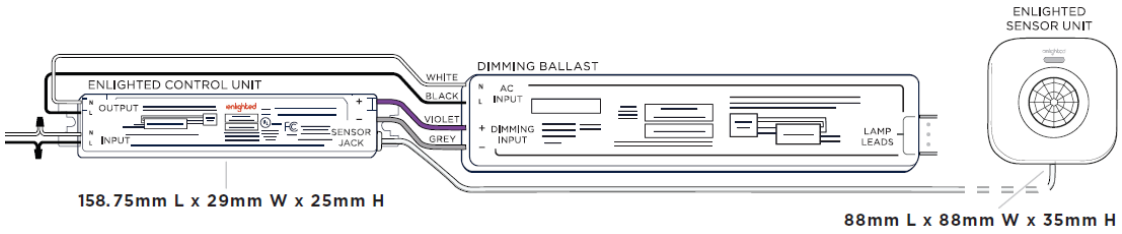


Figure 1: Wiring diagram for an Enlighted sensor connected to a dimming fluorescent ballast.

Figure 2: Enlighted Gateway

Figure 3: Enlighted Energy Manager

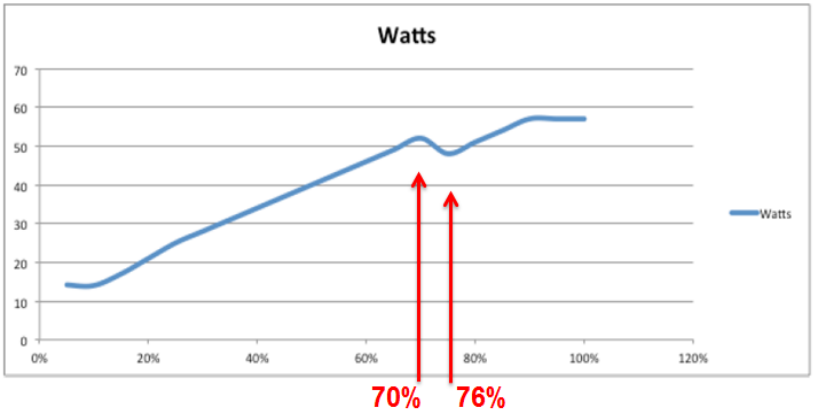
Project Description & Results

In 2012, the Intel Corporation retrofitted 1,048 fluorescent fixtures on the second floor of Building FM3 (Folsom, California) with dimmable ballasts (0-10 VDC) and Enlighted controls[3]. After the installation was completed, Intel implemented a variety of control strategies including task tuning, daylight harvesting and occupancy sensing. On the positive side, the project resulted in energy savings of 49% and electrical demand savings of 32% (compared to the original system). Feedback regarding the user friendliness and capabilities of Enlighted's software was also very favorable. On the downside, the simple financial payback period was over 10 years and some important lessons were learned:

- Initially, the controls were set to turn off individual fixtures when no motion was detected for 5 minutes. Unfortunately, the sound of multiple clicking relays in a quiet open office environment proved to be too distracting. Intel solved this problem by reprogramming the controls for bi-level (high/low) operation during occupied hours.

- Pay close attention to dimmable fluorescent ballast performance curves! Originally Intel chose to task tune all of the fixtures at 70% of maximum output. When subsequent monitoring of the lighting circuits revealed that the energy savings were less than expected, the project team took a closer look at the new dimming ballasts. As illustrated in Figure 4 below, these ballasts consume more power at the 70% level than at 76%, due to the heating of fluorescent lamp cathodes. In order for fluorescent lamps to operate properly while being dimmed, the lamp cathodes must be heated. While some ballast manufacturers choose to use a continuous heating strategy, these ballasts switch from a low heating mode to a high mode at approximately 70% of maximum output. This is what caused the lower than expected savings. Fortunately, it was very easy to adjust the task tuning level via the software.

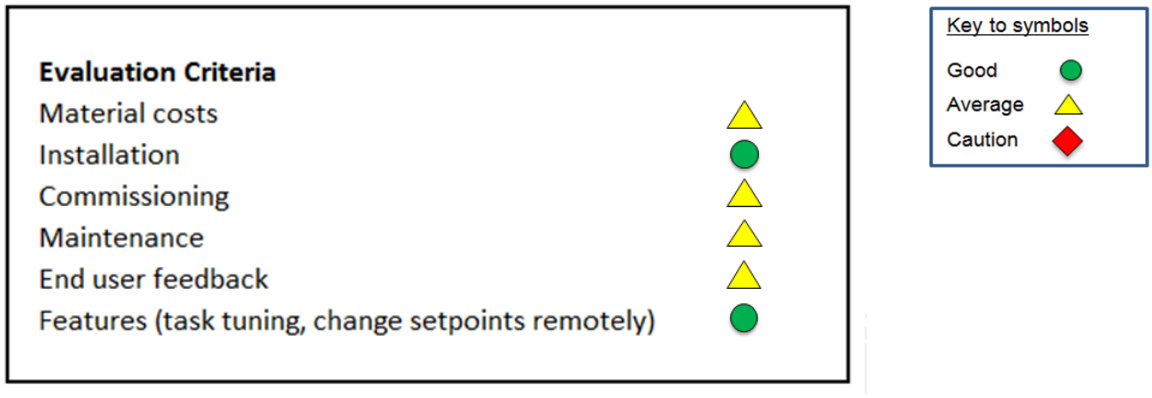
Figure 4: Performance curve for the 0-10V dimming ballast used during the Intel project. Note the power consumption at 76% output is less than at 70%!



[3] A full report for this project is available via SMUD's customer Advanced Technologies Program Website https://www.smud.org/en/business/save-energy/rebates-incentives-financing/customer-advanced-technologies.htm

Project Scorecard

The scores for the Enlighted project are shown below.



Material costs: Compared to other systems that offer control of individual light fixtures, the Enlighted system was less expensive. However to be fair, it is important to note that this is the only system in this report that uses fluorescent lamps, and does not include any type of new optical assembly. Also, the long financial payback (10 years) for the Intel project was primarily because the original lighting system (T8 lamps and electronic ballasts) was already relatively energy efficient.

Installation: Because the multifunction sensors are connected to the controller via an RJ11 jack, installation was easier than expected.

Commissioning: Although the software is easy to use, Intel experienced some problems with the sounds of the clicking relays and the fluorescent ballast curves.

Maintenance: The Enlighted system is proprietary and requires one controller and one sensor per fixture. However, since these controllers are compatible with most 0-10V fluorescent ballasts and LED drivers, some level of future compatibility is assured. Finally, since this project replaced the existing fluorescent lamps and ballasts with new ones, no additional maintenance savings are expected.

End user feedback: Employees who responded to the surveys provided positive feedback, except for the problems noted above. The installers said the system was very easy to install and commission.

Features: Enlighted's software is easy to use and offers a wide range of features including task tuning, daylight harvesting, occupancy sensing, demand response and energy tracking.

2.2 Philips Evokits & Daintree Networks Wireless Controls

System Description

Since installing new fixtures into an existing office space can be very labor intensive, Philips and several other manufacturers offer LED troffer retrofit kits. Generally speaking, these kits require removing all of the existing components (ballasts, lamps, sockets, lenses, etc.). Only the housing of the original light fixture is reused. In 2013, the County of Sacramento decided to install Philips Evokits (Figure 5) with dimmable LED drivers (0-10V control input) and Daintree wireless controls.

Figure 5: Philips Evokits

Daintree Networks offers a wireless control system that is based upon the ZigBee® communication standards. This feature allows users some degree of flexibility when choosing devices such as wireless wall switches, occupancy and daylight harvesting sensors. As long as the devices are compliant with ZigBee, they may be incorporated into Daintree's network. All of the control devices in the system work to form a wireless mesh network, which helps increase reliability (Figure 6). However, sometimes this approach may cause slight delays in response time (more on this later).

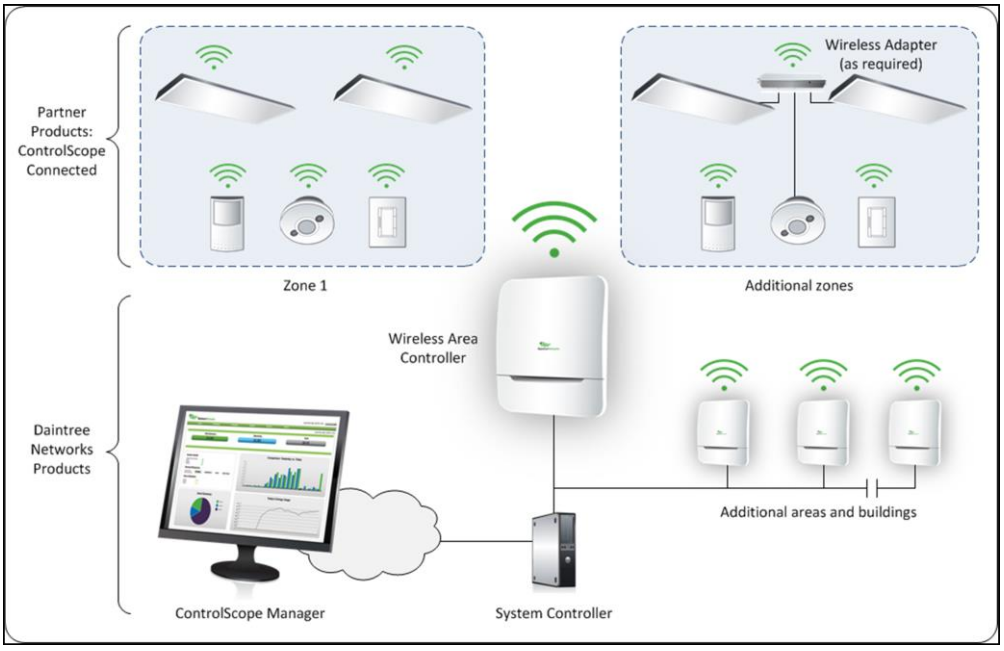


Figure 6: The Daintree Networks system uses ZigBee®. All of the control devices in the system work to form a wireless mesh network, which helps increase reliability.

By far the biggest benefit of the Daintree system is the multitude of powerful features from their ControlScope® software. What makes systems like Daintree attractive is the ability to adjust settings (i.e. maximum light output, illumination levels, time delays, etc.), by using just about any web-enabled device (laptop computers, smartphones, tablets). This is so much easier than the old method of standing on ladders to adjust tiny screws or dip switches.

Project Description & Results

Over the years, the County of Sacramento has been very active in the area of energy efficiency and has worked with SMUD on a wide variety of projects. In 2013, the County agreed to help SMUD test several different LED retrofit and new fixture options for office lighting. SMUD provided research grants to cover the material and equipment costs and the County provided the labor. The site chosen for most of the testing was the County's DGS building in Sacramento, California.

The first system tested was a combination of first generation Philips LED Evokits and Daintree wireless controls[4]. County electricians retrofitted 97 fluorescent fixtures in the office areas and installed 45 LED downlights for the hallways. The project reduced annual lighting energy consumption by 67.9% and peak electrical demand by 71.4% in the tested areas (Figure 7).

[4] A full report for this project is available via SMUD's customer Advanced Technologies Program Website https://www.smud.org/en/business/save-energy/rebates-incentives-financing/customer-advanced-technologies.htm

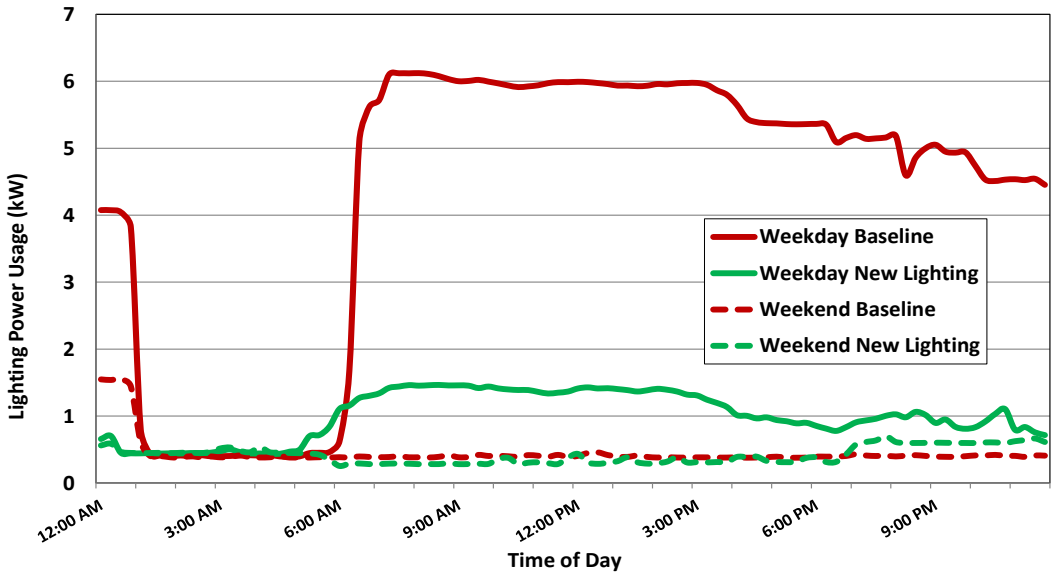


Figure 7: The County's project using Philips Evokits and Daintree controls reduced annual lighting energy consumption by 67.9% and peak electrical demand by 71.4% in the tested areas.

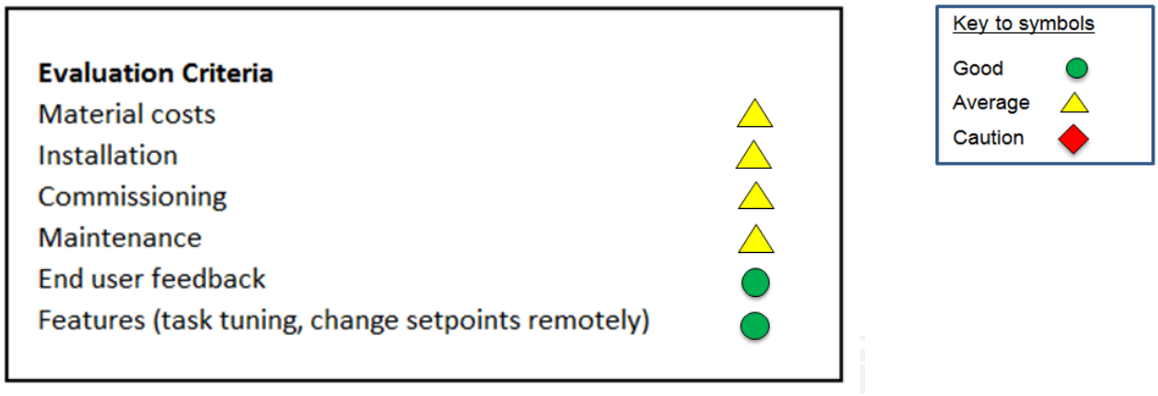
The project wasn't all roses however. Although the savings were impressive, the costs were still too high to be viable for most commercial customers. Without the research grant, the simple financial payback for this project would have been 9.3 years—not including labor costs since the County used in-house electricians to install the system. Furthermore, the installers encountered some unexpected technical challenges:

- The occupancy sensors had delayed response times. Sometimes people had to walk five feet down the hallway before the lights turned on. The County's Energy Manager believes the problem was related to "latency" in the wireless control system, rather than the sensors' detection capabilities. This problem was somewhat mitigated by changing the system setpoints to operate in the 'bi-level' mode (dim the lights when no one is around) rather than using the on/off mode during regular working hours.

- At first, the installers experienced trouble getting some of the LED troffer retrofit kits to lay in flush with the ceiling grid. However, after an initial learning curve, they experienced no more problems.

Project Scorecard

The scorecard for the combination of Philips Evokits + Daintree controls project is shown below.



Material costs: This approach requires a lot of equipment: (a) LED troffer retrofit kits with dimmable LED drivers (b) Daintree wireless adapters (c) occupancy sensors (d) daylight harvesting sensors (e) wireless switches (f) Daintree Wireless Area Controllers and (g) software licensing fees for all wireless devices. Consequently, the total cost for this system was too high to be a viable option for most commercial customers. Fortunately, both Philips and Daintree have since developed more cost-effective options since the time this project was completed.

Installation: As described above, this approach requires the installation and commissioning of multiple devices.

Commissioning: Daintree's ControlScope software offers tremendous flexibility, yet can be time consuming to set up and commission.

Maintenance: The life expectancy for the original fluorescent lamps was 20,000 hours verses 50,000 hours for the new LEDs. It is important to note, however, that the ratings for fluorescent lamps and LEDs are calculated using very different methods. The life expectancy of fluorescent lamps is based on the number of hours when 50% of the lamps are expected to *fail*, whereas LEDs are typically rated for L70—the number of hours when the LEDs are expected to *lose 30%* of their original light output. If the LEDs live up to their expected lifetimes, the County should see a significant reduction in maintenance costs. On the downside, this approach includes numerous devices including wireless switches and occupancy sensors that are powered by batteries. These batteries will need to be replaced periodically.

End user feedback: Overall the installers said they liked the Evokits, but had some concerns regarding the number of devices that had to be installed and commissioned. Employees who responded to the surveys said they liked the new LED lighting, as long as it was dimmed to a comfortable level. Finally, the Energy Manager said he enjoys using the wide range of software features.

Features: This type of system offers maximum capabilities including access via web enabled devices such as smartphones, tablets and computers.

2.3 LG LED Fixtures & Daintree Controls

System Description

In 2014, the LG Company introduced LED troffer retrofit kits and fixtures with ZigBee enabled drivers. This approach allows the fixtures to be incorporated directly into the Daintree system without installing additional Daintree controllers. The goal of this approach is to simplify the installation process and reduce installation costs. Although this is a step in the right direction, the occupancy and daylight harvesting sensors are not integrated within the fixture; it is still necessary to install and commission these devices separately.

Figure 8: New LG LED lighting fixtures

Project Description & Results

County of Sacramento's electricians retrofitted 96 recessed fluorescent fixtures (2 x 4) with LG LED troffer retrofit kits and Daintree wireless controls (Figure 8). Overall the project was a success: lighting energy consumption was reduced by an estimated 75% (Figure 9) while maintaining adequate illumination levels. Since this project also included Daintree's ControlScope software, it provides all of the capabilties and benefits mentioned in the previous section above.

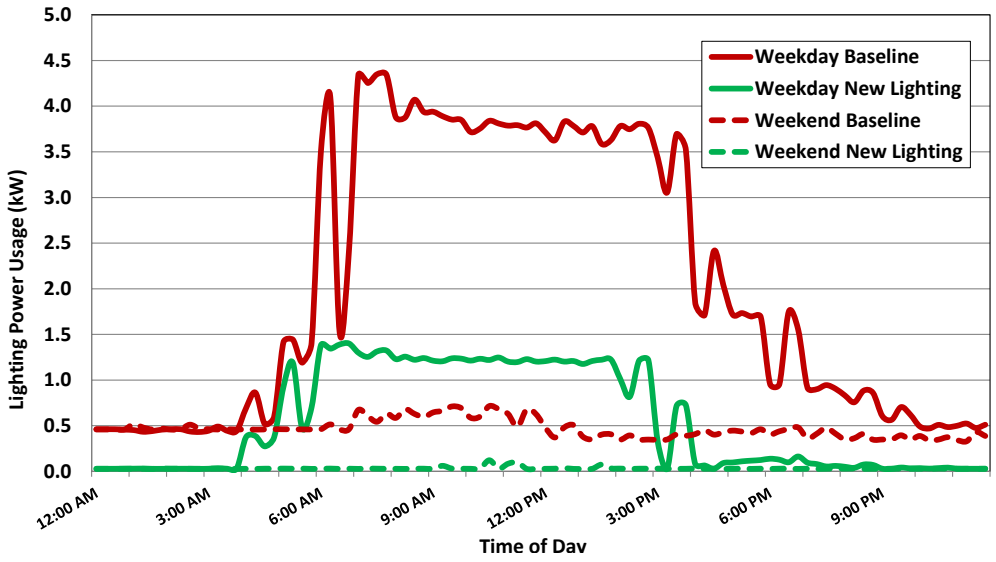


Figure 9: Comparison of the typical weekday and weekend lighting load profiles before and after the LG LED Lighting and Daintree controls retrofit. The new system reduced energy consumption by an estimated 75%.

Project Scorecard

Below are the scores for the LG fixtures + Daintree project:

Evaluation Criteria	
Material costs	◆
Installation	▲
Commissioning	▲
Maintenance	▲
End user feedback	▲
Features (task tuning, change setpoints remotely)	●

Key to symbols	
Good	●
Average	▲
Caution	◆

Material costs: Unfortunately, compared to the other retrofit options in this report, this system had the highest cost per fixture. Although the installation was easier, the costs for the hardware and software licensing fees were significant.

Installation: The system was installed by County electricians. At first, they were excited about LG incorporating Zigbee enabled drivers into their retrofit kits, since this meant not having to install separate controls. However, installing the wireless chip required partial disassembly of the fixtures (Figure 10). The electricians said they would prefer the LG fixtures shipped with the wireless chip preinstalled at the factory.

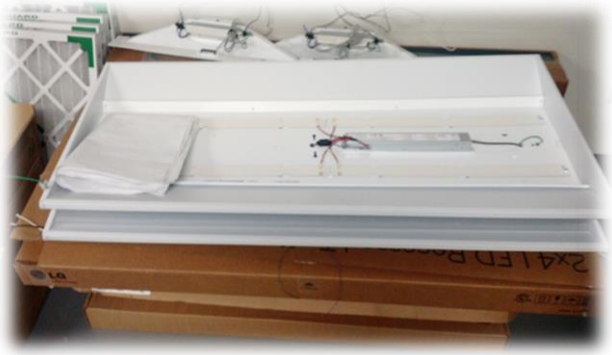


Figure 10: LED troffer disassembly to install wireless chip.

Commissioning: The County Energy Manager said that he really liked the capabilities of Daintree's ControlScope software, but it was time consuming to set up and commission the system.

Maintenance: The life expectancy for the original fluorescent lamps was 20,000 hours verses 50,000 hours (L70) for the new LEDs. If the LEDs and drivers meet their expected lifetimes, the County should see a significant reduction in maintenance costs. On the downside, this system requires still requires external devices (e.g. wireless switches, occupancy sensors) that are powered by batteries. These batteries will periodically need to be replaced.

End user feedback: The feedback from the project participants was mixed. On the positive side, the County's Energy Manager enjoys using the wide range of features offered via the software, and the electricians said they liked not having to install the additional controls. On the downside, the cost of the hardware and licensing fees were viewed as an obstacle to widespread market adoption. Finally, the opinions of the employees working in the offices were split when they asked if the new system provided better lighting.

Features: Since this system uses Daintree's ControlScope software, it offers maximum capabilities including energy tracking and access via web enabled devices such as smartphones, tablets and computers.

2.4 Philips Evokits & SpaceWise Controls

System Description

During 2014, Philips® Lighting introduced a new LED troffer retrofit kit (Evokit) with SpaceWise™ controls. Luminaires and retrofit kits equipped with SpaceWise have integrated motion sensors, daylight harvesting sensors and wireless communication (Figure 11). The SpaceWise system is designed for open office areas and is programmed via a remote control.

Figure 11: Luminaires and retrofit kits equipped with SpaceWise have integrated motion sensors, daylight harvesting sensors and wireless communication.

Project Description & Results

SMUD worked with the County of Sacramento and Bimbo Bakery to test the performance of the system and obtain feedback from installers and end users. The results of these projects were mixed.

On the positive side, Evokits and SpaceWise provided energy savings of up to 49% (Figures 12 and 13) and were easy to install—especially compared to replacing existing fixtures with new ones. People who responded to the surveys generally liked the look of the Evokits, yet several of them said the fixtures were way too bright, and dimmed them down as low as they could.

Figure 12: Typical weekday and weekend lighting load profiles for the Bimbo Bakery test site. The Evokits and SpaceWise system reduced energy consumption by 49%.

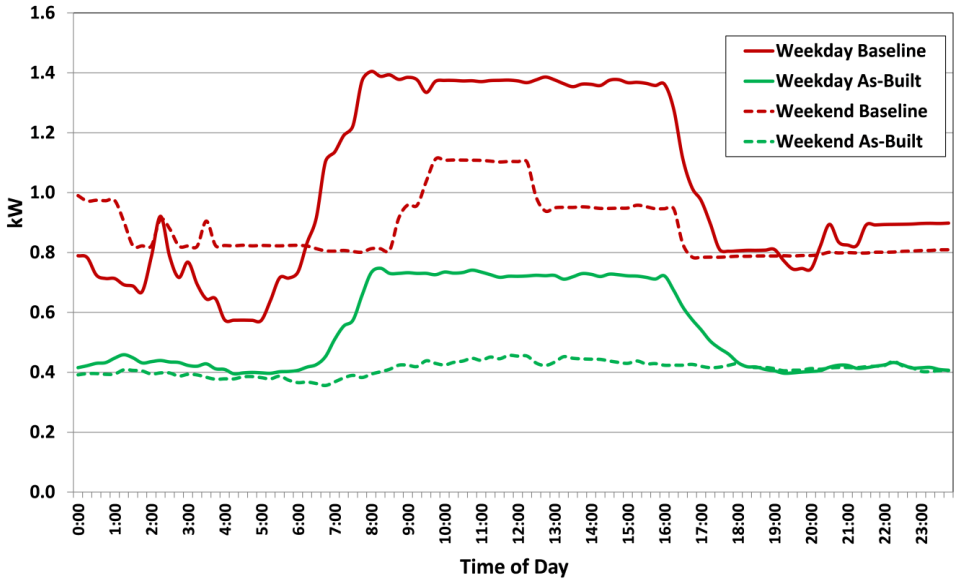


Figure 13: Typical weekday and weekend lighting load profiles for the County of Sacramento test site before and after the Evokit/SpaceWise retrofit. The new system reduced energy consumption approximately 49% at this site.

The SpaceWise controls were designed for simple operation: there is no need for computers, gateways, routers, or software. End users program the system and choose from different factory preset options via a hand-held remote control. Although this seems like a great concept, there were completely opposite reactions from our study participants:

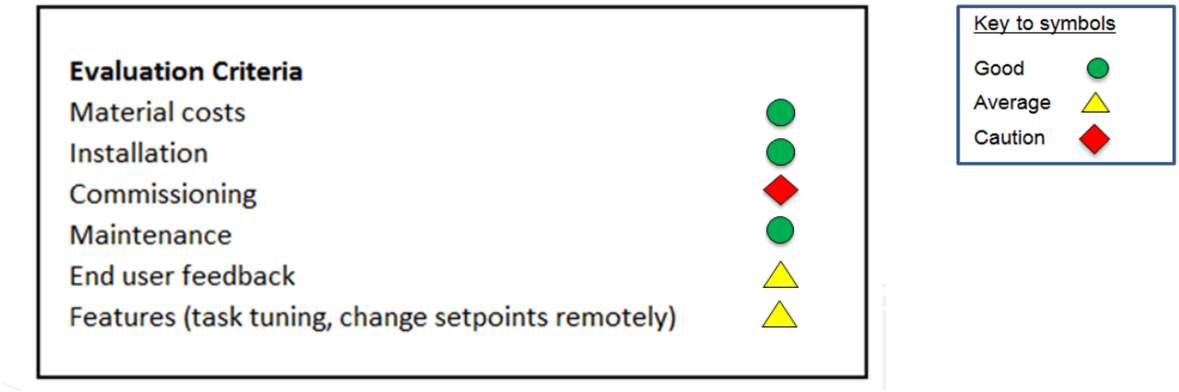
1. Users who were satisfied with the factory preset options and higher illumination levels said the system was very easy to install and commission.

2. Users who wanted lower illumination levels were very frustrated by the limitations of the remote control—particularly the lack of any type of display to adjust the setpoints. One user resorted to covering the sensors with tape to keep the fixture in the "low output, unoccupied" mode (Figure 14).

Figure 14: Some users were frustrated with the limitations of the remote control and resorted to using tape to cover the sensor to keep fixture in the 'low output" mode.

Project Scorecard

Below are the scores for the Philips Evokits + SpaceWise.



Material costs: The Philips Evokits and SpaceWise system was less expensive than most of the other lighting systems in this report.

Installation: The installers said the system was very easy to install – especially compared to new fixtures or installing additional controllers and sensors.

Commissioning: Users who were content with the factory default settings were satisfied. However, users who wanted lower illumination levels or alternate settings were extremely frustrated. Although Philips provided adequate documentation, the limitations of having to use a remote control and having very few programming options, left some users feeling dissatisfied.

Maintenance: The Evokits are rated for 72,000 hours (L70), so both participants should realize significant maintenance savings. Furthermore both the Evokits and SpaceWise controls are highly modular and allow for easy replacement of components if needed.

End user feedback: People working in the office areas said they really liked the appearance of the Evokits. The electricians said the system was very easy to install, but they were very frustrated with the limitations of using the remote control for programming.

Features: This system offers full range dimming, daylight harvesting, occupancy sensing, and task tuning. However, it does not currently have energy monitoring or automatic demand response capabilities.

2.5 Cree SmartCast™

System Description

In 2014 Cree© introduced LED fixtures with an integrated wireless control system known as SmartCast™. The SmartCast system includes motion sensors, daylight harvesting sensors and wireless communication already built into the fixtures. Unlike many other wireless control systems, SmartCast does not require the installation of computer software, routers, or gateways. Instead, all of the programming is completed via a remote control (Figure 15). Users can use the remote to set up control groups, set task tuning levels, adjust the sensitivity and time delays for the motion sensors. Unfortunately, SmartCast does not currently have energy monitoring or automatic demand response (ADR) capabilities.

Project Descriptions & Results

The SmartCast system was installed in small offices at two different locations. Although both participants achieved significant energy savings, the installers had significantly different experiences and opinions about the SmartCast system.

Figure 15: Cree SmartCast fixtures include integrated motion sensors, daylight harvesting sensors and wireless communication.

Project #1: Donahue Schriber

The Donahue Schriber project[5] included replacing twenty-five 2 x 4 fluorescent fixtures (Figure 16) and resulted in energy savings of 59% (Figure 17) while maintaining comparable illumination levels.

Figure 16: New Cree LED lighting fixtures

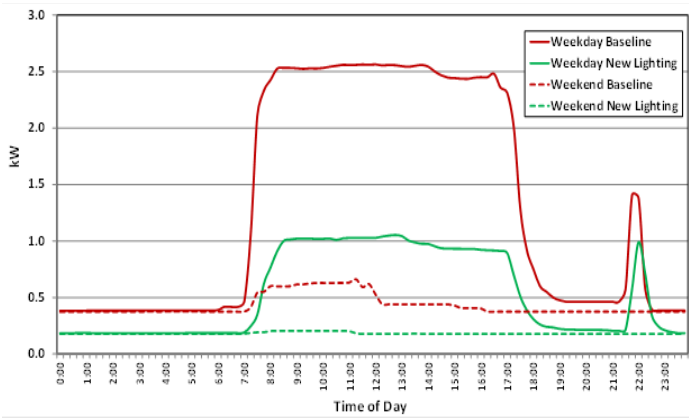


Figure 17: Donahue Schriber lighting energy profile

[5] A full report for this project is available via SMUD's customer Advanced Technologies Program Website https://www.smud.org/en/business/save-energy/rebates-incentives-financing/customer-advanced-technologies.htm

Feedback obtained from the surveys at this site was also very favorable. Employees said they liked the more natural-looking color of the new lighting and the reduced glare. The installers said the lighting fixtures were very simple to install and programming the controls took much less time than anticipated. At this particular site, the only negative aspect mentioned was the cost of the fixtures. Although Donahue Schriber received a generous research grant that resulted in a simple payback of 3.5 years, the simple payback without the grant would have been completely unacceptable for most commercial customers (over 26 years). Fortunately, Cree now offers much lower priced options than the fixtures chosen for this project.

Project #2: County of Sacramento

The County's North Sacramento Service Center and Business Environmental Center is located in McClellan and provides a variety of community services. The facility has two floors totaling 7,000 square feet; however, currently only the first floor is occupied. There is a common cubicle area which seats the majority of employees. The remaining employees have personal offices surrounding the cubicle area.

Figure 18: Original fluorescent lighting

The original lighting system for the open cubicle areas and hallways consisted of 2 x 4 fluorescent lights (Figure 18). The lights were replaced on a one-for-one basis with Cree CR Series LED Architectural Troffers with SmartCast controls (Figure 19).

Figure 19: New LED lighting fixtures

The project resulted in energy savings of 76% (Figure 20) and a simple payback of 5.7 years (not including labor costs).

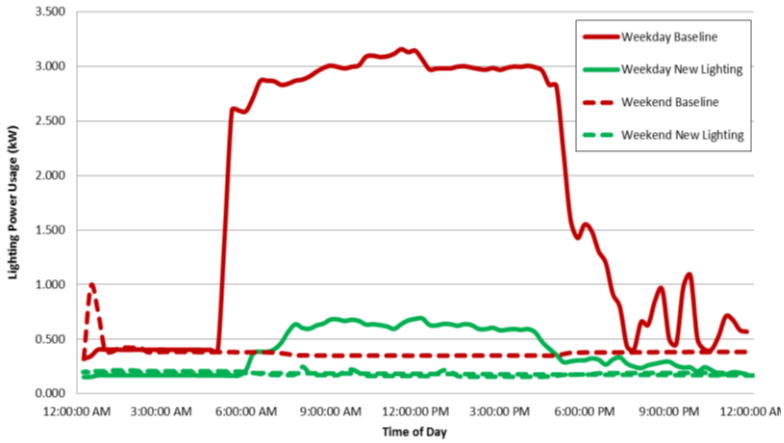


Figure 20: County of Sacramento lighting energy profile. The project resulted in energy savings of 76% and a simple payback of 5.7 years (not including labor costs).

The baseline lighting level measurements ranged from 21 to 77 foot-candles (fc) and averaged 44 fc. The new lighting level measurements ranged from 7 to 63 fc and averaged 30 fc. Note however, that the illumination levels were lower with the new lighting system because the employees chose to dim the lights. Nevertheless, the new illumination still met the County's stated targets of 10 fc in hallways and 30 fc in work areas. Feedback from the County employees who work in the space was positive: they said they liked the appearance and lighting quality. However, the County's electricians expressed some concerns:

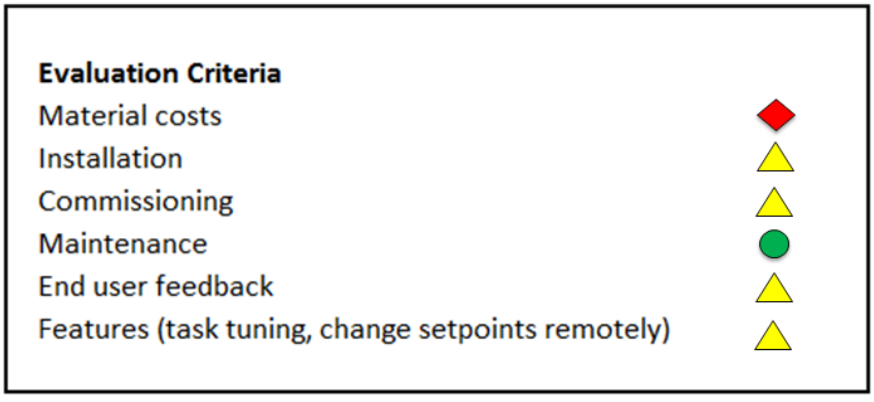
- The new fixtures were more difficult to install (compared to the LED retrofit kits) because of the necessity of removing ceiling tiles, and reattaching seismic safety straps (aka earthquake wires).

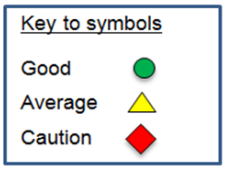
- The installers said the commissioning was frustrating and time consuming due to the slow communication speed of the remote control, and the lack of an instruction manual. The setup required using the remote control to communicate with each fixture in order to assign the fixture to a lighting zone and set the operating mode of the fixture. A picture of this procedure is shown in Figure 21.

Figure 21: Installers said the commissioning was frustrating and time consuming, due to the slow speed of the remote control and the lack of an instruction manual.

Project Scorecard

Scores for the Cree SmartCast system projects are shown below:





Material costs: The costs for the Cree fixtures and SmartCast controls were the highest of all of the systems tested. Fortunately, Cree now has less expensive options available.

Installation: In retrofit applications, new fixtures are usually more difficult to install than some retrofit options. This is due to the necessity of removing ceiling tiles to reattach seismic safety straps (aka earthquake wires).

Commissioning: Feedback from the installers was very mixed. Some thought the system was fairly straightforward while others were frustrated by the remote control and the lack of a user's manual.

Maintenance: The Cree fixtures are rated for 100,000 hours (L70), so both participants should realize significant maintenance savings.

End user feedback: The feedback was mixed. Employees working in the spaces really liked the appearance and the lighting quality. Some of the installers said the system was very easy to commission while others were very frustrated.

Features: The Cree SmartCast system offers full range dimming, daylight harvesting, occupancy sensing, and task tuning. However, it does not offer energy monitoring or automatic demand response capabilities.

3. Conclusion & Recommendations

Today, consumers have many exciting options for upgrading their fluorescent troffers. The industry's movement towards integrating sensors and wireless controls into LED retrofit kits and fixtures is definitely a step in the right direction. Obviously the costs for these options are still a bit too high for most applications, but the trend towards lower cost is encouraging. Based upon these field tests, we offer the following advice to lighting manufacturers:

1. Equip electrical contractors for success:
    - Focus on integrated controls.
    - LOSE THE REMOTES and replace them with applications for mobile devices, and/or other electronic interfaces with two-way communication capabilities.
    - Provide tools for commissioning and troubleshooting. This includes detailed instructions for installation, commissioning and troubleshooting procedures.
    - Reduce the amount of field assembly steps.
2. Include provisions for demand response and energy monitoring.

The future promises to be exciting! LED lighting and controls are continuing to improve at a rapid pace. Ultimately, lighting systems are on track to becoming a big part of the "Internet of Things." Who knows what future capabilities will emerge? In the meantime, all of the systems featured in this report are currently eligible for SMUD's commercial energy efficiency incentives. For more information, please visit www.SMUD.org.